Econ 230A: Public Economics
Lecture: Public Goods, Externalities

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Outline

- Public Goods

1. What are public goods?
2. First Best: The Samuelson Rule
3. Decentralized Implementation
4. Crowd-Out
5. Empirical Evidence on Crowd-Out

- Externalities

1. What are externalities?
2. Correcting Externalities
3. Prices. vs. Quantities
4. Optimal 2nd Best Taxation with Externalities
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1. What are public goods?

- Thus far, we have discussed how to set up a tax system to optimally collect money and meet a revenue requirement.
- Natural questions: Why do we want to raise that money?
  1. fund public goods (correct externalities)
  2. fix market failures (social insurance)
  3. redistribution
- Start now with the public finance of public goods.

1. Public Goods - what we will do

- How do we characterize goods that ought to be provided publically (Note we are concerned with public *provision* not public *production*)
- If the government knew the preferences of all members of society, how ought the supply of public goods be determined?
- What pricing should be used?
- Does one need to worry about moral hazard? *Crowdout* of private provision?

1. What are public goods?

- **Nonrivalry:** first feature of public goods
- Private goods only benefit a single user (eg coke)
- Public goods provide benefits to a number of users simultaneously (eg teaching a class)
  - If public good can accommodate any number of users: it is **pure**.
  - In this case, given the existence of the public good at the given scale then the marginal cost of adding another user $= 0$.
  - If congestion occurs, it is **impure**. (roads with traffic). [MC of adding another user > 0]
- More generally: a pure public good is characterized by **non-rivalry.**
  - Consumption of the public good by one household does not reduce the quantity available for consumption for the others. Ex: National Radio.

1. What are public goods?

- **Excludability:** second feature of public goods
- Is it possible to exclude individuals from consuming the public good?
  - Example: National Radio: impossible to exclude. Teaching: possible to exclude.
- Impossible, or extremely costly to exclude from consuming the public good (critical for free rider problem)
  - This is often related to technology
- Most economic analysis focuses on pure public goods
  - Abstraction (no public good is really pure) but useful benchmark.

1. Public goods and Implications for demand

- Let h denote households in the economy
- For private goods, we have $\sum_h X^h = X$, aggregate demand is the sum of individual demands
- For public goods, we have that $X^h = X$ for every h
  - If there is free disposal (not everyone has to consume the good) then $X^h \leq X$ for every h

2. First Best Allocation: The Samuelson Rule

- Public good does not fit into usual competitive framework of Arrow-Debreu b/c of production externalities
  - $\Rightarrow$ *competitive outcome may not be efficient*.
- Economy with H households, indexed by $h = 1, .., H$
- Two goods X and G. X is always private, individual consumes quantity X^h.
- Denote by $X = \sum_h X^h$ total quantity of good X consumed in the economy.

2. First Best: The Samuelson Rule

Suppose first that G is private

- Denote by G^h consumption of good G by h, with $G = \sum_h G^h$.
- Utility of h is $U^h = U^h(X^h, G^h)$.
- Assume that U^h is increasing in X and G.
- Social welfare = weighted sum of utilities, β^h weight on h in social welfare
  - $\beta^h \geq 0$ and at least one $\beta^h > 0$.
- Production possibility $F(X, G) = 0$.

2. First Best: The Samuelson Rule (G private)

- To identify Pareto efficient outcomes (highest SWF given constraints), solve:

$$\max \sum_h \beta^h U^h(X^h, G^h)$$
$$\text{s.t. } F(\sum_h X^h, \sum_h G^h) \leq 0$$

- FOCs using λ on the constraints:

$$[X^h] \quad : \quad \beta^h U_X^h = \lambda F_X$$
$$[G^h] \quad : \quad \beta^h U_G^h = \lambda F_G$$

2. First Best: The Samuelson Rule (G private)

- Taking ratios of FOCs

$$\frac{U_G^h}{U_X^h} = \frac{F_G}{F_X}$$

$$MRS_{GX}^h = MRT_{GX} \ \forall h$$

- This defines the pareto efficient allocations
- Condition says: Marginal rates of substitution between G and X equal across individuals and equal to the marginal rate of transformation between G and X.
- For private goods we know we can get there because we all choose X st MRS=price. By our ability to choose X (and our being forced to pay for X to consume X), prices work!
  - First Welfare Theorem!!

2. First Best: The Samuelson Rule

Now suppose G is a pure public good.

- Let G denote level of PG, which everyone consumes.
- Utility of h is $U^h = U^h(X^h, G)$. $(G^h = G \; \forall h)$
- Production possibility $F(X, G) = 0$ as before.
- Next, solve same optimzation (max SWF st PPF)

2. First Best: The Samuelson Rule

- To identify Pareto efficient outcomes,

$$\max \sum_h \beta^h U^h(X^h, G)$$
$$\text{s.t. } F(\sum_h X^h, G) \leq 0$$

- FOC's:

$$\begin{aligned} [X^h] &: \beta^h U_X^h = \lambda F_X \\ [G] &: \sum_h \beta^h U_G^h = \lambda F_G \end{aligned}$$

- Using $\beta^h = \lambda F_X / U_X^h$ from X^h-FOC combine with G-FOC to obtain:

$$\sum_h \frac{U_G^h}{U_X^h} = \frac{F_G}{F_X}$$

2. First Best: The Samuelson Rule

- $$\sum_h MRS^h_{GX} = MRT_{GX}$$
- Contrast with private good case: Condition for Pareto efficiency: **sum of** MRS is equal to MRT.
- This is the Samuelson Rule (developed in famous ReStat 1954, 3 page paper by Samuelson).
- Intuition: The MB of an increase in G of one unit is the sum of the MB for each person (which in the optimum is = MC). This is in contrast to the private good case where the indi MB equals the MC.

2. First Best: The Samuelson Rule

Remarks:

- This solution works in a "fully controlled" situation where the government has perfect information about preferences and then can set G optimally.
- The formula above does not account for any distortionary taxes that are needed to raise funds for the public goods.
- Excludability plays no role in the analysis. Excludability is only relevant for determining feasible provision mechanisms.
- In this sense,
  Samuelson analysis can be considered as a First-Best analysis.
- Practical question: How can optimal provision of public good be decentralized given available policy tools and respecting information constraints?

What if we can get first best?

1. Subscription Equilibrium: What happens if there is no government involvement in the public good?.
2. Lindahl Equilibrium: Is there a mechanism that gets us to pareto efficient solution (with similarities to competitive market equilibrium)?
3. Voting Equilibrium: What happens with political models of voting? [we will spend less time on this]
   Generally, how can optimal provision of public good be decentralized given available policy tools and respecting information constraints?

Public good with no government

- Pure public good in the model we have outlined (nonrival, nonexcludable)
- Free rider problem. No group would voluntarily pay for the public good. They can get access to the public good even if they do not contribute.
    - This is called the Nash equilibrium outcome.
    - Not Pareto-efficient. market outcome leads to underprovision of public good
- Yet, we see people contributing to charities
    - Earthwquake in Haiti
    - Increase in contributions to food pantries in the current recession
- People may derive direct utility from giving: $U(X^h, G^h, G)$.
    - This is Andreoni's (1990 Economic Journal) famous "warm glow" model of charitable contributions that is now viewed as the central paradigm in this literature.
    - We will come back to this shortly (crowdout- what happens to private contributions when government funding increases?)

3. Decentralized Implementation - Lindahl Prices

How can the efficient outcome be implemented?

- Idea: can we come up with "individualized prices" that vary across individuals reflecting their willingness to pay
- Known as Lindahl prices.
- Tax share (of total cost of public good) becomes individualized price
- Equilibrium is a set of prices such that all persons demand the same level of the public good.

3. Decentralized Implementation - Lindahl Prices

Model:

- private good X and a pure public good G.
- Each household starts with an endowment Y^h of good X.
- Assume that individual h has to pay a share τ^h of the public good and, given that, can choose freely their desired level of the public good G. Individual h contributes $\tau^h G$ to public good funding (pays this amount)
- Individual h maximizes $U^h(X^h, G)$ st $X^h + \tau^h G = Y^h$.
- Taking FOC for X^h and G, and then the ratios of FOC: $\tau^h U_X^h = U_G^h$
- Demand function of $G^h = G^h(\tau^h, Y^h)$

3. Decentralized Implementation: Lindahl Prices

- Lindahl Equilibrium satisfies two conditions:
  1. $\sum_h \tau^h = 1$ (public good must be fully financed).
  2. All individuals must demand the same quantity of public good G.
- In general you have H equations ($G^1 = .. = G^H$ and $\sum_h \tau^h = 1$) and H unknowns (τ^h) so there exists a Lindahl equilibrium

3. Decentralized Implementation

What happens in this setting?

- Our FOC implies for each h that $MRS^h = \frac{U_G^h}{U_X^h} = \tau^h$
- Therefore summing over households, $\sum_h [\frac{U_G^h}{U_X^h}] = \sum_h \tau^h = 1$
- So the Lindahl equilibrium satisfies the Samuelson Rule and outcome is Pareto efficient.
- Intuition: each individual bears only a fraction of the cost of the PG, so people end up picking the right amount of the PG
- General Conclusion: efficiency can be attained with public goods by the use of personalized prices.

3. Decentralized Implementation

Two practical constraints that limit use of Lindahl pricing:

1. Need the ability to exclude a consumer from the use of the public good (cannot work with non-excludable public good).
2. Each agent has to face a personalized price τ^h. Problem: need to know individual preferences to obtain prices τ^h. Agents have no incentives to reveal their preferences. In fact, each agent has interest in pretending that he has little taste for the public good.

- Key difference between Lindahl equilibria and standard equilibria: no decentralized mechanism for coming up with prices – no market forces that will generate the right price vector.

4. Decentralized Implementation: Voting Mechanisms

In practice, people vote over the quantity G of public goods to be provided. Does voting lead to the FB solution?
Summary of main results from voting models:

- *Voting equilibrium:* G_* of public good that cannot be defeated in a majority rule by any other alternative $\hat{G}$.
- *Problem*: Voting equilibrium does not exist in general
- Need two strong assumptions to ensure the existence of a voting equilibrium.

1. G is unidimensional (e.g. choice of size of a unique public project: how large should the defense budget be)
2. preferences over G are single-peaked,i.e. each person has a unimodal favorite level of G and then has lower preferences on both sides.

Optimal Second Best Provision of PG's

- Suppose govt has decided to levy a tax and provide public goods based on some rule
- Two complications arise when trying to get to Samuelson First best level

1. Interactions wtih private sector (crowdout) $250B/yr in private contributions.
2. Government can not finance PG's through lump sum taxation; must use distortionary taxes

5. Crowd-Out: Govt Provision with Endog Private Provision

- Start with private market donations funding the public good. Individual h solves
  $\max U^h(X^h, G^h + G^{-h})$ st $X^h + G^h = Y^h$.
- Nash equilibirum: all individuals optimize given others' behavior –> G^* is private mkt eq
- Now govt introduces lump sum taxes t^h to finance public good $T = \sum t^h$ so individual's problem becomes
  $\max U^h(X^h, G^h + G^{-h} + T)$ st $X^h + G^h = Y^h - t^h$.
- Let $Z^h = G^h + t^h$, total contribution for individual h.
- This is isomorphic to original problem $\Longrightarrow Z^* = G^* \Longrightarrow$ PG provision unchanged $\Longrightarrow$1-1 crowdout

5. Crowd-Out: Govt Provision with Endog Private Provision

- Above model ignores direct utility from giving, Andreoni (1990) warm glow model $U(X^h, G^h, G)$
- Examples:
  - Bush policies, govt aid for the poor is not necessary. Private contributions will make up for public support
  - Important new topic of interest given increase in wealth inequality and large-scale charitable contributions and foundations (Gates)
  - Private giving to public institutions like UC: risk of commensurate cut in public funding?

5. Empirical Evidence on Crowd-Out

Key empirical questions motivated by theory:

1. How large is the degree of crowd-out in practice?
2. What are the income and price effects on charitable giving (private provision of PGs). (This determines optimal tax policy toward charity.)

- Hard problem empirically to work on (endogeneity, hard to predict private giving)
- Two strands of empirical literature: nonexperimental evidence and lab experiments. Traditionally, lab experiments have been more influential in this area b/c the field evidence was not very convincing. This may change as empirical studies improve.
- There is a literature on taxes and charitable giving that uses tax reforms for identification. This is decent.

5. Empirical Evidence on Crowd-Out: Hungerman 2005

- Studies crowdout of church-provided welfare (soup kitchens, etc) by govenrment welfare
- Identifies shifter for government spending using welfare reform
  - 1996 PRWORA dramatic changes to cash welfare; also severely reduced access for *legal* immigrants (who has previously had similar eligibility as naturalized citizens)
  - Because of weakness of pre/post design, he interacts the % share non-citizen with post-1996
- Sort of a DD: before/after, high/low share non-citizen areas
- Data: Presbyterian Chuch level data 1994-2000.
  - 2011 statistical abstract: 230m people, 5m Presbyterian (60M catholic, 36M baptist, 11M methodist)
  - data on spending, donations for 11,000 churches

5. Empirical Evidence on Crowd-Out: Hungerman 2005

- Motivation for their approach: Suppose you have panel data state-years on government spending and total charity spending
- You regress church spending $church_{st}$ on government spending gov_{st}
  $church_{st} = \delta gov_{st} + \beta X_{st} + \epsilon_{st}$
- Fig 1 gives the time series correlations of these two variables
- What do you think of this model?
- What is missing?
- What is the nature of the omitted variable bias?

5. Empirical Evidence on Crowd-Out: Hungerman 2005

- more details:
- Government welfare: AFDC/TANF, Food Stamps, Medicaid, SSI [measured for county that church resides in]
- Church: Donations per member, Spending per member (spending=local missions, see pp. 2256-2257)
- Do churches know about the reform? some quotes on p.2254 suggest they do
- model controls for county labor market conditions, other demographics of county
- 66,899 church x year observations

5. Empirical Evidence on Crowd-Out: Hungerman 2005

- Figure 3: Visual of reduced form, relate change in spending to percent noncitizen
- But? What about a pre-trend? How would you examine this? Need to know this to have confidence in the approach
- How about same as Fig 5 but for 1993-1996? Hope flat line, don't know.
- Table 5: spending regression shows OLS Is biased towards zero, intuition?
- Table 5: member donations are similar between OLS and IV
- Results imply crowdout of 20 cents on the dollar.

5. Empirical Evidence on Crowd-Out: Hungerman 2005

- Robustness (Table 6)
  - government programs unaffected by citizenship changes
  - church operating expenditures

5. Empirical Evidence on Crowd-Out

- Summary: nonexperimental crowd-out literature (from above paper and others) shows that crowdout is 20-30 cents on the dollar. Non-trivial but far from full crowdout.
- Larger crowdout estimates in the experimental (lab) literature, maybe 70 percent
  - Interesting factors of real world are missing: sympathy, political or social commitment, peer pressure, warm glow, lack of salience.
  - Hence, this is considered an upper bound of degree of crowd out.
- But crowd-out may not be very big b/c most individuals have no idea what government is spending.

1. What are externalities?

- An externality arises whenever the utility or production possibility of an agent depends *directly* on the actions of another agent (firm or individual).
- Directly means that the effect is not transmitted through prices (i.e., through a market mechanism).
- Examples:
  - consumption of an apple: pecuniary externality, internalized in market prices.
  - pollution/consumption of loud music: these externalities enter directly into the utility or production functions.
- "pecuniary" vs. "non-pecuniary" is not an exogenous, technological definition. Depends fundamentally on markets that are in place.

1. What are externalities?

- Presence of externalities depends in details of the institutional arrangement like definition of commodities and property rights.
- Example: 2 firms: 1 firm pollutes the river and the second firm is a fish farm on that river that suffers from pollution of firm 1. If the two firms merge or if one owns the river and can charge the other for pollution, then external effect gets internalized and there is no longer an externality.
- Old Chicago view (Coase): Can convert all externalities into pecuniary externalities with appropriate markets.
- Note connection to theory of public goods. Public goods are goods that have large-scale productive externalities.

1. What are externalities?

- Here we will focus more on 1-1 externalities (your behavior affects my welfare and we need to correct that).
- Key questions:
  1. Theoretical: What is the best way to correct externalities and move closer to the social optimum?
  2. Empirical: How to measure the size of externalities?

2. Correcting Externalities

Consider a two-good model where firms produce cars x using the numeraire y.

- Producing x cars entails use of $c(x)$ units of the numeraire and generates x units of pollution (P).
- Consumers have wealth Z and quasilinear utility

$$u(x) + y - dP$$

- Social welfare:

$$W = u(x) + Z - c(x) - dP$$

- Competitive equilibrium: let p denote price of cars. Firms maximize

$$\max px - c(x)$$

- Consumers maximize utility taking pollution as fixed (free rider problem – my car consumption has very little impact on overall level of pollution, so I treat it as fixed and therefore does not affect my optimization):

$$\max u(x) + Z - px$$

2. Correcting Externalities

- Demand satisfies

$$u'(x^D) = p$$

- Supply satisfies

$$c'(x^S) = p$$

- Hence in equilibrium, marginal private benefit equals marginal private cost – the standard optimality condition

$$u'(x^D) = c'(x^S)$$

2. Correcting Externalities

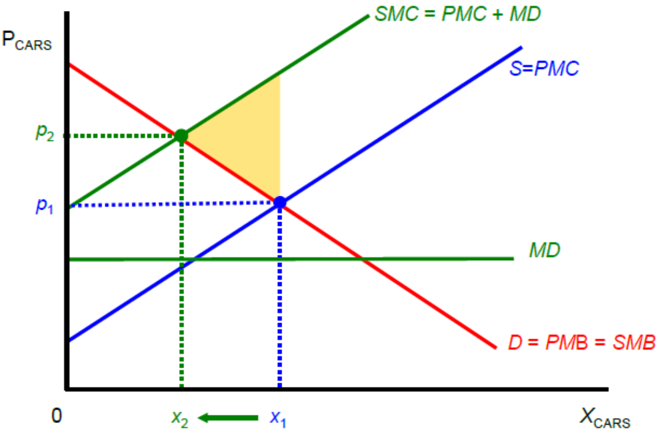
Problem: this solution is now not Pareto efficient.

- Marginal damage of production: $MD = d$
- Marginal social cost of production: $c'(x) + d > c'(x)$

2. Correcting Externalities

- Why is there inefficiency? deadweight loss triangle (Gruber figure 1)

Figure 1 Negative Production Externalities: Pollution



2. Correcting Externalities

- Can see this inefficiency formally using a perturbation argument: suppose I reduce production by dx. Then

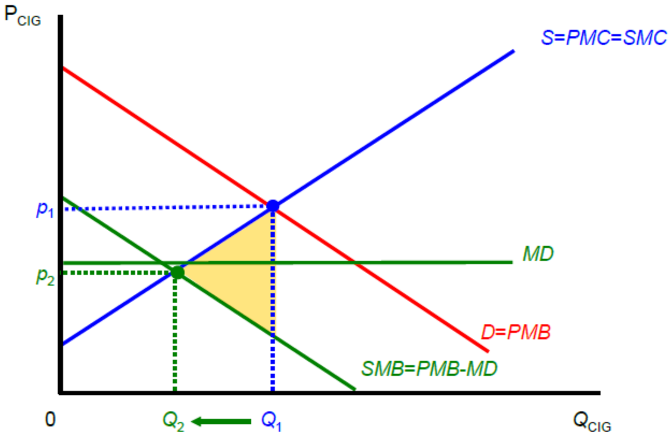
$$dW = u'(x)dx - c'(x)dx - d \cdot dx = -d \cdot dx > 0 \text{ if } dx < 0$$

- Hence social welfare rises if production is reduced and First Welfare Theorem fails.
- Analogous result for consumption externalities. (see figure 2)
  - Social optimum: Q^* such that $MPC = MSB$
  - Market outcome Q^M such that $MPC = MPB$.

2. Correcting Externalities

- DWL and Consumption externalities(Gruber figure 2)

Figure 2 **Negative Consumption Externalities: Cigarettes**



2. Correcting Externalities

Key lessons in a model with externalities:

1. Private markets do not produce Pareto Efficient outcome because firm does not take into account social cost of pollution.
2. Zero pollution is not (necessarily) desirable.
3. Need to know the shapes of MB, MPC, MD to implement Q^*. Measurement of MD is especially problematic because you cannot use revealed preference (no market – that is why there is an externality).

2. Correcting Externalities: Remedies for Externalities

1. Establish property rights and create markets for pollution (Coasian solution):
2. Emission taxes or Pigouvian corrective taxation:
3. Regulation: Command and Control
4. Permits (cap-and-trade).

2. Correcting Externalities: Remedies for Externalities

1. Establish property rights and create markets for pollution (Coasian solution):

- Externalities emerge because property rights are not well defined.
- Suppose that the firm pollutes a river. If the river is owned by the consumer, then the firm has no right to pollute the river without the agreement of the consumer.
- In a competitive market, consumer would charge d for every unit of pollution emitted –> firm's marginal cost of production becomes $c'(x) + d$. This would restore first-best.
- General point: Creating a market for buying the right to pollute would lead to the Pareto efficient outcome.

2. Correcting Externalities: Remedies for Externalities

Note that it does not matter who is assigned the property rights for the Coasian solution.

- Suppose firm owned the river. Then it would offer to sell the consumer rights access to a less polluted river, and in equilibrium the price for a river that is 1 unit less polluted would be $\$d$ higher. Thus the firm's effective opportunity cost of producing a car would be $c'(x) + d$ and efficiency is restored.
- Assignment of property rights affects distribution but not efficiency – all that matters is that we need to create markets.

2. Correcting Externalities: Remedies for Externalities

Two problems with Coasian solution:

1. Cost of bargaining neglected. Cost of bargaining very large when the number of agents involved is large.
    - Example: air pollution, millions of people suffer from atmospheric pollution.
    - Need an association to come in to bargain in the name of agents who are affected. This "association" is precisely the role of the government.
2. Asymmetric information problem: Resource owners need to be able to identify source of damage. For atmospheric pollution, difficult to identify precisely what harm each polluter is doing. Competitive equilibrium can break down if information is not perfect.

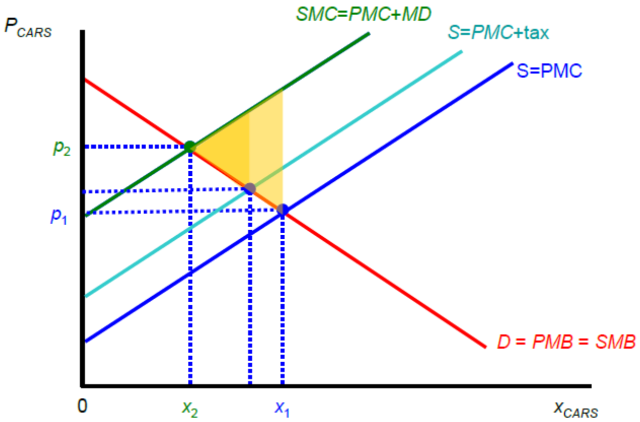
2. Correcting Externalities: Remedies for Externalities

2. Emission taxes or Pigouvian corrective taxation:
   - Impose a tax equal to the marginal damage inflicted at the optimum Q^*. Effective MPC shifts up, and new market equilibrium is at Q^*. (see figure 3)
   - Optimal Pigouvian tax of $t = d$ restores Pareto efficiency and maximizes welfare in our simple model.
   - General principle of optimal taxation in this context: set tax equal to wedge between marginal social cost of production and marginal private cost to restore production efficiency (i.e. set tax equal to marginal damage).

2. Correcting Externalities: Remedies for Externalities

2. Emission taxes (Pigouvian corrective taxation): Optimal pigouvian tax sets $t = MD(Q^*)$

Figure 3 **Pigouvian Tax**



2. Correcting Externalities: Remedies for Externalities

Practical problems with corrective taxation

- Need to know MD function to set-up the optimal tax. Hard if MD not constant.
- Think of gasoline tax and car pollution: True that cars produce pollution, but difficult to measure the marginal damage done by cars. What is the optimal Pigouvian tax: European level or US level?

2. Correcting Externalities: Remedies for Externalities

3. Regulation: Command and Control

- Each polluter has to cut pollution down to a certain level or use only certain types of production processes or else face legal sanctions.
- In the simple model sketched above, Pigouvian tax and regulation produce exactly the same outcome.

2. Correcting Externalities: Remedies for Externalities

- Advantages of regulation:
  1. Easier to enforce/administer.
  2. Useful to quickly reduce pollution levels if you want to meet a certain salient target. Can be sure to meet a certain target, easier to enforce politically, rather than agree on some taxes that may or may not achieve much of a pollution reduction.
- Disadvantage of regulation:
  1. [Dynamics] Discourages innovation: no monetary incentives to discover new technologies to reduce pollution further. With a tax, there is such an incentive.
  2. [Heterogeneity] Inefficient allocation when there is heterogeneity in costs of pollution abatement across firms

2. Correcting Externalities: Remedies for Externalities

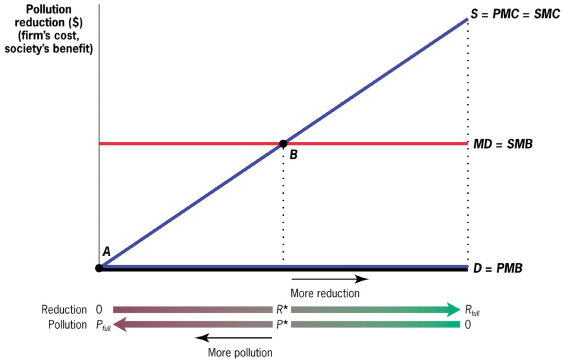
4. Permits (cap-and-trade).
    - Problems raised above can be addressed using a auction-based permit system.
    - Cap total amount of pollution and allow firms to sort out between themselves who pollutes more and less using tradeable permits
    - In equilibrium, firms with highest marginal costs of reducing pollution will end up buying the most permits. Firms that can easily reduce pollution will do so.
    - If total number of permits is set to achieve the social optimum, both allocative and productive efficiency will be achieved.
    - Also have dynamic incentives to innovate because each firm is bearing a marginal cost of pollution.
    - Note that price mechanism (Pigouvian tax) also has these desirable properties with heterogeneity and dynamics. So how to choose between price mechanism (tax) and permit (quantity) mechanism? Weitzman (REStud 1974).

3. Prices vs. Quantities: Weitzman REStud 1974

- Weitzman's key insight: When there is uncertainty about MB and/or MC, price and quantity policies may no longer be equivalent.
- Easiest to think about Weitzman's result in terms of the market for **pollution (externality) reduction** rather than production of a good.
- Let P denote amount of pollution reduction starting from private market equilibrium ($P = 0$). Let $B(P)$ denote social benefits of pollution reduction and $C(P)$ denote social costs.
  - Note: you can map any externality model into a model of costs and benefits of externality reduction. So, the model we considered above implied that the SMB of pollution reduction is constant ($MD = d$). [Private MB of abatement is 0.] MC of abatement is the loss in surplus from producing one less car, which is $u'(x) - c'(x)$. (see figure next slide)
  - More generally, though, there are other ways to reduce costs (technology) besides just reducing production.

3. Prices vs. Quantities: Weitzman REStud 1974

- Showing model with MC and MB of abatement (gruber Figure 8) with no uncertainty

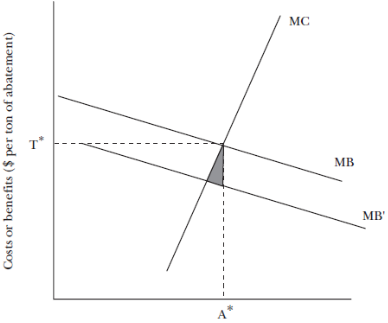


- Private market equilibrium: PMB=PMC, $P = 0$ (usual result)
- Social optimum:SMB=SMC, $P = P^*$
- With no uncertainty, can obtain optimum with a quantity policy (do P^*)or price policy ($t = MD(P^*)$)

3. Prices vs. Quantities: Weitzman REStud 1974

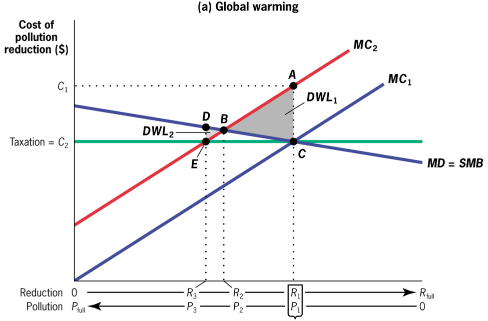
- Now suppose that we are uncertain about MB of reducing pollution (marginal damages) – hard to know health costs
- Setup: Regulators use MB (Actual is MB') $\Longrightarrow tax = T^*$ (when it should be lower). Quantity policy sets A^* when it should be lower.
- In this case, P and Q policies both get you to A^* and are inefficient (see DWL). No difference between two policies with this source of uncertainty.

A: Uncertainty over the Marginal Benefits of Abatement



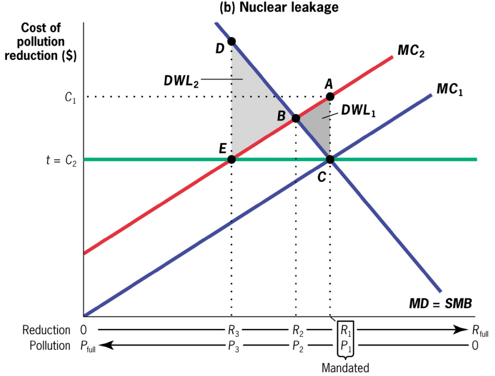
3. Prices vs. Quantities: Weitzman REStud 1974

- Now suppose that we are uncertain about MC of reducing pollution – hard to know exactly how much it will cost GM to reduce pollution
- Setup: Regulators use MC_1 (Actual is MC_2) $\Longrightarrow$ $tax = C_2$ (when it should be higher). Quantity policy will set P_1 (when it shuold be P_2).
- P policy: tax will get pollution to P_3 (when it should be P_2) and DWL is small triangle
- Q policy: will get to P_1 (when it should be P_2) and DWL is large triangle.



3. Prices vs. Quantities: Weitzman REStud 1974

- But if the MB (=MSB) curve is steep (steeper than MC), then DWL of P policy is larger than Q policy.



- Intuition: With flat MD curve, then tax is likely to be "close.". With steep MD curve, then Q is likely to be "close."
- Steep MD curve is the case of a very risky outcome–nuclear leakage.

4. Empirical Applications

- Measuring externalities is hard because there is by definition no direct market that can be used to recover willingness-to-pay. If there were a market, there would be no externality.
- Two approaches: indirect market-based methods and contingent valuation
- Chay and Greenstone JPE is example of indirect market method

4. Empirical Applications: Chay and Greenstone JPE

- Question: can we value the impact of pollution on housing prices. This is one part of the MD of pollution or alternatively the WTP for clean air
- Existing literature uses cross section variation in (levels of or changes in) pollution. Inconsistent findings, some with wrong sign.
- Their approach
  - Use exogenous variation from Clean Air Act, assigns counties to attainment and nonattainment status based on clear decision rule
  - Estimate as reduced form and IV. Overall and as RD.
  - Results are robust and show larger effects on property prices than prior literature.
- Paper is a great example of classic Ken Chay paper: hands above the table, showing you all of the supporting information so that you believe the results are causal.

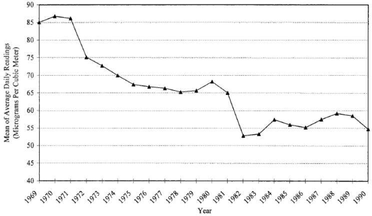
4. Empirical Applications: Chay and Greenstone JPE

- Clean Air Act 1970
- First significant federal environmental legislation (prior to this, some states had laws, most did not).
- Set air quality standards for 5 pollutants (in this paper they focus on TSPs)
- Law established that EPA would assign "attainment/nonattainment" status to each county annually. Nonattainment defined as meeting either one of 2 conditions:
  1. annual mean concentration > 75
  2. second highest daily concentraion exceeds 260 (bad day)
- If nonattainment, then state is responsible for making plan for fix it.

4. Empirical Applications: Chay and Greenstone DATA

1. Pollution monitors
2. TSP attainment/nonattainment (they could not get data from EPA so they calculated this themselves
3. Housing values (1970, 1980 Census). [Note they can not use census micro data because counties are not identified; you can only get county tabs from the summary files.]

- They argue (and present evidence) that attainment status in 1976 is preferred rather than 1972. They then relate this to 1970-1980 changes in housing value



4. Empirical Applications: Chay and Greenstone JPE

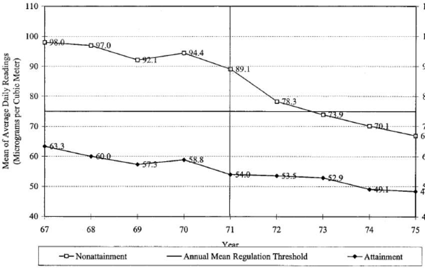
- What is a hedonic model?
- Rosen (1974), emprical approach aimed at estimating value of non-market amenities (characteristics of homes, location, schools, weather, etc). Here the application is pollution.
- Why is the prior literature subject to a bias?
- $y_c = \theta T_c + X_c\beta + \epsilon_c$ or in differences $\triangle y_c = \theta \triangle T_c + \triangle X_c\beta + \epsilon_c$
- Could be third factor driving both pollution and housing values. What is shifting pollution?
- Cross-section bias: they argue is positive because high pollution areas are urban, etc
- Changes bias: Biased upwards because areas local labor markets may be shifting both (recession means less pollution and lower housing prices)
- Selection bias: do people sort into areas based on MWTP?

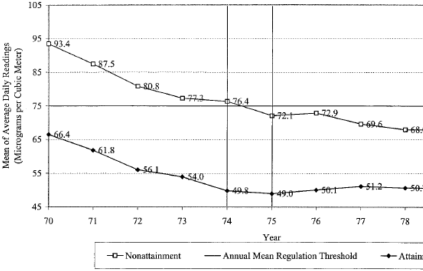
4. Empirical Applications: Chay and Greenstone JPE

- Their approach is to use the attainment status as an instrument for pollution
- first stage: $\triangle T_c = \triangle X_c \beta + Z_c \Pi_{TZ} + \upsilon$ where Z is the instrument
- reduced form: $\triangle y_c = Z_c \Pi_{yZ} + \triangle X_c \beta + \epsilon_c$ (this is the program evaluation estimate, interesting in its own right)
- second stage: $\triangle y_c = \theta \triangle T_c + \triangle X_c \beta + \epsilon_c$
- Turns out that the IV estimate when the instrument is 0/1 is just the ratio of the $\theta_{IV} = \Pi_{yZ} / \Pi_{TZ}$ called the wald estimator.

4. Empirical Applications: Chay and Greenstone JPE

- 1976 attainment status: they argue that this is preferrable because (1) pre-trends match up, (2) observables balanced, and (3) less time to respond and move.





4. Empirical Applications: Chay and Greenstone JPE

- Regression discontinuity: use counties "close" to attainment line (50-75,75-100) and control for smooth function in pollution. See the nonattainers who are below the threshold but still nonattainers because of the "bad day" rule.

FIG. 4.—1970–80 change in mean TSPs by 1975 nonattainment status and the geometric mean of TSPs in 1974.

4. Empirical Applications: Chay and Greenstone JPE

- Col 1: difference in mean Xs between areas with above vs below median pollution, shows positive bias (dirty areas are higher price)
- Col 2: shows procycal pollution (pos bias)
- Cols 3-4 shows balance between T (nonattainers) and C (attainers) group is better in 1976 attainment rule

TABLE 2

DIFFERENCES IN SAMPLE MEANS BETWEEN GROUPS OF COUNTIES, DEFINED BY TSPs LEVELS, CHANGES, OR NONATTAINMENT STATUS

			TSPs NONATTAINMENT			
	CROSS SECTION 1970 (1)	FIRST DIFFERENCE 1980–1970 (2)	In 1970, 1971, or 1972 (3)	In 1975 or 1976 (4)	In 1975 Regression Discontinuity Sample (5)	In 1975 Bad Day Sample (6)
Total counties (nonattainment)	988	988	988 (380)	988 (280)	475 (123)	419 (67)
Housing value	1,092 (918)	−3,237** (713)	−517 (726)	2,609** (806)	2,007 (1,193)	2,503 (1,585)
Mean TSPs	39.2** (1.2)	−30.9** (1.0)	−19.6** (1.4)	−10.0** (1.8)	−12.3** (2.4)	−4.8 (2.9)
Economic condition variables:						
Income per capita (1982–84 dollars)	377.7** (94.7)	−159.9** (40.7)	−81.6* (41.2)	48.6 (46.4)	47.2 (65.1)	−37.2 (94.1)
Total population (% change)	142,016** (24,279)	−.058** (.013)	−.046** (.013)	−.001 (.017)	.005 (.028)	.015 (.030)
Unemployment rate (×100)	−.144 (.120)	.519** (.129)	.200 (.132)	.043 (.152)	.305 (.215)	−.032 (.274)
% employment in manufacturing (×10)	.098 (.083)	−.119** (.026)	−.081** (.026)	−.005 (.028)	−.057 (.042)	−.066 (.051)
Demographic and socioeconomic variables:						

4. Empirical Applications: Chay and Greenstone JPE

- Estimating OLS models (like the literature). Shows nonrobust and many wrong signed estimates.

TABLE 3
CROSS-SECTIONAL AND FIRST-DIFFERENCE ESTIMATES OF THE EFFECT OF TSPS POLLUTION ON LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. 1970 Cross Section			
Mean TSPs (1/100)	.032	−.062	−.040	−.024
	(.038)	(.018)	(.017)	(.017)
R^2	.00	.79	.84	.85
Sample size	988	987	987	987
	B. 1980 Cross Section			
Mean TSPs (1/100)	.093	.096	.076	.027
	(.066)	(.031)	(.030)	(.028)
R^2	.00	.82	.89	.89
Sample size	988	984	984	984
	C. 1970–80 (First Differences)			
Mean TSPs (1/100)	.102	.024	.004	−.006
	(.032)	(.020)	(.016)	(.014)
R^2	.02	.55	.65	.73
Sample size	988	983	983	983
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes

4. Empirical Applications: Chay and Greenstone JPE

- 1st stage (good power) and reduced form (shows value of policy). Robust. Ratio of estimates gives IV (Wald).

TABLE 4
ESTIMATES OF THE IMPACT OF MID-DECADE TSPs NONATTAINMENT ON 1970–80 CHANGES IN TSPs POLLUTION AND LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. Mean TSPs Changes			
TSPs nonattainment in 1975 or 1976	−9.96	−10.41	−9.57	−9.40
	(1.78)	(1.90)	(1.94)	(2.02)
F-statistic TSPs nonattainment*	31.3	29.9	24.4	21.5
	(1)	(1)	(1)	(1)
R^2	.04	.10	.19	.20
	B. Log Housing Changes			
TSPs nonattainment in 1975 or 1976	.036	.022	.026	.019
	(.012)	(.009)	(.008)	(.008)
F-statistic TSPs nonattainment*	8.5	6.2	9.3	6.4
	(1)	(1)	(1)	(1)
R^2	.01	.56	.66	.73
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes
Sample size	988	983	983	983

4. Empirical Applications: Chay and Greenstone JPE

- IV estimates.

TABLE 5
INSTRUMENTAL VARIABLES ESTIMATES OF THE EFFECT OF 1970–80 CHANGES IN TSPs POLLUTION ON CHANGES IN LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. TSPs Nonattainment in 1975 or 1976			
Mean TSPs (1/100)	−.362	−.213	−.266	−.202
	(.152)	(.096)	(.104)	(.090)
Sample size	988	983	983	983
	B. TSPs Nonattainment in 1975			
Mean TSPs (1/100)	−.350	−.204	−.228	−.129
	(.150)	(.099)	(.102)	(.084)
Sample size	975	968	968	968
	C. TSPs Nonattainment in 1970, 1971, or 1972			
Mean TSPs (1/100)	.072	−.032	−.050	−.073
	(.058)	(.042)	(.041)	(.035)
Sample size	988	983	983	983
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes

4. RD results

- This is an early verion of a regression discontinuity paper. You do not see the figures and specifications that are usually presented in an RD setting.
- Table 6: running variable is quadratic in TSPs.
- Loss of precision but estimates similar.

4. Empirical Applications: Indirect Market-Based Methods

- Results: 1% increase in pollution -> 0.2-0.35% decline in house values.
- Fairly large WTP for cleaner air. Suggest that clean air act increased (on net) house values by 45 billion in nonattainment counties.
- Possible concern: Coefficients in home price regressions decline across specifications with more controls. Often a sign of omitted variables .
- Concern with these short-run market based methods: People may be ignorant of changes in pollution in short run and effects on health, and thus market price difference might not reflect the real societal cost of pollution.
- This is the tip of a large literature on environmental economics. Particularly active in the context of assessing consequences of global warming and optimal response.

4. Other papers estimating MD of pollution

- Large Literature on impacts of pollution on child health
  - Natality & Mortality data, birthweight & infant mortality
  - Uses various research designs to identify causal impacts on birth outcomes and infant mortality
  - Chay and Greenstone (2003), economic shock as instrument for pollution, infant mortality
  - Economic activity, traffic, pollution (Knittel, Miller, Sanders 2010, Currie and Walker 2009)
  - Chernobyl fallout (Almond, Edlund, Palme 2007)
  - Mother fixed effects (Currie, Neidell & Schmieder 2009)
- See Almond and Currie (2010) Handbook chapter for Handbook of Labor Economics, excellent review of the literature on early life interventions.

4. Empirical Applications: Contingent Valuation

- Sometimes impossible to have a market value for some outcomes:
- Example: protect endangered species, protect remote area (Alaska) with few tourists
- You have to rely on non-market methods.
- Common technique: Ask individuals with surveys what are their valuation for different outcomes.

4. Empirical Applications: Contingent Valuation

- The way these “contingent valuation” surveys work is in two steps:
  1. Statement of a hypothetical scenario
  2. Ask how much people would be willing to pay for it
- Example: how much would you be willing to pay to have avoided Exxon Valdez oil spill? How much would be willing to pay to avoid extinction of that species of whales.

4. Empirical Applications: Contingent Valuation

Problems with this method:

1. No resource cost to respondents, thus noisy answers and upward biased.
    - Warm glow: people feel good having the idea that they are supporters of good causes.
2. People do not have well defined preferences over these type of hypothetical choices.
    - Framing effect: timing of questions matters
    - How much to save whales then how much to save seals
    - not same answers as the reverse.
    - Amount to clean one lake $\approx$ amount to clean 5 lakes
    - Income effects are not typically large enough to explain discrepancy.

4. Empirical Applications: Contingent Valuation

- Bottom line: people do not exhibit coherent preferences.
- Not surprising, because private valuation for any particular project is very small at the individual level, and we have no day-to-day experience in making such assessments.
- References: survey by Diamond-Hausman JEP 94 (who have a critical view of this method). See Hanemann (same issue of JEP) for a more positive view.
- Diamond and Hausman's conclusion: Government-hired experts deciding on budget much better than simply aggregating valuation based responses. Decide how much to allocate to environment via a voting mechanism, and then let experts decide how to divide environment budget into different projects.