Spatial Environmental Economics
Lecture 3: Environmental Externalities and Regulation

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Roadmap

1. Market Failures
2. Example: Power Plant Emissions
3. Example: Refineries and Feedlots
4. Pigouvian Taxes with Market Power
5. Example: OPEC

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Market failures

- When an unregulated market "fails" to produce socially-optimal (=efficient) outcomes
- There are many potential sources of market failure, such as
  1. Externalities (private actions have unintended effects)
  2. Public Goods (nonrival and nonexcludable)
  3. Market Structure/Power (one party can influence the market equilibrium)
  4. Information Asymmetries (one party in a transaction knows more than the other)
- Last lecture illustrated #1 and policies to address the failure
- This lecture explores how that interacts with #3, and provides examples of #1 and #3

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Local governments and power plant emissions

- Our 2-region pollution model illustrated how local governments can maximize local welfare by "exporting" locally produced negative externalities
  - Our policy was a tax
  - Same rationale applies to regulating the location of polluting firms inside a region
- Morehouse and Rubin (2021) study the siting of electricity generation plants in the U.S.
- Coal-powered electricity generation plants
  - Generate economic benefits for operators, workers, an local government
  - Emit air pollutants that are carried by the wind, potentially crossing admin. boundaries
- As a result, local governments have incentives to site polluters where the jurisdiction can simultaneously enjoy the benefits of pollution production while exporting the costs

Morehouse and Rubin (2021)

Are power plants sited to capture local benefits and export their negative externalities?

- Approach:
  - Analyze historical power-plant siting relative to admin. borders and prevailing wind directions
  - Also compare coal-powered (high polluters) and natural-gas-powered plants (low polluters)
- Findings:
  - Plant's pollution travels far: within 6 hours, 50% leave source states and 99% source county
  - Coal-fueled plants disproportionally sited near administrative units' downwind borders
  - Natural gas plants sited near borders, but not disproportionally downwind borders

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Examples of Coasian bargaining "in the wild"

Deryugina et al. (2021)

- Exxon and Shell have bought properties near their refineries
  - Apparently after explosions at their facilities caused damage to the people living nearby
  - Example of polluter paying, and solving the coordination problem
  - Note: bargain under the threat that property rights (to e.g. safety) may be enforced in court
  - Note: the outcome need not be efficient, because the polluter had monopsony power
- City Council of Santa Maria, California, paid a nearby cattle feedlot to move
  - Cattle feedlot produced noxious odors and other air emissions
  - Example of the pollutee paying
  - The local government solved the coordination problem by imposing a tax on residents

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Model setup: one producer and one consumer

- The **producer** chooses quantities to maximize profits:

$$\pi(y) = py - C(y) - ty$$

  - A regulator imposes a per-unit tax t paid by the producer
  - Assume $C(y) = 0.5y^2$
- We consider two alternative market structures
  1. Perfect competition (PC): producer takes price p as given
  2. Monopoly (MO)
- The **consumer** demands the producer's good according to the inverse demand function

$$p(y) = a - y$$

- Production generates a negative environmental externality on the consumer $D(y) = y^2$

Market outcome: perfect competition

- In perfect competition, the producer's problem is

$$\max_{y} py - C(y) - ty$$

so the quantity supplied y^S must satisfy the FOC:

$$p = C'\left(y^S\right) + t$$

  - i.e. price = marginal cost

- Replacing $C(y)$ we obtain the **supplied quantity** as a function of price and taxes:

$$y^S(p, t) = p - t$$

Market outcome: perfect competition (cont.)

- An **equilibrium price** p^{PC} must satisfy that supplied = demanded quantities:

$$y^S\left(p^{PC}, t\right) = y^D\left(p^{PC}\right)$$
$$p^{PC} - t = a - p^{PC}$$
$$\Longleftrightarrow$$
$$p^{PC} = \frac{a+t}{2}$$

- Replacing into supply we obtain **equilibrium output** as a function of taxes:

$$y^{PC}(t) = \frac{a-t}{2}$$

Market outcome: monopoly

- The monopolist's problem is

$$\max_{y} p(y)\, y - C(y) - ty$$

so the quantity supplied y^{MO} must satisfy the FOC:

$$p'\left(y^{MO}\right) y^{MO} + p\left(y^{MO}\right) = C'\left(y^{MO}\right) + t$$

  - i.e. marginal revenue = marginal cost

- Replacing $C'(y)$, $p(y)$ and $p'(y)$ we solve for **equilibrium output** as a function of taxes:

$$y^{MO}(t) = \frac{a - t}{3}$$

Market outcome: monopoly (cont.)

- We find prices replacing y^{MO} in the inverse demand:

$$p^{MO} = p\left(y^{MO}\right) = \frac{2}{3}a + \frac{t}{3}$$

Market outcomes: perfect competition vs. monopoly

- Consider for now an unregulated market ($t = 0$)
- Monopoly reduces quantities and increases prices relative to competitive market:

$$y^{MO} = \frac{a}{3} < \frac{a}{2} = y^{PC}$$

$$p^{MO} = \frac{2}{3}a > \frac{a}{2} = p^{PC}$$

- **But**: lower quantities mean less pollution!

$$D\left(y^{PC}\right) > D\left(y^{MO}\right)$$

- An optimal tax policy in the presence of market power should consider the two forces

Optimal Pigouvian tax

- Before, we (i) solved socially-optimal output without taxes and (ii) showed that the Pigouvian tax equal to marginal damages leads to the optimum
- Alternative: set up the problem as choosing taxes t to maximize social welfare $\mathcal{W}$:

$$\mathcal{W} = CS + \pi + ty$$

  - i.e. consumer surplus + producer profits + tax revenue
- Then the optimal tax $t^\star$ solves the FOC

$$\frac{\partial \mathcal{W}(t^\star)}{\partial t} = 0$$

  - We will do it separately with perfect competition ($t^{\star,PC}$) and monopoly ($t^{\star,MO}$)

Consumer surplus

- We have an inverse demand function $p(y)$ - measures the maximum willingness to pay
- How can we measure the welfare/ well-being of the consumer?
- **Consumer surplus** measures the amount that consumers gain from purchases as the difference between (i) the price they paid and (ii) the maximum price they would be willing to pay for each unit consumed
- So we "add up" (infinitesimally, integrate over) the y units consumed:

$$\int_0^y (p(x) - p)\, dx = \int_0^y p(x)\, dx - p\int_0^y dx = \int_0^y p(x)\, dx - py$$

- And in our case we also add the pollution externality:

$$CS(y, p) = \int_0^y p(x)\, dx - py - D$$

Social welfare

- Social welfare is then given by

$$\mathcal{W} = \left[\int_0^y p(x)\,dx - \cancel{py} - D(y)\right] + [\cancel{py} - C(y) - \cancel{ty}] + \cancel{ty}$$

- Solving the integral:

$$\int_0^y p(x)\,dx = \int_0^y (a-x)\,dx = \left[-\frac{1}{2}(a-x)^2\right]_{x=0}^{y} = ay - \frac{1}{2}y^2$$

- Replacing $C(y)$, $D(y)$, and the solved integral:

$$\mathcal{W} = ay - 2y^2$$

Optimal Pigouvian tax: perfect competition

- Recall:

$$y^{PC}(t) = \frac{a-t}{2}$$

- Then

$$\mathcal{W}^{PC}(t) = a\left(\frac{a-t}{2}\right) - 2\left(\frac{a-t}{2}\right)^2$$

- And the optimal Pigouvian tax $t^{\star,PC}$ solves the FOC

$$\frac{\mathcal{W}^{PC}\left(t^{\star,PC}\right)}{\partial t} = 0 \iff t^{\star,PC} = \frac{a}{2}$$

Optimal Pigouvian tax: monopoly

- Recall:

$$y^{MO}(t) = \frac{a-t}{3}$$

- Then

$$\mathcal{W}^{MO}(t) = a\left(\frac{a-t}{3}\right) - 2\left(\frac{a-t}{3}\right)^2$$

- And the optimal Pigouvian tax $t^{\star,MO}$ solves the FOC

$$\frac{\mathcal{W}^{MO}\left(t^{\star,MO}\right)}{\partial t} = 0 \iff t^{\star,MO} = \frac{a}{4}$$

Optimal Pigouvian tax: perfect competition vs. monopoly

- In a competitive market, the tax is the marginal damage done by pollution $t^{\star,PC} = \frac{a}{2}$
- In a monopoly, the the optimal tax is lower: $t^{\star,MO} = \frac{a}{4} < t^{\star,PC}$
  - If you apply the PC tax in a monopoly, output would be too low
  - Because the monopolist already suppresses demand
- The tax serves two purposes, correcting both pollution externality and market power
- The tax reflects that monopolists respond differently to prices than price-takers

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Example: the OPEC cartel

- Our model (slides 23-) compared monopoly and perfect competition
- Monopolies are rare, but other forms of market power are not
- Moreover, oligopolists can collude to behave as a monopolist - form a "cartel"
- Asker et al. (2024):
  - Study the Organization of the Petroleum Exporting Countries' (OPEC) cartel
  - Member countries coordinate to restrict oil supply and affect world prices
  - Ask: how has OPEC's market power affected carbon emissions since 1970?

Asker et al. (2024)

How has OPEC's market power affected carbon emissions since 1970?

- Approach:
  - Estimate marginal costs and emission intensities in OPEC and non-OPEC oil fields
  - Compare the actual history of oil to scenario with a competitive oil market
- Findings:
  - Collusion prevented an estimated $4 trillion in emissions-related externalities since 1970
  - The "volume effect" of higher prices and lower consumption reduced emissions
  - A "composition effect" partially offsets the gains: shifts in production to non-OPEC producers who, on average, employ more energy-intensive oil extraction
- We illustrated the "volume effect" in our simple model!
- Notice how space matters in two ways
  - Oil fields are unevenly distributed across countries
  - Emission intensity of oil extraction differs between oil-producing countries

Appendix

References I

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