9. Public Goods and Externalities

See Varian Ch 23-24, and other micro textbooks for a more complete presentation.

I. Introduction

A. The invisible hand can go astray (i.e., CE may not be efficient) when activities of buyers and sellers affect ("external") third parties.

B. We'll consider general production and consumption externalities, and important particular sorts, such as public goods and network effects.

C. In principle, there are ways to restore efficiency in all these cases. In practice, it may be difficult or impossible.

D. Once you understand the principles, you may see opportunities for mutual gain in novel situations.

II. Public Goods

A. Public goods have one or both of the following special properties:

- Non-rival consumption: the amount I consume does not affect the amount potentially available for others to consume.
- Non-excludable consumption: once the good exists, it can be consumed by anyone (nearby), whether or not they pay for it.

B. Example. A local sports contest is held in a stadium with 50,000 seats, and is broadcast on live TV. The TV broadcast is both non-rival and non-excludable. If the signal were scrambled and viewable only by those who had a decoder box and paid for the key, then it would be excludable. The seats themselves are excludable and rival, so they are not public goods.

C. Other standard examples of public goods are national defense, public parks, and communication and transportation infrastructure. Infrastructure is congestible, so only partly non-rival.

D. The efficient quantity of a (nonrival) public good maximizes the *sum* of WTP's less production cost. Assuming continuous divisibility (e.g., air quality, or bandwidth), the FOC for efficiency is that the sum of WTP's for the last unit equals its marginal cost.

E. The CE amount of a non-excludable public goods is typically inefficiently low, since consumers can "free-ride."

III. A calculus example.

- Measure the quantity of the public good by its total cost Y, so $C(Y) = Y$.
- Agents $i = 1, ..., n$ have quasilinear utility $u_i(m, Y) = m + g_i(Y) = m + b_i \ln Y$.
- Thus each has WTP (or inverse demand) $g'(Y) = b_i/Y$.
- With non-rival consumption, the total social benefit is $B(Y) = b_T \ln Y$, where $b_T = \sum_{i=1}^n b_i$.
- Thus the efficient amount Y^o maximizes $B(Y) - C(Y) = b_T \ln Y - Y$. The FOC (which here is necessary and sufficient) is $0 = B'(Y) - 1 = b_T/Y - 1$, so $Y^o = b_T = \sum_{i=1}^n b_i$.
- A competitive market will provide the amount Y^c demanded by the most eager agent, and others will free ride. In this example, $Y^c = b_M$, where $b_M = \max_{i=1,...n} b_i$.
- For example, if there are $n = 100$ identical agents with $b_i = 5$, then $Y^c = 5$. Free riding causes a 99% shortfall from the social optimum $Y^o = 500$.

IV. Possible solutions to under-provision / free riding:

- If producers of the public good can make it excludable and can discover consumers' WTP, then they can restore efficiency by charging each agent the unit price $p_i = g_i'(Y^o)$, her marginal WTP. This is called Lindahl pricing.
- To spell it out, at price p_i, agent i will demand the efficient amount Y^o of the public good. In the previous example, $p_i = b_i/Y^o$, so she pays $p_i Y^o = b_i$. The

total amount purchased is $\sum_{i=1}^{n} b_i = b_T = Y^o$ — the efficient level of the public good !

- VCG mechanisms (discussed below) can elicit true WTP.
- In tight-knit communities, roughly efficient contribution levels for public goods can be attained via norms of behavior enforced by peer pressure.
- In mass societies, taxation can approximate efficient provision.
  - Suppose that agents vote on the per-capita tax, $s = Y/n$, and that the vote determines the outcome $Y = ns$.
  - Agent i's desired tax s_i solves $\max_x g_i(nx) - x$, so in the log example $s_i = b_i$.
  - In a simple voting model, the median desired rate $s_m = b_m$ will prevail.
  - In this case, $G^v = nb_m \approx \sum_{i=1}^{n} b_i = b_T$. The approximation is exact if median=mean, e.g., if the b_i distribution is symmetric.

V. Other sorts of externalities. General (albeit superficial) classification of externalities include

- positive (third parties benefit) vs negative (are harmed);
- consumption side (as in public goods) vs production side (spillovers from creating goods); and
- pecuniary (3rd party benefit or harm is due to changed prices) vs non-pecuiary (due to direct impact).

Here are some examples for you to classify in all three dimensions.

A. Increased UCSC enrollments drive up rents for non-student residents of Santa Cruz.

B. Driving your car increases the level of CO2 in the atmosphere.

C. Joining Facebook increases its value to your friends.

D. Drummers on West Cliff Drive affect your enjoyment of walking at sunset.

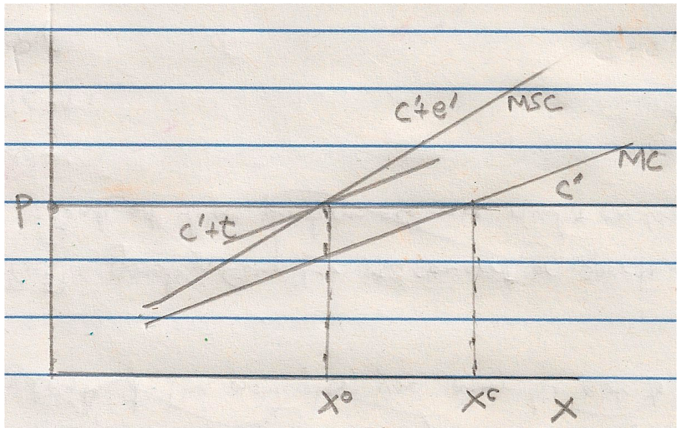

Figure 1: A negative production externality. Price-taking firm maximizes profit at x^c, but output level x^o maximizes total surplus.

E. Bee keepers increase the productivity of neighboring farms.

What can we say about the efficiency impact and remedies? Let's begin with a non-pecuniary negative production externality, such as a chemical plant polluting a nearby stream.

- The firm seeks to $\max_{x \geq 0}[px - c(x)]$, but output level x also creates costs $e(x)$ borne by downstream agents.
- Firm rationally chooses x^c that satisfies FOC $p = c'(x)$.
- Socially efficient choice x^o maximizes total surplus, $TS = px - c(x) - e(x)$. It typically satisfies the FOC $p = c'(x) + e'(x)$, i.e., price = marginal social cost, which includes the marginal external cost $e'(x)$ as well as marginal private cost $c'(x)$.
- Under the usual assumptions regarding costs ($c', e' > 0$ and $c'', e'' > 0$), we have $x^o < x^c$. That is, the competitive output (and pollution) level is higher than the socially optimal level, as in Figure 1.

How to remedy inefficiencies arising from externalities? The general idea is to somehow internalize the externality, so the invisible hand can resume its magic.

A. One way to internalize is to merge. The polluting firm could buy up all the downstream agents, and then it would recognize the entire cost $c(x) + e(x)$. Profit maximization now would be efficient. Of course, such mergers are often impractical.

B. Another perspective is to say that there is a missing market. If the polluting firm needed a permit to produce, and permits were sold in a competitive market, then (it can be argued) the market clearing price of the permit would be $e'(x)$. Then the firm's private MC would include $e'(x)$, restoring efficiency.

   - Should the missing market start by giving the polluters the right to pollute, or start by giving the downstream agents the right to clean water? Coase argued that it doesn't matter; whatever the assignment of property rights, the competitive outcome will be efficient. (His argument assumes quasi-linear preferences.)
   - Can you get a competitive market with only one agent (the polluter) on one side? Coase again argued that it doesn't matter; a bargaining process could also produce the same outcome.
   - Ronald Coase (1910-2013) won the 1991 Nobel prize, largely for the insight that, in principle, externalities can be internalized if property rights are properly established and transactions costs (in markets or bargaining) are negligible. The insight is very useful even though, as a practical matter, transactions costs are often prohibitive and the necessary property rights are unclear and/or unenforceable.

C. In some cases, the most practical way to internalize the externality is via a Pigovian tax (after British economist A.C. Pigou, 1877-1959). If the polluter has to pay a per-unit tax of $t = e'(x^o)$, then the invisible hand would again restore efficiency, as illustrated in Figure 1.

The points made here for a negative production externality apply, with suitable modifications, to other non-pecuniary externalities. Take one case, e.g., positive production externality, and see how far you can get. E.g., the Pigouvian tax becomes a subsidy, to boost production to the socially optimal level.

Pecuniary externalities are often regarded as wealth transfers, not as sources of inefficiency. This is debatable, but I will not do so here.

VI. **Network externalities.** Sometimes the value of a good depends on how many others use it. For example,

- Facebook is valuable to consumers mainly because so many other consumers use the platform. Likewise for popular on-line games.
- The QWERTY keyboard is valued mainly because so many people already use it. Conversely, US firms refuse to switch to the metric system because it isn't used by very many of their suppliers and customers.
- High trading volume lowers transactions costs on the New York Stock Exchange, as compared to a startup trading platform.
- Classic examples include narrow-gage railroads, telephone service and fax machines. The internet is a very prominent example in the 21st century.
- A classic "folk" model is that the costs of a network are proportional to the number of agents n, but benefits are proportional to the number of possible pairs of agents, roughly n^2.
- Thus we have increasing returns to scale, and a natural monopoly. The network effects are a sort of barrier to entry.

Suppose a new platform (or game or app) comes along that, given the same level of usage, would be more efficient than the incumbent.

- If strong network effects are present, the new platform may never get enough usage to catch on, which would be a loss of TS.
- Some observers argue that that sort of inefficient "lock-in" is common, and exemplified in the failed betamax format for video casette recorders and the Dvorak

keyboard. If so, the invisible hand has gone astray. (Others dispute that, and argue that the VHS and QWERTY formats are more efficient than claimed.)

- Lab experiments with weakest link games are indisputable instances.
- Managerial economics texts argue for "penetration pricing," bring-a-friend bonuses, and other up-front inducements to overcome the problem.

VII. **VCG and other demand-revealing mechanisms.** Recall that Lindahl pricing, Pigouvian taxes and Coasian bargaining all assume that agents know each others' WTP. Of course, true WTP is typically unknown by other parties. How can this informational problem be overcome?

The problem arises in many contexts, not just for externalities. We first saw it when considering price discrimination, and noted that self-sorting mechanisms (as in 2^opd) can mitigate the problem.

Another place it shows up is in auction theory. The Vickrey second price auction encourages bidders to fully reveal WTP.

Varian presents Clarke-Groves mechanisms for public good provision.

The basic ideas in these Vickrey-Clarke-Groves (VCG) mechanisms are

- Arrange things so that announcing true WTP is a dominant strategy.
- This requires that the payment each agent receives (or pays) is independent of her announced WTP, but the outcome (e.g., winning an auctioned item, or the amount Y of public good) does depend on her announcement.
- The payment is often calculated as the agent's externality, i.e., $p_i = [TS| - i]_{-i} - [TS|i]_{-i}$, where
- $[TS| - i]_{-i}$ (resp $[TS|i]_{-i}$) is total surplus of agents other than i when i does not (resp does) participate.

Example: Ad auctions, GSP vs VCG.