Public Economics

Lecture 4: Public goods and externalities

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1. Introduction
2. Public goods
3. Externalities

1. Introduction
2. Public goods
3. Externalities

- Two failures of the first welfare theorem.
- Require state intervention:
    - Direct intervention;
    - Incentives;
    - Market development.

1. Introduction
2. Public goods
   - Definitions
   - Canonical model and Samuelson rule
   - Decentralized private provision and Lindhal equilibrium
   - Voting on public good provision
   - Crowding out
   - Distortionary taxation
   - More on public goods
3. Externalities

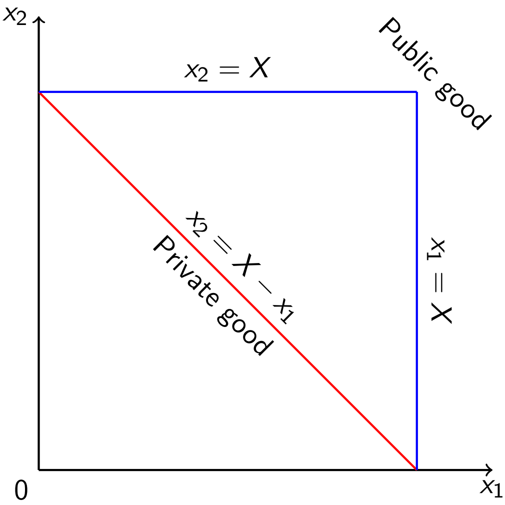
Public and private goods

- Consumption of a private good benefit only to one individual:

  $$\sum_{i=1}^{N} x_i \leq X,$$

  where x_i is quantity consumed by individual i, and X is total available quantity.
- Consumption of a public good benefit to many individuals at the same time:

  $$\forall i, \qquad x_i \leq X.$$


x_2
$x_2 = X$
Public good
$x_2 = X - x_1$
Private good
$x_1 = X$
0
x_1

Pure and impure public goods

- A pure public good can be consumed by any number of individuals.
- An impure public good may be subject to congestion.
- Example: Radio broadcast and roads.

Rival and non-rival public goods

- Consumption of a rival public good by one individual prevents its consumption by another individual.
- A pure public good is non-rival.

Exculdable and non-excludable public goods

- It is possible to prevent the consumption of an excludable public good by a specific individual.
- Example: Public lightning and teaching.

Equilibrium production

- Decreasing marginal cost and/or large scale production externalities.
- Inefficient equilibrium production.

Canonical model with two private goods

- N individuals, $i = 1, \ldots, N$.
- Two goods: g and x.
- Individual i consumes good x in quantity x_i.
  Total consumed quantity is $\sum_{i=1}^{N} x_i = X$.
- Individual i consumes good g in quantity g_i.
  Total consumed quantity is $\sum_{i=1}^{N} g_i = G$.
- Utility of i is $U^i = U^i\left(x_i, g_i\right)$, with U^i increasing in x_i and g_i.

- Production possibilities are defined by $F(X, G) \leq 0$.
- Assume that social welfare function is simply the (unweighted) sum of individual utilities.

- Pareto efficient outcomes are solutions of:

$$\begin{array}{ll} \max & \sum_{i=1}^{N} U^{i}\left(x_i, g_i\right), \\ \text{s.t.} & F\left(\sum_{i=1}^{N} x_i, \sum_{i=1}^{N} g_i\right) \leq 0. \end{array}$$

- First order conditions using a Lagrangian λ:

$$\forall i, \left\{ \begin{array}{l} \frac{\partial U^i}{\partial x} = \lambda \frac{\partial F}{\partial x}, \\ \frac{\partial U^i}{\partial g} = \lambda \frac{\partial F}{\partial g}. \end{array} \right.$$

- This yields:
$$\forall i, \qquad \frac{\partial U^i/\partial g}{\partial U^i/\partial x} = \frac{\partial F/\partial g}{\partial F/\partial x}.$$
- Pareto allocations are such that the marginal rate of substitution of every individual is equal to the marginal rate of technical substitution.
- From the first welfare theorem, we know that market equilibrium leads to such an allocation.

Canonical model with one private good and a pure public good

- Assume now that g is a pure public good, i.e. consumption of good g by individual i equals G.
- Utility of i is now $U^i = U^i(x_i, G)$, with U^i increasing in x_i and G.

- Pareto efficient outcomes are solutions of:

$$\begin{array}{ll} \max & \sum_{i=1}^{N} U^{i}\left(x_i, G\right), \\ \text{s.t.} & F\left(\sum_{i=1}^{N} x_i, G\right) \leq 0. \end{array}$$

- First order conditions using a Lagrangian λ:

$$\left\{ \begin{array}{ll} \forall i, & \frac{\partial U^{i}}{\partial x} = \lambda \frac{\partial F}{\partial x}, \\ \sum_{i=1}^{N} \frac{\partial U^{i}}{\partial g} = \lambda \frac{\partial F}{\partial g}. \end{array} \right.$$

Samuelson rule

- This yields to the Samuelson rule:

$$\sum_{i=1}^{N} \frac{\partial U^i / \partial g}{\partial U^i / \partial x} = \frac{\partial F / \partial g}{\partial F / \partial x}.$$

- Pareto allocations are such that the sum of marginal rates of substitution is equal to the marginal rate of technical substitution.
- One more unit of the public good increases the utility of all individuals. On the opposite, when g was a private good, one more unit only increases one individual's utility.

- Samuelson rule is simple but hardly implementable:
    - One would need to know preferences.
    - Does not say anything on the way to finance the public good.
- This rule is a first-best benchmark.
- Can we implement the optimal level of public good with available policy tools?

Decentralized provision

- Assume each individual i uses its income y_i to consume quantity x_i of private good and contribute to public good provision by g_i.
- Total quantity of public good is $G = \sum_{i=1}^{N} g_i$. Everyone enjoys it.
- Each individual solves:

$$\begin{array}{ll} \max & U^i\left(x_i, \sum_{i=1}^{N} g_i\right), \\ \text{s.t.} & x_i + g_i \leq y_i. \end{array}$$

- This leads to:

$$\forall i, \qquad \frac{\partial U^i}{\partial x} = \frac{\partial U^i}{\partial g} \Leftrightarrow \frac{\partial U^i/\partial g}{\partial U^i/\partial x} = 1.$$

- Samuelson rule is not satisfied.
- What if each individual invest $\frac{1}{N}$ more euro in public good provision?

$$\begin{aligned}\Delta U^i &= \frac{\partial U^i}{\partial x}\Delta x_i + \frac{\partial U^i}{\partial g}\Delta G\\ &= -\frac{\partial U^i}{\partial x}\frac{1}{N} + \frac{\partial U^i}{\partial g}\\ &= \frac{\partial U^i}{\partial g}\left(1 - \frac{1}{N}\right) > 0.\end{aligned}$$

- Decentralized provision of the public good is inefficient. There is under-provision of public good.

- Can we achieve Pareto efficiency thanks to a decentralized mechanism?
- Assume that it is possible to let each individual i pay unit price τ_i to enjoy full quantity G of public good, i.e. that it is possible to set individual contributions.
- Total public good provided is the sum of individual contributions.
- Individual i maximizes:

$$U^i\left(y_i - \tau_i G, G\right),$$

where y_i is individual i's income.

- First order condition yields:

$$\tau_i = \frac{\partial U^i / \partial U^g}{\partial U^i / \partial U^x}.$$

- Implicit demand function of public good by individual i:

$$G^i\left(\tau_i, y_i\right).$$

Lindhal equilibrium

A Lindhal equilibrium satisfies the following conditions:

- Full financing of public good provision:

$$\sum_{i=1}^{N} \tau_i = 1;$$

- All individuals demand the same quantity:

$$G^1 = \ldots = G^N.$$

- Samuelson rule is satisfied:

$$\sum_{i=1}^{N} \frac{\partial U^i/\partial g}{\partial U^i/\partial x} = \sum_{i=1}^{N} \tau_i = 1,$$

  as marginal rate of transformation equals 1.
- Lindhal pricing requires to set personalized prices, but there is not incentives for individuals to reveal their preferences (need to design mechanism to reveal preferences).
- Lindhal pricing requires to be able to exclude individuals who do not pay.

Voting on public good provision

- Assume that the government is not able to charge different prices and ask each voter to pay the same amount for public good provision.
- Knowing this, individuals vote on G.
- Individual i maximizes:

$$U^i\left(y_i - \frac{G}{N}, G\right),$$

- First order condition yields:

$$\frac{\partial U^i/\partial U^g}{\partial U^i/\partial U^x} = \frac{1}{N}.$$

- Thus, according to median voter theorem, the winning level of public good will be such that the marginal rate of substitution of the median voter equals $\frac{1}{N}$:

$$\text{MRS}^m = \frac{1}{N}.$$

- Samuelson rule:

$$\sum_{i=1}^{N} \text{MRS}^i = 1 \Leftrightarrow \frac{\sum_{i=1}^{N} \text{MRS}^i}{N} = \frac{1}{N}.$$

- The voting outcome is efficient if and only if:

$$\mathrm{MRS}^m = \frac{\sum_{i=1}^N \mathrm{MRS}^i}{N},$$

  i.e. if the median voter's marginal rate of substitution is equal to the mean marginal rate of substitution of the population.
- No reason that it will happen.

Temporary conclusion

- First best provision of public good seems hardly feasible.
- Toward second best provision: Assume that the government has decided to levy taxes and to provide public goods following some rule.
- Two complications arise:
    - Interactions with the private sector (crowding out);
    - Lump-sum taxation cannot be used because of distributional concerns.

Crowding out

Roberts, Russell D., 1984. “A Positive Model of Private Charity and Public Transfers,” Journal of Political Economy, University of Chicago Press, vol. 92(1), pages 136-48, February.

- In the US, the expansion of government actions has been accompanied by a comparable decline in charitable giving since the Great Derpession.
- Government has grown without having any net impact on welfare.

Private provision without government

Bergstrom, Theodore & Blume, Lawrence & Varian, Hal, 1986. "On the private provision of public goods," Journal of Public Economics, Elsevier, vol. 29(1), pages 25-49, February.

- Each individual i chooses x_i and g_i in order to maximize:

$$\begin{array}{ll} \max & U^i\left(x_i, g_i + G_{-i}\right), \\ \text{s.t.} & x_i + g_i \leq y_i, \end{array}$$

  where x_i is private consumption, g_i is individual i's contribution to public good provision, and G_{-i} is total contribution by other individuals.
- $G = \sum_{i=1}^{N} g_i$.

- First order condition yields:

$$\frac{\partial U^i/\partial g}{\partial U^i/\partial x} = 1.$$

- There exists a unique Nash equilibrium.
- Implicitly define G^* such as all individuals optimize given others' choice.

Public and private provision

- Assume that the government taxes individual i using lump-sum tax τ_i.
- Total tax revenue is used to finance public good provision:

$$\sum_{i=1}^{N} \tau_i = T.$$

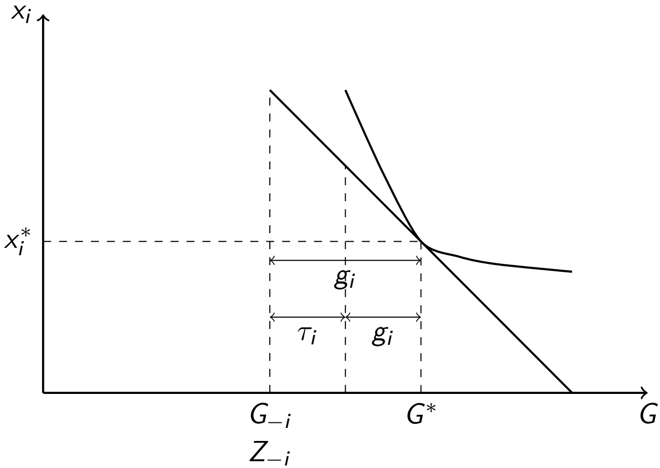
- Each individual i chooses x_i and g_i in order to maximize:

$$\begin{array}{ll} \max & U^i\left(x_i, g_i + G_{-i} + T\right), \\ \text{s.t.} & x_i + g_i \leq y_i - \tau_i, \end{array}$$

- Note that T can be written as $\tau_i + T_{-i}$.
- Let us write $z_i = g_i + \tau_i$ and $Z_{-i} = G_{-i} + T_{-i}$.
- Each individual's problem can be rewritten as :

$$\begin{array}{ll} \max & U^i\left(x_i, z_i + Z_{-i}\right), \\ \text{s.t.} & x_i + z_i \leq y_i, \end{array}$$

- We obtain the same solution as before, i.e. $Z^* = G^*$. Total quantity of public good is unchanged, but part of it is now produced by the state.
- Individual i's voluntary provision has simply decreased by τ_i.


x_i
x_i^*
g_i
τ_i
g_i
G_{-i}
Z_{-i}
G^*
G

Empirical evidence on crowding out

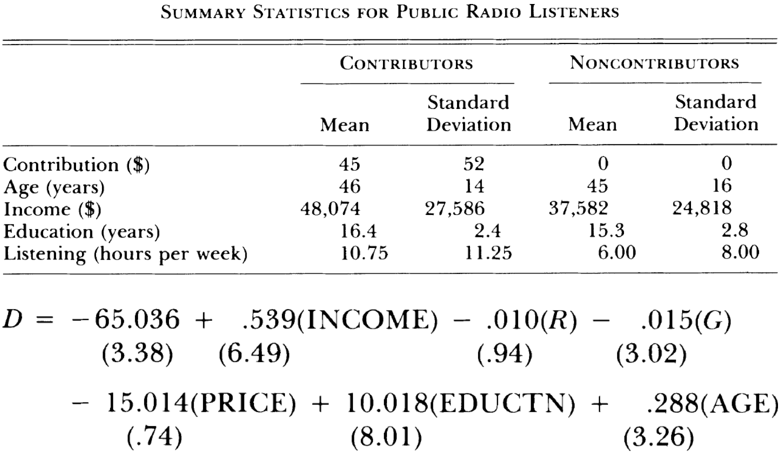
- How large is crowding out in practice?
- What are the income and price effects on charitable giving?

Kingma, Bruce Robert, 1989. “An Accurate Measurement of the Crowd-Out Effect, Income Effect, and Price Effect for Charitable Contributions,” Journal of Political Economy, University of Chicago Press, vol. 97(5), pages 1197-1207, October.

- Observational study of individual contributions to public radio stations.
- $3,541$ individuals and 63 radio stations.
- OLS regression of individual contributions on government support:

$$D_i = \alpha + \beta G_i + \varepsilon_i,$$

where D_i is individual contribution by individual i to the station she listens to, and G_i is public funding of this station.



Summary Statistics for Public Radio Listeners

	Contributors		Noncontributors	
	Mean	Standard Deviation	Mean	Standard Deviation
Contribution ($)	45	52	0	0
Age (years)	46	14	45	16
Income ($)	48,074	27,586	37,582	24,818
Education (years)	16.4	2.4	15.3	2.8
Listening (hours per week)	10.75	11.25	6.00	8.00

$$D = \underset{(3.38)}{-65.036} + \underset{(6.49)}{.539}(\text{INCOME}) - \underset{(.94)}{.010}(R) - \underset{(3.02)}{.015}(G)$$

$$- \underset{(.74)}{15.014}(\text{PRICE}) + \underset{(8.01)}{10.018}(\text{EDUCTN}) + \underset{(3.26)}{.288}(\text{AGE})$$

Source: Kingma (1989)

- Crowd-out rate of 20%.
- Negative, but far from the 100% theoretical prediction .
- Identification problem:
  Public support is likely to be (partly) determined by individual contributions. For example, low contributions may be compensated by the government. This would lead to a spurious negative correlation.
- Need of a better identification strategy.

Hungerman, Daniel M., 2005. "Are church and state substitutes? Evidence from the 1996 welfare reform," Journal of Public Economics, Elsevier, vol. 89(11-12), pages 2245-2267, December.

- Study of crowding-out of church-provided welfare (e.g. soup kitchens, assistance to the poors) by government-provided welfare.
- 1996 welfare reform strongly reduced welfare spendings toward non-citizens.
- Difference in differences strategy: compare the evolution of charitable giving to churches in places with many or low non-citizens.

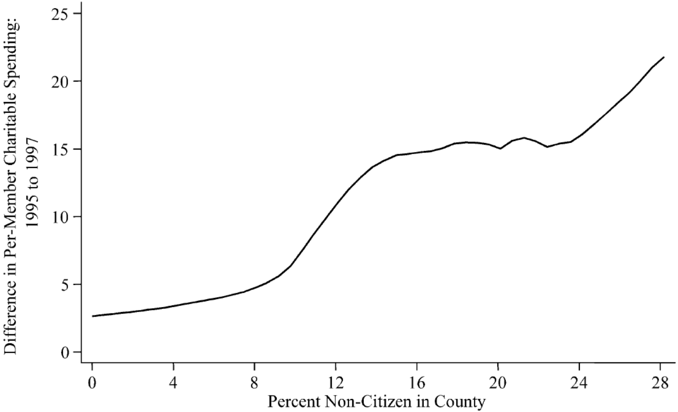


Fig. 3. Per-member church activity before and after the welfare law, by percent non-citizen in the community. The figure is an Epanechnikov kernel estimate of the level growth in per-member charitable church spending between 1995 and 1997 as a function of percent non-citizen in the county in 1994. The vertical axis is in dollars.

Source: Hungerman (2005)

- After the reform, church-members spent more in counties hit more severely by the reform.
- Numerical estimates:
  Total church expenditure goes up by 0.4$ when public spending is cut by 1$.
- Other fields observations and laboratory experiments suggest that average crowd-out rate is around 30%, but highly heterogeneous.
- Other forces drive individual contributions, especially regarding charity: warm glow preferences and salience (signaling).
- Carefully targeted programs can still have a considerable net impact.

Distortionary taxation

- Here, forget about crowding out.
- Lump-sum taxation cannot be used by the government because of distributional concerns.
- Pigou's conjecture (1947):

> *At the optimum, the marginal benefit of the public good should be equal to the marginal cost of its production.*
>
> *The optimal level of public goods with distortionay taxation is lower relative to a first-best situation where government can use lump-sum taxation.*

- Formally shown by Atkinson and Stern (1974).

Setup of the model

- Large number of identical individuals who derive utility from private consumption c, labor l, and consumption of public good G:

  $$U^i\left(c,l,G\right)=c-\frac{l^{k+1}}{k+1}+v(G),$$

  where $k>0$ and $v(.)$ has normal properties.
- Real prices of both c and G are equal to 1, such that the marginal rate to transformation is 1.
- Two policy instruments: lump-sum tax T and linear tax on labor income τ.

- Each individual's budget constraint can be written as:

$$c = wl\,(1-\tau) - T.$$

- Each individual maximizes her utility considering G as given (atomistic individuals).
- The solution leads to:

$$l^* = w^{1/k}\,(1-\tau)^{1/k}\,,$$

where $1/k$ is the elasticity of labor supply with respect to net of tax rate $1-\tau$.

- Considering that the mass of individuals equals 1, public good level equals total tax revenues:

$$G = wl^*\tau + T.$$

Solution with available lump-sum tax

- The government chooses τ and T in order to maximize:

$$\begin{aligned} \mathbb{W} &= wl\left(1-\tau\right) - T - \tfrac{l^{k+1}}{k+1} + v(G) \\ &= wl^{*}\left(1-\tau\right) - T - \tfrac{{l^{*}}^{k+1}}{k+1} + v\left(wl^{*}\tau + T\right) \end{aligned}$$

- First order condition with respect to T leads to Samuelson rule:

$$\frac{\partial v(G)}{\partial T}\left(G^{*}\right) = 1.$$

- First order condition with respect to τ:

$$\begin{array}{ll} \frac{\partial \mathbb{W}}{\partial \tau} & = 0 \\ \Leftrightarrow & -wl + w\left(1-\tau\right)\frac{\partial l}{\partial \tau} - l^{k}\frac{\partial l}{\partial \tau} + v'\left(G^{*}\right)wl + v'\left(G^{*}\right)w\tau\frac{\partial l}{\partial \tau} = 0 \\ \Leftrightarrow & v'\left(G^{*}\right)w\tau\frac{\partial l}{\partial \tau} = 0 \\ \Rightarrow & \tau^{*} = 0 \end{array}$$

- In first-best situation, only lump-sum taxation is used.

Solution with unavailable lump-sum tax

- The government cannot use lump-sum taxation: $T = 0$.
- The government chooses τ in order to maximize:

$$\begin{aligned} \mathbb{W} &= wl\left(1-\tau\right) - \frac{l^{k+1}}{k+1} + v(G) \\ &= wl^{*}\left(1-\tau\right) - \frac{{l^{*}}^{k+1}}{k+1} + v\left(wl^{*}\tau\right) \end{aligned}$$

- First order condition with respect to τ:

$$\begin{aligned} \frac{\partial \mathbb{W}}{\partial \tau} &= 0 \\ \Leftrightarrow \quad & -wl + w\left(1-\tau\right)\frac{\partial l}{\partial \tau} - l^{k}\frac{\partial l}{\partial \tau} + v'\left(G^{*}\right)wl + v'\left(G^{*}\right)w\tau\frac{\partial l}{\partial \tau} = 0 \\ \Leftrightarrow \quad & -wl + v'\left(G^{*}\right)\left\{wl + w\tau\frac{\partial l}{\partial \tau}\right\} = 0 \end{aligned}$$

- Modified Samuelson rule:

$$v'\left(G^{*}\right)\left\{1-\frac{\tau}{1-\tau}\frac{1}{k}\right\}=1$$

- Since $\frac{\tau}{1-\tau}\frac{1}{k}>0$:

$$v'\left(G^{\mathrm{T}=0}\right)>v'\left(G^{\mathrm{T}>0}\right)\Rightarrow G^{\mathrm{T}=0}<G^{\mathrm{T}>0}.$$

- When lump-sum tax cannot be used, public good provision is sub-optimal.
- Elasticity of labor supply plays an important role.

More on public goods

- The ranking of public good provision across situations can be changed if individuals have redistributive tastes. In particular:

  $$G^{\mathsf{T}=0} > G^{\mathsf{T}>0},$$

  if households have such preferences.
- Subsidies to private provision can be used as an alternative to distortionary taxes. For example, tax refunds for charitable contributions.
- Rival public goods (club goods, local public goods).

1. Introduction
2. Public goods
3. Externalities
    - Definition
    - A simple model with externalities
    - Correcting externalities
    - Price versus quantities
    - Empirical measurement

An externality arises whenever the utility or the production possibility of an agent depends directly on the actions of another agent, provided that this link is non-pecuniary.

- Distinction between "pecuniary" and "non-pecuniary" is crucial:
  - Depends on existing markets;
  - Not a technological distinction;
  - According to the Coasian approach, it is possible to convert all externalities into pecuniary externalities thanks to appropriate markets and property rights.
- Only non-pecuniary externalities require public intervention.

Examples

- Pollution.
- Smoking:
  Direct externality from "pollution". Indirect (medium-term) externality from health care.
- Tragedy of the commons:
  Common right to access a resource leads to over-exploitation and not to social efficiency because everyone only takes its own profit into account and not the reduction in resource's availability imposed to others.

Main questions about externalities

- Theoretical: what is the best way to correct externalities and move closer to the social optimum?
- Empirical: How to measure the size of externalities?

A simple model with externalities

- The representative firm produces good x at cost $c(x)$ using the numeraire y as input.
- The production of x units generates $P(x) = x$ units of pollution.
- The representative consumer is endowed with wealth W and has a quasilinear utility function:

  $$\mathbb{U} = u(x) + y - d \times P(x),$$

  where d is the marginal damage of pollution.
- Total social welfare is:

  $$\mathbb{W} = u(x) + W - c(x) - d \times x.$$

- Let p be the market price of good x.

Market equilibrium

- The firm chooses x in order to maximize:

$$px - c(x).$$

- Supply of good x satisfies:

$$c'(x) = p.$$

- The consumer maximizes her utility, taking the level of pollution as given:

$$u(x) + W - px.$$

- Demand of good x satisfies: u'(x)=p.
- At the market equilibrium:

$$u'(x^*) = p^* = c'(x^*).$$

Social optimum

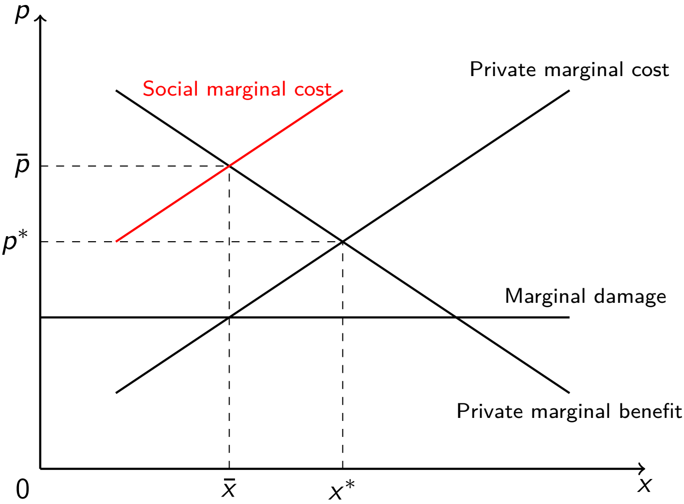
- Let us maximize social welfare:

$$\mathbb{W} = u(x) + W - c(x) - d \times x.$$

- First order condition with respect to x yields:

$$u'(\bar{x}) = c'(\bar{x}) + d.$$

- Market equilibrium leads to over-production of good x.


p
$\bar{p}$
p^*
0
$\bar{x}$
x^*
x
Social marginal cost
Private marginal cost
Marginal damage
Private marginal benefit

- Starting from x^*:

$$\begin{aligned} \Delta\mathbb{W} &= u'(x^*)\Delta x - c'(x^*)\Delta x - d\Delta x \\ &= -d\Delta x > 0 \text{ if } \Delta x < 0. \end{aligned}$$

- First Welfare theorem does not hold.

Correcting externalities

- Coasian bargaining solution;
- Pigouvian corrective taxation;
- Regulation;
- Permits.

Coasian solution

- Externalities emerge because property rights are not defined.
- Solution: Establish property rights and create markets for externalities.
- For example, if a river is polluted by a plant:
  - If neighbors "owns" the river, the firm will pay d for every unit of pollution at equilibrium:
    Marginal cost of production is now $c'(x) + d$, leading to first best situation.
  - If the firm "owns" the river, neighbors will pay to decrease pollution.
- Initial assignment of property rights affects distribution, but not efficiency.

Coase theorem

> *In a competitive economy with complete information and zero transaction costs, the allocation of resources will be efficient and invariant with respect to legal rules of entitlement.*

- No need for public intervention, except to ensure that property rights are defined (and enforced).

Illustration

- Assume consumers are endowed with all property rights over pollution.
- The unit market price of pollution z is α.
- The firm must now pay αx per unit of good x produced. It maximizes:

$$px - c(x) - \alpha x.$$

- Supply of good x satisfies:

$$c'(x) + \alpha = p.$$

- Consumers maximize:

$$u(x) + W - px - dz + \alpha z.$$

- Demand and supply functions satisfy:

$$\begin{aligned} u'(x) &= p \\ d &= \alpha \end{aligned}$$

- At the market equilibrium, production of good x is such that:

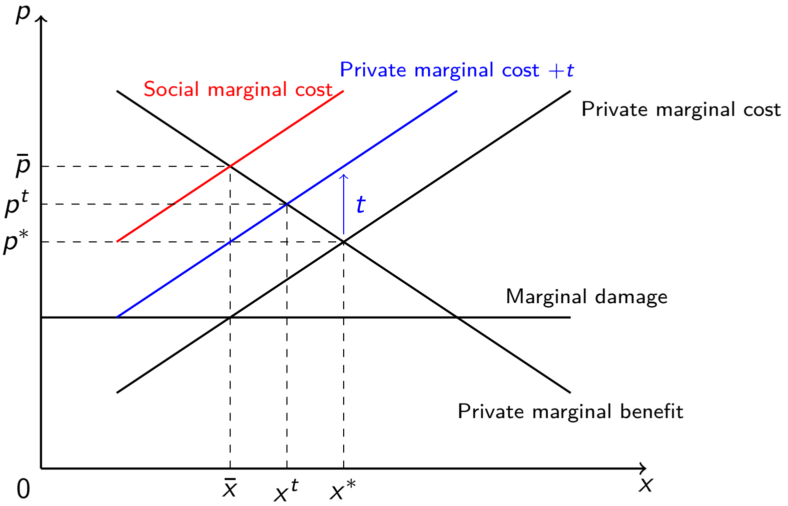
$$c'(x) + d = p = u'(x) \Leftrightarrow x = \bar{x}.$$

Limitations of Coasian approach

- Need coordination of millions of agents (e.g. air pollution).
- Transactions costs may be reduced by setting a representative association to act in the name of agents (e.g. the government).
- Mis-allocation of property rights may create market-power.
- Asymmetric information may prevent competitive equilibrium to be satisfying.
- Allocation of property right requires *ex ante* implicit recognition of rights to “pollute” or to ”breathe fresh air”.
- Precise source of damage often hard to identify.

Pigouvian taxation

- Idea: Impose a tax t on the externality-producing activity, such as Pareto efficiency is achieved and social welfare maximized.
- Implementation: $t =$ Marginal damage $(\bar{x})$.
- Limitation:
  - Need to know marginal damage function.
  - Need to “measure” marginal damages.


p
Social marginal cost
Private marginal cost $+t$
Private marginal cost
$\bar{p}$
p^t
p^*
t
Marginal damage
Private marginal benefit
0
$\bar{x}$
x^t
x^*
x

Regulation

- Impose polluters to reduce negative externalities below a threshold. Encounters face legal sanctions.
- Same outcome as Pigouvian taxation.
- Advantages:
    - Clear design;
    - Enforcement is easy.
- Disadvantages:
    - Allocative inefficiency if polluters are heterogeneous in cost of pollution reduction.
    - Need perfect information about pollution and pollution sources.
    - No dynamic incentives to innovate.

Cap and trade

- Set a total cap for the negative externality and allow polluters to trade permits to pollute.
- Initial allocation of permits thanks to some auction-based mechanism.
- Hybrid of pure regulation and Coasian mechanism.
- In equilibrium, polluters with largest marginal cost of reducing pollution will buy permits to others; those with low marginal cost to reduce pollution will do so.
- If total number of permits is sets to achieve social optimum, both allocative and productive efficiency will be achieved.
- Dynamic incentives to innovate because each firm face its own marginal cost of pollution.

How to choose between methods?

How to choose between price mechanism (tax) and quantity mechanism (permits)?

Weitzman, Martin L, 1974. "Prices vs. Quantities" Review of Economic Studies, Wiley Blackwell, vol. 41(4), pages 477-91, October.

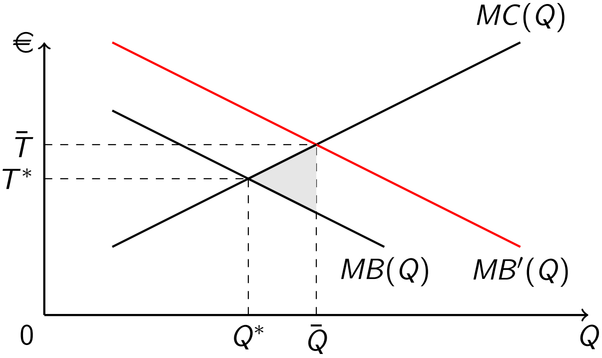
- If then is uncertainty about marginal benefit and/or marginal cost, price and quantity policies may no longer be equivalent.
- Take again the example of pollution.
- Let us start from private market equilibrium.
- Let Q be pollution reduction. At market equilibrium, $Q = 0$.
- $B(Q)$ denotes social benefits of pollution reduction.
- $C(Q)$ denotes social costs of pollution reduction.

Remarks:

- Any externality model can be mapped into a model of costs and benefits of externality variation.
- The previous model had a constant social marginal benefit of pollution reduction d.
- Marginal costs of pollution reduction is the loss in surplus from producing less, i.e. $u'(x) - c'(x)$.
- Here, we keep on not considering other methods to reduce pollution such as changes in technology.

Uncertainty on marginal benefits

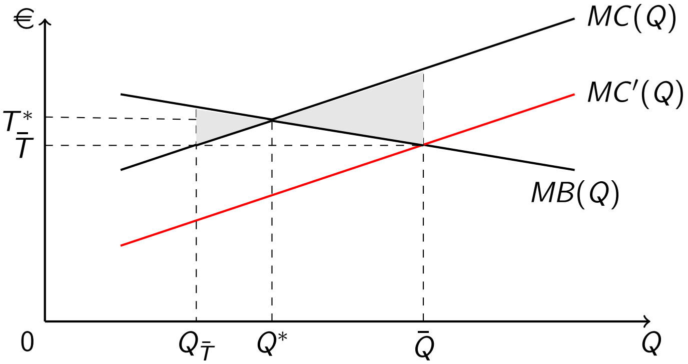
- Assume that there is some uncertainty about marginal benefits of reducing pollution, i.e. uncertainty on marginal damages.
- Marginal benefit of Q is $MB(Q)$, but regulators use $MB'(Q)$, with $MB' > MB$. Regulators over-estimate damages.



- Both policies (tax $\bar{T}$ and cap $\bar{Q}$) move the economy to the same situation.
- Both are equally inefficient with respect to social optimum (Q^{*}, T^{*}).
- With this source of uncertainty, both are equivalent.

Uncertainty on marginal costs

- Assume that there is some uncertainty about marginal costs of reducing pollution, e.g. in terms of utility derived from goods whose production is associated to pollution, or in terms of direct costs.
- Marginal cost of Q is $MC(Q)$, but regulators use $MC'(Q)$, with $MC' < MC$. Regulators under-estimate costs.


€
$MC(Q)$
$MC'(Q)$
T^*
$\bar{T}$
$MB(Q)$
0
$Q_{\bar{T}}$
Q^*
$\bar{Q}$
Q

- Social loss is larger when using quantities (pollution cap $\bar{Q}$) rather than prices (tax $\bar{T}$).
- Here, one would conclude that it is better to intervene using prices.
- Warning: this result depends on the slope of curves, especially of the one of marginal benefits.

Empirical measurement

- Need to know the size/cost of externalities to design policy intervention.
- Two approaches:
  - Indirect market-based approach: estimate externality cost from observed behaviors;
  - Contingent valuation.

Road-accident externality

- Driving induces externalities: pollution, accidents.
- If someone drives, the probability that someone else goes into an accident increases: others support the externality cost imposed by the additional driver.
- From Pigouvian perspective, a tax should be imposed on drivers.
- Need to estimate the externality cost to adequately set the tax.

Aaron S. Edlin & Pinar Karaca-Mandic, 2006. "The Accident Externality from Driving," Journal of Political Economy, University of Chicago Press, vol. 114(5), pages 931-955, October.

- Study of the relationship between traffic density and per-capita insurance costs and premiums within US states from year to year.
- Slope of the relationship allow to estimate the externality cost.
- Identification relies on the assumption that variation in traffic density at the state level is not correlated with other determinants of premiums (e.g. type of cars, quality of roads).

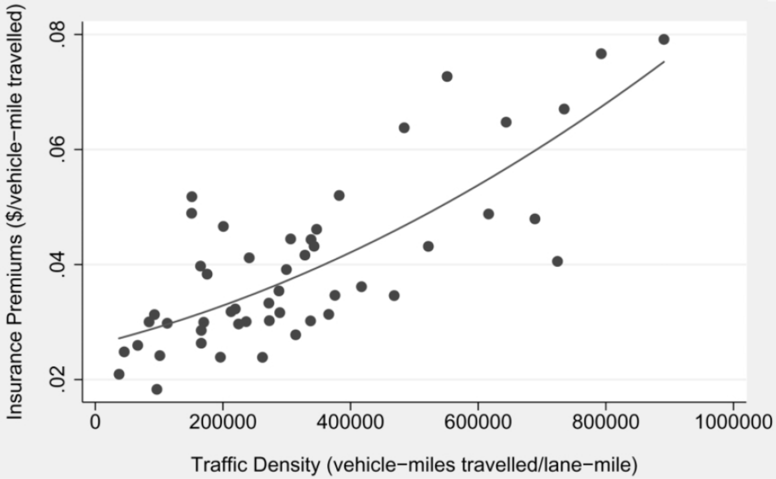


FIG. 2.—Traffic density and insurance premiums (1996 dollars)

Source: Edlin and Karaca-Mandic (2006)

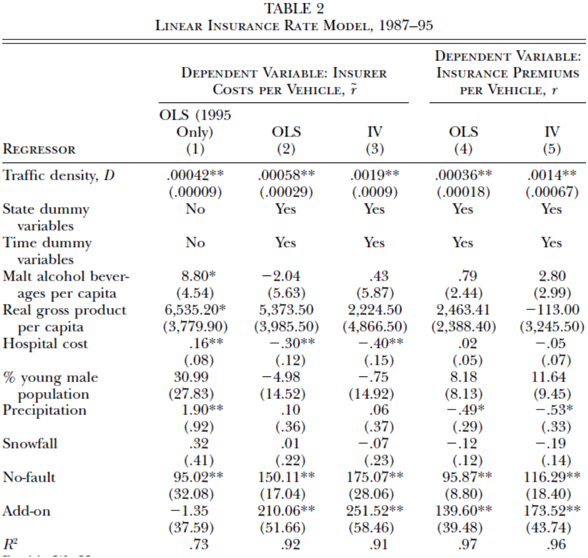


TABLE 2
LINEAR INSURANCE RATE MODEL, 1987–95

Regressor	Dependent Variable: Insurer Costs per Vehicle, $\tilde{r}$			Dependent Variable: Insurance Premiums per Vehicle, r	
	OLS (1995 Only) (1)	OLS (2)	IV (3)	OLS (4)	IV (5)
Traffic density, D	.00042**	.00058**	.0019**	.00036**	.0014**
	(.00009)	(.00029)	(.0009)	(.00018)	(.00067)
State dummy variables	No	Yes	Yes	Yes	Yes
Time dummy variables	No	Yes	Yes	Yes	Yes
Malt alcohol beverages per capita	8.80*	−2.04	.43	.79	2.80
	(4.54)	(5.63)	(5.87)	(2.44)	(2.99)
Real gross product per capita	6,535.20*	5,373.50	2,224.50	2,463.41	−113.00
	(3,779.90)	(3,985.50)	(4,866.50)	(2,388.40)	(3,245.50)
Hospital cost	.16**	−.30**	−.40**	.02	−.05
	(.08)	(.12)	(.15)	(.05)	(.07)
% young male population	30.99	−4.98	−.75	8.18	11.64
	(27.83)	(14.52)	(14.92)	(8.13)	(9.45)
Precipitation	1.90**	.10	.06	−.49*	−.53*
	(.92)	(.36)	(.37)	(.29)	(.33)
Snowfall	.32	.01	−.07	−.12	−.19
	(.41)	(.22)	(.23)	(.12)	(.14)
No-fault	95.02**	150.11**	175.07**	95.87**	116.29**
	(32.08)	(17.04)	(28.06)	(8.80)	(18.40)
Add-on	−1.35	210.06**	251.52**	139.60**	173.52**
	(37.59)	(51.66)	(58.46)	(39.48)	(43.74)
R^2	.73	.92	.91	.97	.96

Source: Edlin and Karaca-Mandic (2006)

- Traffic density increases insure costs.
- This relationship is convex (access to road is subject to congestion).
- In California, one more "average" driver increases total cost from about $2,000$\$ per year.
- In North Dakota, one more "average" driver increases total cost from about 10\$ per year.
- In California, a tax that would double insurance premiums should be implemented to achieve social optimum.

What is the value of clean air?

- Difficult to answer this question by observation.
- Indirect approach: study the effect of pollution on goods sold on markets.
- Example: housing prices.
  Difference in prices between houses in polluted and non-polluted areas reflects damages of pollution and willingness to pay for clean air.

Brookshire, David S, et al, 1982. "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches," American Economic Review, American Economic Association, vol. 72(1), pages 165-77, March.

- Compare prices of houses in polluted and non-polluted areas:

$$\text{Price}_i = \alpha + \beta \text{Pollution}_i + \varepsilon_i.$$

- Problems:
    - Omitted variables bias: polluted areas worse on many dimension beside pollution.
    - Sorting: people with health problems avoid polluted neighborhoods.

Kenneth Y. Chay & Michael Greenstone, 2005. “Does Air Quality Matter? Evidence from the Housing Market,” Journal of Political Economy, University of Chicago Press, vol. 113(2), pages 376-424, April.

- Use Clean Air Act as an exogenous change in pollution.
- Clean Air Act: imposed ceilings on pollution levels by county in mid-1970s.
- High pollution counties experience sharp reductions in pollution levels relative to low pollution counties.
- Compare changes in housing prices in counties with large reduction in pollution to changes in housing prices with low reduction in pollution.

Clean Air Act (1970):

- First significant federal environmental legislation.
- Set air quality standards for five pollutants.
- Law established that the Environmental Protection Agency would assign "attainment" or "nonattainment" status to each county annually. Nonattainment defined as meeting either one of two conditions:
  - Annual mean concentration exceeds $75\mu g/m^3$.
  - Second highest daily concentration exceeds $260\mu g/m^3$.

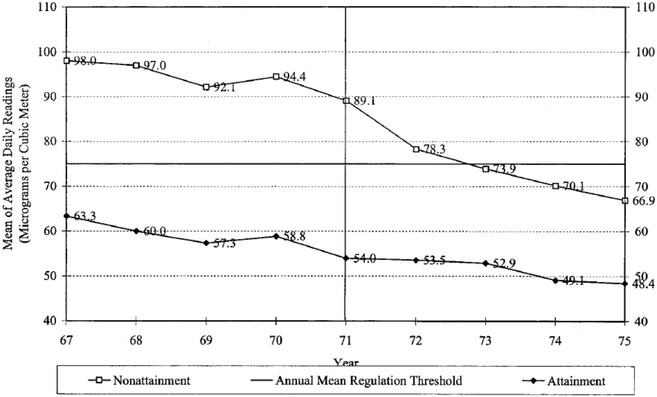


FIG. 2.—1967–75 trends in TSPs concentrations, by 1972 attainment status. The data points are derived from the 228 counties that were continuously monitored in this period. The 116 attainment counties had a 1970 population of approximately 25.8 million people, whereas about 63.4 million people lived in the 112 nonattainment counties in the same year. Each data point is the unweighted mean across all counties in the relevant regulatory category.

Source: Chay and Greenstone (2005)

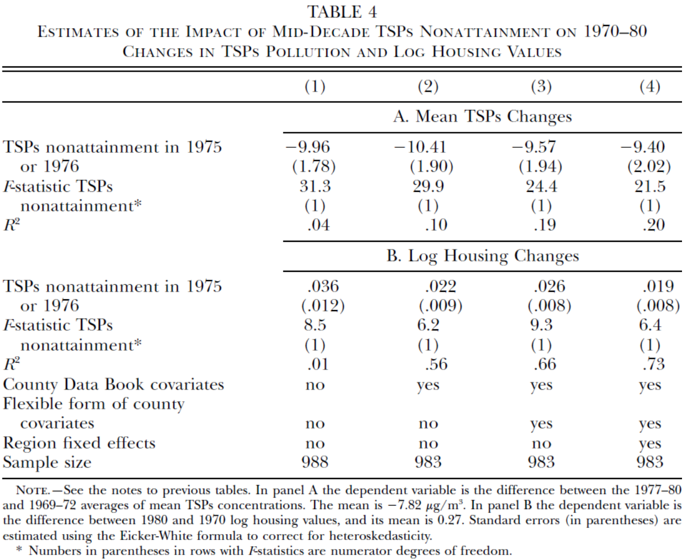


TABLE 4
ESTIMATES OF THE IMPACT OF MID-DECADE TSPS NONATTAINMENT ON 1970–80 CHANGES IN TSPS POLLUTION AND LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. Mean TSPs Changes			
TSPs nonattainment in 1975 or 1976	−9.96 (1.78)	−10.41 (1.90)	−9.57 (1.94)	−9.40 (2.02)
F-statistic TSPs nonattainment*	31.3 (1)	29.9 (1)	24.4 (1)	21.5 (1)
R^2	.04	.10	.19	.20
	B. Log Housing Changes			
TSPs nonattainment in 1975 or 1976	.036 (.012)	.022 (.009)	.026 (.008)	.019 (.008)
F-statistic TSPs nonattainment*	8.5 (1)	6.2 (1)	9.3 (1)	6.4 (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

NOTE.—See the notes to previous tables. In panel A the dependent variable is the difference between the 1977–80 and 1969–72 averages of mean TSPs concentrations. The mean is $-7.82\ \mu g/m^3$. In panel B the dependent variable is the difference between 1980 and 1970 log housing values, and its mean is 0.27. Standard errors (in parentheses) are estimated using the Eicker-White formula to correct for heteroskedasticity.

* Numbers in parentheses in rows with *F*-statistics are numerator degrees of freedom.

Source: Chay and Greenstone (2005)

- Results estimates using different methods, including regression discontinuity at nonattainment thresholds.
- All in all: 1% increase in pollution lowers housing prices by $0.2 \sim 0.35\%$.
- Total willingness to pay: Clean Air Act increased house values by 45×10^6\$, i.e. 5%, in treated counties.
- Concern with short-run market-based methods: People may be ignorant of changes in pollution in short run and of its effects on health; thus, market price differences might not reflect the real social cost of pollution.

Contingent valuation

- For some topics, it is impossible to have a market value, even indirectly. For example: protection of endangered species.
- A direct solution is “contingent valuation” surveys:
    - How much would you be willing to pay to avoid extinction of whales?

Problems with contingent valuation surveys

Peter A. Diamond & Jerry A. Hausman, 1994. “Contingent Valuation: Is Some Number Better than No Number?,” Journal of Economic Perspectives, American Economic Association, vol. 8(4), pages 45-64, Fall.

- No cost for respondents: “How much *would you be willing*. . . ”
- Lack of consistency in answers:
  - Framing effects: “ask about whales, then seals ”does not lead to answers consistent with those obtained if you “ask about whales and seals”.
  - The willingness to pay to clean 1 lake is equal to the willingness to pay to clean 5 lakes.

Let experts decide based on a budget on which individuals have agreed on.

End of lecture.

Lectures of this course are inspired from those taught by R. Chetty, G. Fields, N. Gravel, H. Hoynes, and E. Saez.