Economics 134 L3. Externalities

Will Rafey

UCLA

October 6, 2025

Social choice theory recap: A metaphor

Imagine that we are baking a pie.

Key takeaway: two related but **distinct** questions:

1. what is the best recipe to use to bake the largest pie? (efficiency)
2. how should we divide the pie? (distribution)

Pareto criterion: only change the recipe and pie slicing rule if [i] no one gets a smaller slice than they did before and [ii] at least one person gets a large slice

Pareto criterion with transfers ("Kaldor-Hicks"): change the recipe if it gives a larger pie, as long as we can divide it so that [i] no one is worse off and [ii] at least one person is better off than before

- Why might the sharing rule need to change? (i.e., need transfers)
  - $\hookrightarrow$ the pie might be a new flavor and people may have different tastes

In economics, the search for **efficient outcome** is the recipe that can bake the largest pie. Then, we can ask **distributional** questions, such as who would be worse off if we didn't change how we divide the new pie.

Plan for today

Externality: social cost $\neq$ private cost

$\hookrightarrow$ private markets do not produce efficient outcomes because firms do not take into account the social cost of pollution

Designing policy solutions to externalities:

1. ~~Quantity regulation~~ ✓
2. Corrective tax
3. Property rights and trade
4. Merger

Plan for today

Policy #1. Regulation

Policy #2. Corrective taxation

Prices versus quantities

Policy #3. Private property rights

Coase Theorem

Policy #4. Mergers

Optimal quantity regulation: Recap

We've shown that a cap on output

- guarantees q^{FB}. ✓
- creates net benefits of Δ. ✓

What are the distributional effects of the regulation?

- The neighbor gains $D(q^*) - D(q^{\mathrm{FB}})$ (total benefits)
- The firm loses $\pi(q^*) - \pi(q^{\mathrm{FB}})$ (costs)

So, in addition to correcting the externality, the regulation **redistributes** resources from the firm to the neighbor!

Policy solutions (2/4)

Alternatively, let's look at the first-order conditions to maximize welfare:

$$
\begin{aligned}
0 &= W'(q^{\mathrm{FB}}) \\
&= \pi'(q^{\mathrm{FB}}) - D'(q^{\mathrm{FB}}) \\
&= p - c'(q^{\mathrm{FB}}) - \underbrace{D'(q^{\mathrm{FB}})}_{\text{externality}}.
\end{aligned}
$$

Recall that the firm maximizes profits when $p - c'(q) = 0$.

If the firm incurs a per-unit cost $D'(q^{\mathrm{FB}})$ for each unit of q, then the firm's problem becomes the same as the social planner's.

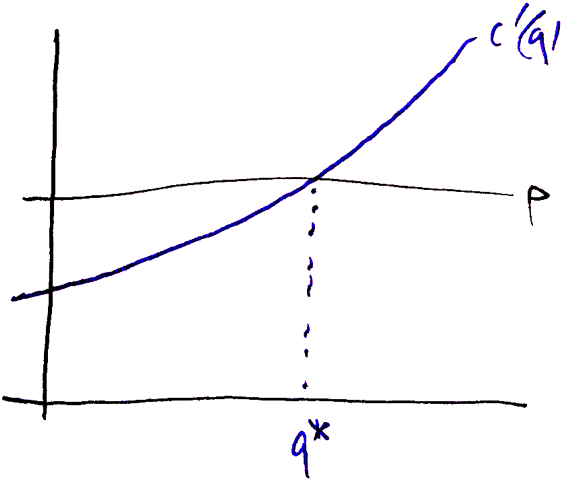
Solution 2. Pigouvian tax. Charge the firm a tax $\tau = D'(q^{\mathrm{FB}})$ for each unit of output, so that its profit becomes

$$\tilde{\pi}(q) = pq - c(q) - \tau q.$$

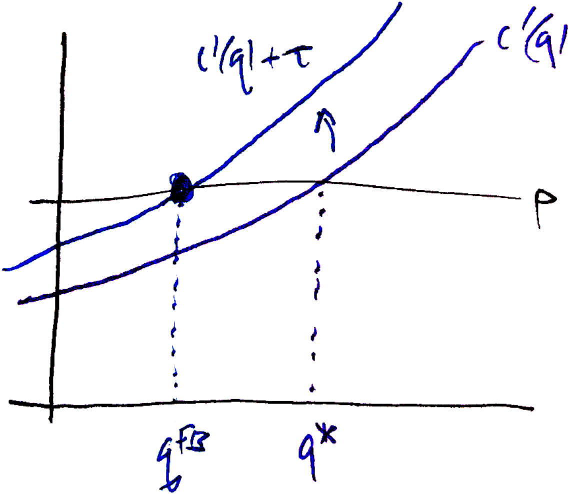
Then let the firm maximize profits.

(Named for Arthur Pigou (1877–1959).)

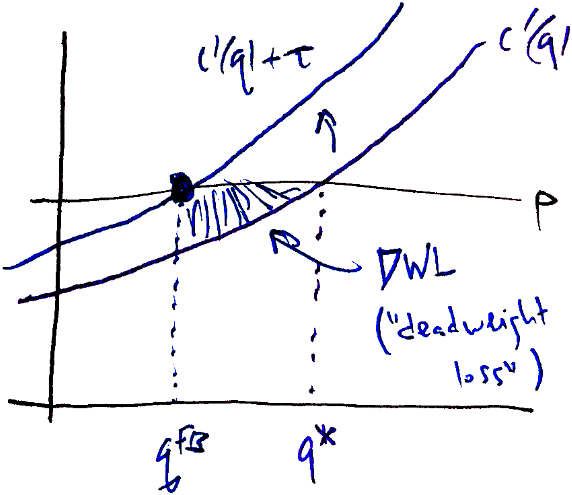
Optimal tax



Optimal tax



Interpretation of cost as deadweight loss (DWL)



Optimal tax

We showed that the optimal corrective tax, the “Pigouvian tax,” is equal to marginal damages:

$$\tau = D'(q^{\mathrm{FB}}).$$

Crucial result in environmental economics.

Core intuition: a tax forces the firm to internalize the harm done to the neighbor

- the optimal tax, which incentivizes the firm to perfectly internalize the neighbor’s harm at the margin, is the marginal damage

Remark. Zero pollution is **not** (necessarily) desirable!

Optimal tax

Like the optimal quantity regulation, the optimal tax also gives us q^{FB}, so it is efficient.

What about distributional effects?

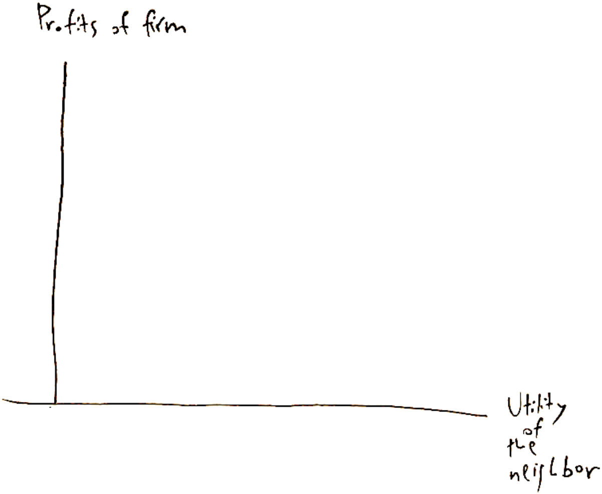
$\hookrightarrow$ Depends on what happens to the tax revenue!

In our example, revenue is $R = \tau \cdot q^{\mathsf{FB}} = D'(q^{\mathsf{FB}}) \cdot q^{\mathsf{FB}}$.

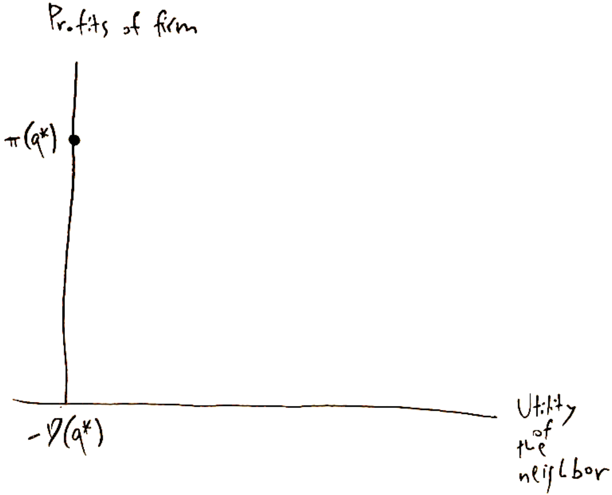
- Could redistribute (any amount) to the firm
  - But must preserve incentives
  - A **lump-sum** transfer works (but <u>not</u> a per-unit rebate!)
- Could transfer to the neighbor
  - Neighbor is already strictly better off; this makes them even happier
  - In fact, since $R > D(q^{\mathsf{FB}})$, the neighbor will be better off than if $q = 0$!

Distributional outcomes, Pigouvian tax

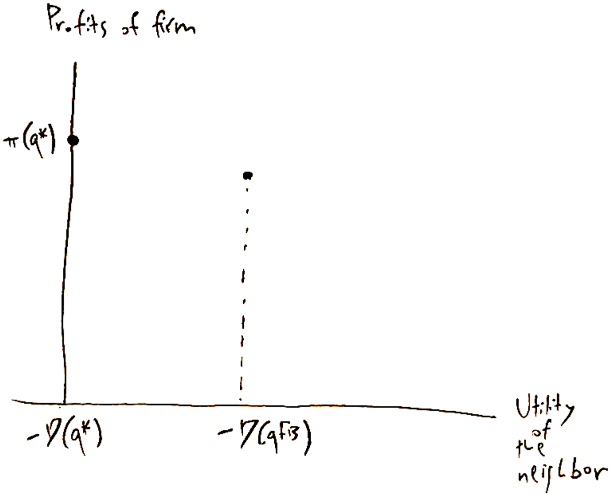
Distributional outcomes, Pigouvian tax



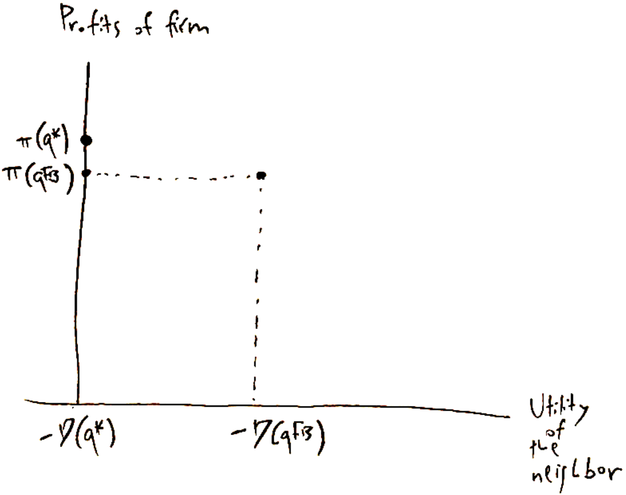
Distributional outcomes, Pigouvian tax



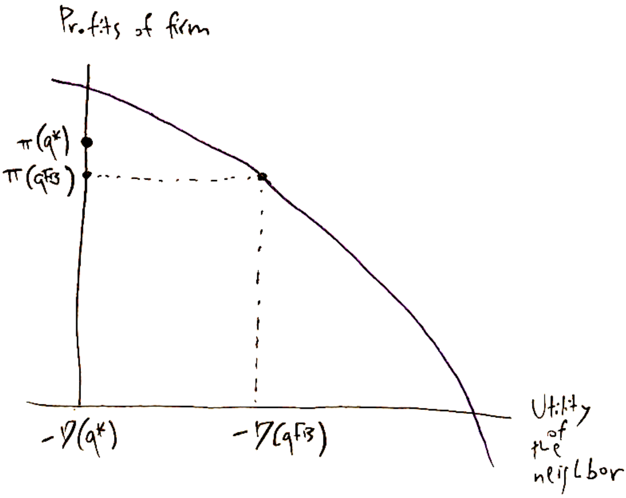
Distributional outcomes, Pigouvian tax



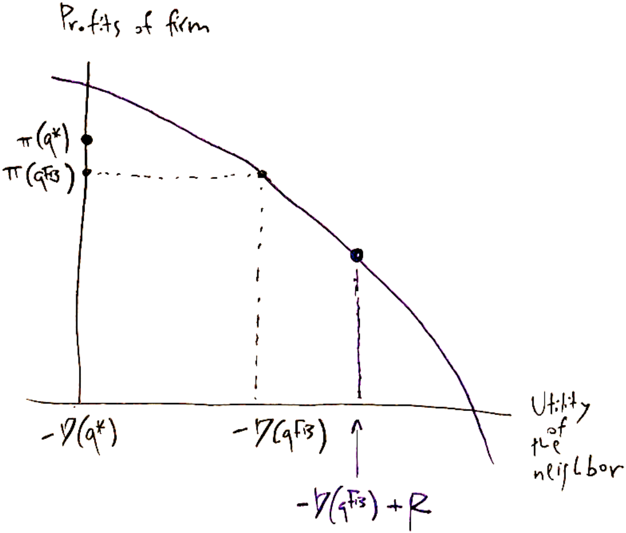
Distributional outcomes, Pigouvian tax



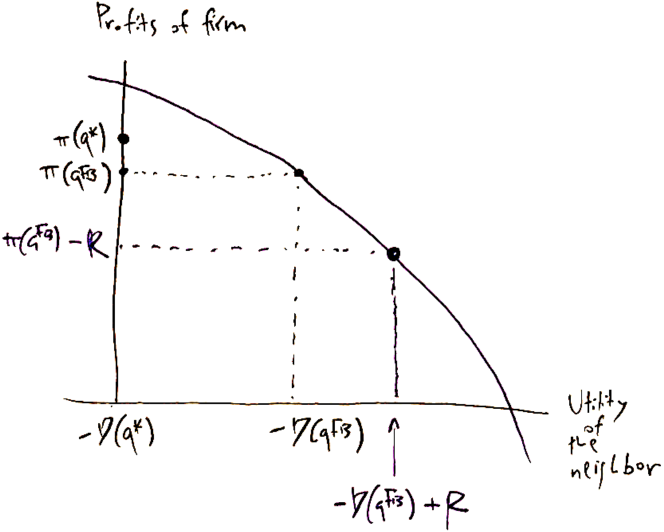
Distributional outcomes, Pigouvian tax



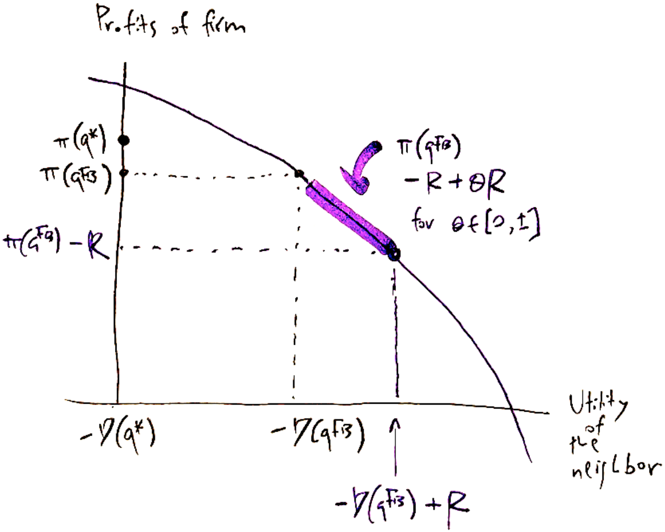
Distributional outcomes, Pigouvian tax



Distributional outcomes, Pigouvian tax



Distributional outcomes, Pigouvian tax



Prices versus quantities

When should a tax be used relative to a quota?

So far:

- no difference in terms of efficiency
- may have different distributional outcomes
- possibly different implementation costs

Prices versus quantities

What information do we need to implement these policies?

- usually, **no difference** in informational requirements

$\hookrightarrow$ solving for $\tau = D'(q^{\text{FB}})$ or solving for q^{FB} is the same problem

However:

- when D is linear (so that D' is constant), we don't need to calculate q^{FB} to set the Pigouvian tax if we know D'
- when we only care about damages at some threshold q^{FB} where they become prohibitively large, we don't need τ for a quota if we know q^{FB}

$\hookrightarrow$ If we are uncertain, are we more likely to "get it right" with a tax in the former case and a quota in the latter case?

Briefly, we'll describe a famous example for which, if costs are uncertain, then the policy design does affect efficiency.

This example is due to Weitzman (1974). $\hookrightarrow$

Prices versus quantities

Suppose that we are uncertain whether marginal costs are either high or low.

- Assume we have to commit to either a fixed quota or fixed tax.
- Then the firm learns their true cost and chooses output to maximize profits.

Under the tax, the eventual output level is random:

- If costs are high, then the firm produces less
- If costs are low, then the firm produces more

Under the quota, the eventual output is certain, but the firm cannot adjust its output in the face of lower or higher costs $\implies$ the eventual cost is random.

Weitzman shows that

- if damages are steeper, it's worse for output to be random $\implies$ should fix q
- if costs are steeper, the opposite holds $\implies$ should fix τ

That is, choose tax over quota $\iff$ $c'' > D''$.

Prices versus quantities

For example:

- If you are operating a river system with dams, then
  - too much water can overflow, cause destructive deluges
  - too little water can destroy the ecosystem irreversibly
- probably want to set a **fixed volume** for river diversions
- "it doesn't pay to 'fool around' with prices in such situations" (p. 487)

For example:

- If you are designing climate policy in South Africa, then
  - the marginal climate damage of emissions might be approximately constant ($\approx$ 1 tCO_2/42 billion tCO_2/year)
  - but some industries (e.g., aluminum smelting) in South Africa may operate on razor-thin margins; could shut down completely with a bad cost shock
  - job losses, dislocation of communities
- perhaps would like a **fixed tax** on carbon emissions

Prices versus quantities

National Treasury, Republic of South Africa, 2013:

> *Taxes provide certainty with respect to price, but no certainty with regard to emissions reductions. A [cap], however, provides certainty of the emissions reduction levels to be achieved, but not of the resulting carbon price. [. . .]*
>
> *In the South African context, a carbon tax is more appropriate than a cap-and-trade scheme [. . .]*
>
> *This will provide the necessary flexibility and space for the country's economic development needs while also addressing environmental problems, such as climate change.*

(Carbon Tax Policy Paper, 2013, p. 9)

More on this in our climate change + environmental market design lectures. . .

Policy solutions (3/4)

Solution 3(a). Private property rights. Suppose that prior to producing output, the firm requires permission from the neighbor to produce a given level $\tilde{q}$.

Moreover, suppose that the firm can sign a binding contract with the neighbor to obtain their permission; in particular, that they can offer the neighbor any $t(\tilde{q})$.

That is, for a contract $t(\tilde{q})$, the neighbor will obtain

$$-D(\tilde{q}) + t(\tilde{q})$$

and the firm will obtain $\pi(\tilde{q}) - t(\tilde{q})$.

Our preceding analysis indicates:

1. The neighbor's marginal value for increasing output is $-D'(q)$
   - $\hookrightarrow$ Neighbor needs to be paid at least $D'(q)$ to accept any offer
2. The firm's marginal value for increasing output is $\pi'(q) = p - c'(q)$
   - $\hookrightarrow$ Firm will never pay more than $\pi'(q)$ for more output at the margin

Property rights with contracts

Claim: in 3(a), the resulting allocation $\tilde{q}$ is efficient.

Proof. Suppose $\tilde{q} > q^{\text{FB}}$. This implies that $D'(\tilde{q}) > p - c'(\tilde{q})$.

- The neighbor will require marginal compensation of at least $D'(\tilde{q})$.
- But the firm will not offer to pay the neighbor more than its marginal profit.

Conversely, suppose that $\tilde{q} < q^{\text{FB}}$. Then, $D'(\tilde{q}) < p - c'(\tilde{q})$.

- I.e., firm's marginal profits exceed the marginal harm to the neighbor.
- Then the firm can increase profits by offering any $t' \in [D'(\tilde{q}), p - c'(\tilde{q})]$ to produce (infinitesimally) more than $\tilde{q}$.

Hence, $\tilde{q} = q^{\text{FB}}$. ■

Property rights with contracts

Solution 3(b). Instead, grant the firm the right to produce any level of $\tilde{q}$, but allow the neighbor to offer the firm a binding contract.

Note that the same logic from above applies!

- If $\tilde{q} > q^{\mathsf{FB}}$, then neighbor is willing to pay up to $D(\tilde{q}) - D(q^{\mathsf{FB}})$; in particular, they are willing to pay at least $\pi(\tilde{q}) - \pi(q^{\mathsf{FB}})$.
- Alternatively, if $\tilde{q} < q^{\mathsf{FB}}$, then there is no offer that the neighbor will make to the firm that the firm will accept.

Property rights with contracts

What are the **distributional** considerations?

Total surplus under the efficient allocation is

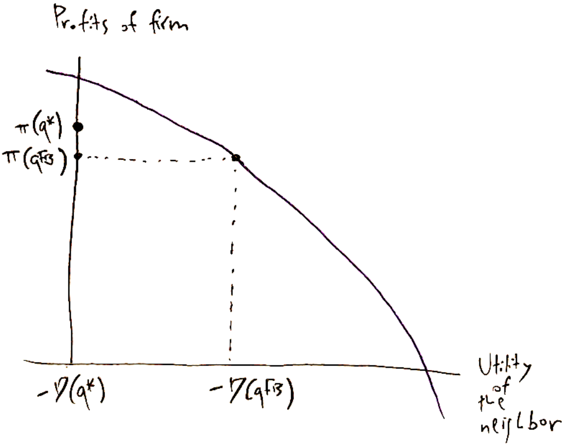
$$W(q^{\mathsf{FB}}) = \pi(q^{\mathsf{FB}}) - D(q^{\mathsf{FB}}).$$

Its distribution across the firm and the neighbor will depend on the initial property rights and the bargaining protocol.

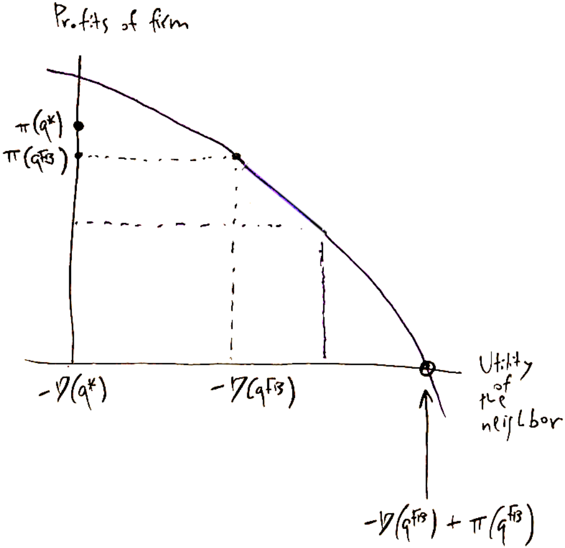
For example:

- In 3(a), the neighbor can charge the firm up to $\left[\pi(q^{\mathsf{FB}}) - \pi(0)\right]$, with the firm indifferent between not producing at all and striking a deal.
- In 3(b), the firm can charge the neighbor up to $\left[D(q^*) - D(q^{\mathsf{FB}})\right]$, with the neighbor indifferent between suffering the free market outcome and striking a deal.

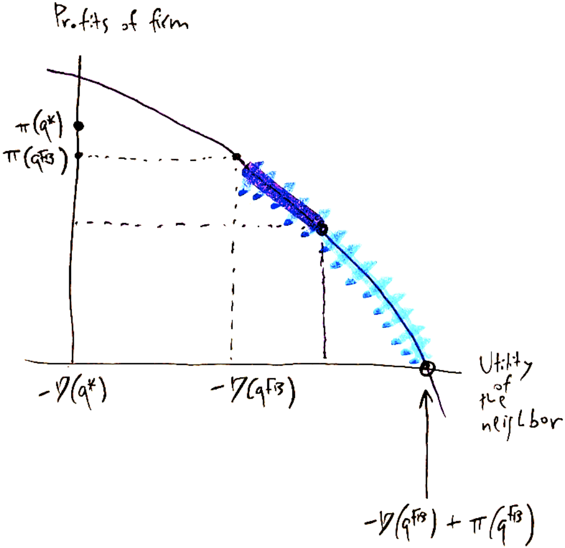
Distributional outcomes, bargaining



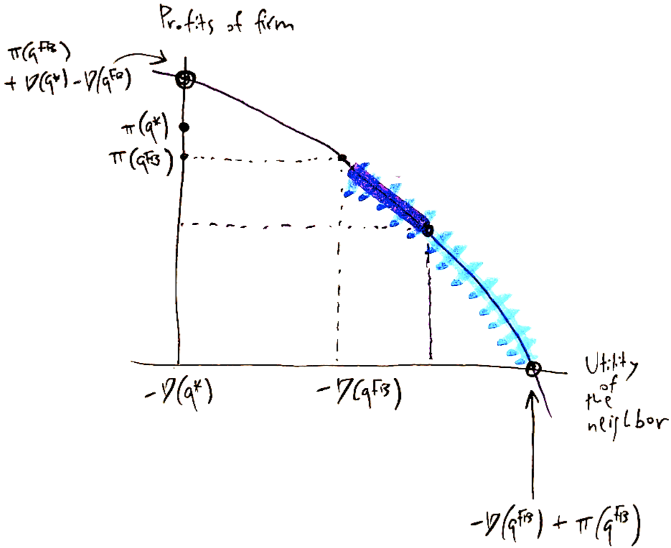
Distributional outcomes, bargaining, 3(a)



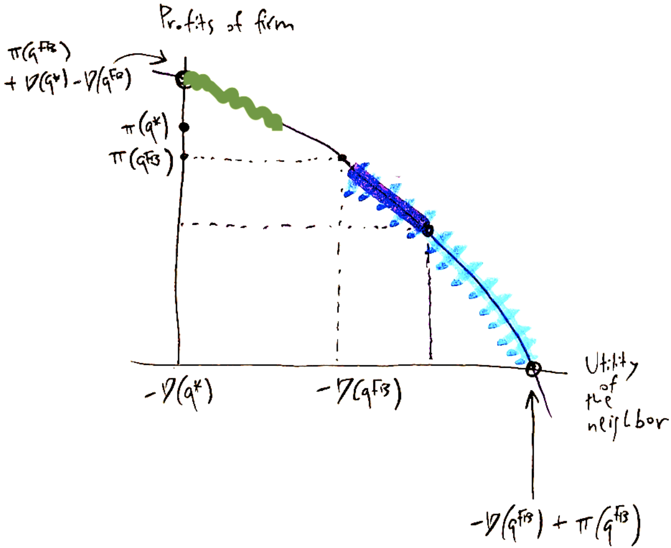
Distributional outcomes, bargaining, 3(a)



Distributional outcomes, bargaining, 3(b)



Distributional outcomes, bargaining, 3(b)



Policy #1. Regulation

Policy #2. Corrective taxation

Prices versus quantities

Policy #3. Private property rights

Coase Theorem

Policy #4. Mergers

Coase Theorem

That we get the same (efficient) allocation in both cases is a special case of a more general result, known as the **Coase theorem**.

Theorem (Coase 1960)

If private property rights are well-defined for the externality, and all participants

1. *can transact with another costlessly*
2. *maximize their utility (or profits)*
3. *have the same information*

then the resulting allocation is efficient **regardless** *of initial assignment of property rights.*

Under ideal conditions, initial assignment of rights does not matter for efficiency.

∴ In such contexts, the role of government is to define and enforce property rights.

Strong result, **strong assumptions** $\hookrightarrow$

Coase Theorem

Immensely useful when applicable:

> *Pigou lays considerable stress on this [tax] solution, although he is, as usual, lacking in detail...to do so would require a detailed knowledge of individual preferences and I am unable to imagine how the data needed for such a taxation system could be assembled. Indeed, the proposal to solve the smoke-pollution and similar problems by the use of taxes bristles with difficulties: the problem of calculation, the difference between average and marginal damage, the interrelations between the damage suffered on different properties, etc. But it is unnecessary to examine these problems here. (Coase 1960, pp. 41–42)*

A1. Transaction costs

Should be clear why zero transaction costs is an important assumption.

Transaction costs can

- prevent contracting entirely (e.g., fixed transaction costs)
- distort the level of the contract (e.g., variable transaction costs)

Coase's closing statement:

> *Actually very little analysis is required to show that an ideal world is better than a state of laissez faire, unless the definitions of a state of laissez faire and an ideal world happen to be same. [. . .]*
>
> *But in choosing between social arrangements. . . we have to take into account the costs of involved in operating the various social arrangements (whether it be the working of a market or of a government department), as well as the costs involved in moving to a new system. [. . .]*
>
> *This, above all, is the change in approach which I am advocating. (Coase 1960, pp. 43–44)*

A1. Transaction costs: Examples

Transaction/bargaining costs can be very high

- e.g., air pollution, tens of thousands of people suffer
- need an association to bargain for the agents who are affected
- this "association" is the role for government!

Indeed, Coase gives this example ("the standard case of a smoke nuisance").

Transaction/bargaining costs can be quite low

- firms sign contracts with one another and other people all the time (e.g., to whom is the firm selling its output?)
- may be no obvious reason the neighbor is different

The Coase Theorem is often a useful starting point for economic analysis

- ask: which conditions fail to hold?
- guides subsequent analysis

A2. Profit and utility maximization

If either the firm (or the neighbor) cannot maximize profits (or utility), then the Coase Theorem also fails.

One common example of this is the presence of **borrowing constraints**.

For example, suppose the neighbor cannot go into debt and starts with some initial level of wealth $y > 0$.

1. In case 3(a), the neighbor owns the property rights; they receive a positive transfer from the firm, so the allocation will be unchanged.
2. In case 3(b), if wealth is less than the firm's forgone profits,

$$y < \pi(q^*) - \pi(q^{\text{FB}}),$$

then the neighbor cannot afford to pay the firm to produce q^{FB} instead of q^*.

Here, the initial distribution of rights **can** affect whether the outcome is efficient ✓

A3. Informational issues

A last crucial assumption is that the firm and the neighbor both know π and D.

To see this informally, let's modify example 3(a):

Suppose now that the firm has more information than the neighbor. Specifically, suppose that π could either be π^H or π^L (high or low).

Before, the neighbor knew that the firm would not refuse an offer that took all of $\pi^H(q^{\mathrm{FB}})$. Now, the neighbor is **uncertain** about the true type of the firm.

Can't rule out that the neighbor could benefit from offering a take-it-or-leave it offer that works for the high-profit firm but not for the low-profit firm.

But in that case, if the firm turns out to be low-profit, then they do not trade and the firm ends up producing q^* instead

- $\hookrightarrow$ the outcome is **inefficient** in this state of the world
- $\hookrightarrow$ i.e., the Coase Theorem does not hold.

Policy solutions (4/4)

A last solution worth mentioning:

Solution 4. Merger. Suppose that the neighbor is also a firm, with net revenue $\pi_2(q) = -D(q)$. Then let the firm and the neighbor merge into a single firm, with joint profits

$$\pi(q) + \pi_2(q).$$

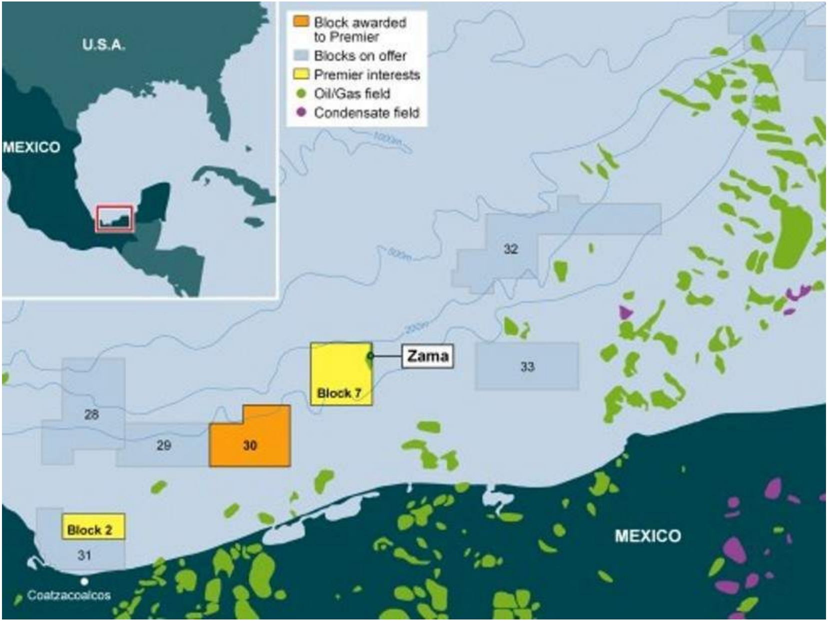
The subsequent market allocation is efficient.

Example: "unitization" in oil fields.

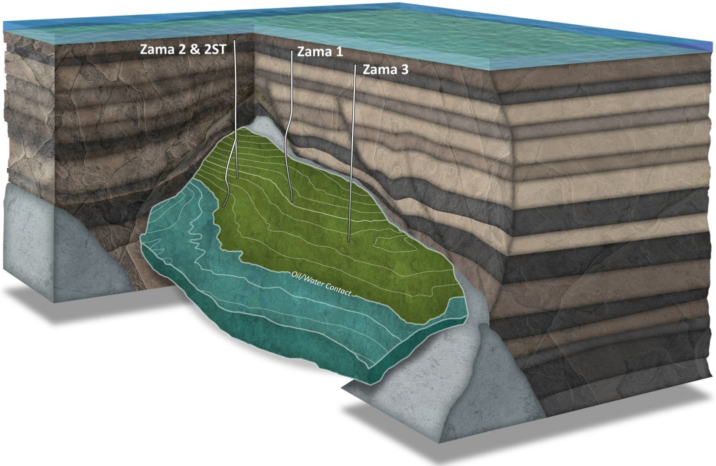
Note:

- similar to Coase in that private contracts solve the problem without government involvement
- key difference: do not need to define property rights for the externality; instead, require a legal framework that allows mergers

Unitization example. A Pemex oil-producing field in the Gulf of Mexico



Zama oil field: between Talos Energy's Block 7 and Pemex-owned block in the Bay of Campeche



Subsurface geology of Zama oil reservoir (Talos Energy), discovered 2017

Recap

Four policy designs to solve externalities:

1. Regulate output
2. Tax output
3. Assign property rights and allow contracts
4. Merge the respective parties

All four give the "efficient" allocation q^{FB}.

But:

1. Very different distributional implications
2. Different institutional requirements

Policy design matters.

Next time

- On Wednesday, we will discuss empirical approaches to identify costs and benefits of environmental policies.
- Problem set 1 posted
  - Due next Monday, October 13, at the start of lecture (submit online via Gradescope)