EXTERNALITIES; PUBLIC GOODS

Week 10

(Chapter 35, except 35.1; Chapter 37.1–37.4)

Today's Plan

1. Externality
   - The concept
   - An example
     - Internalizing Externality
     - Coase Theorem
   - Tragedy of the Commons

2. Public Good
   - The concept
   - The Free Rider Problem
   - How much Public Good is efficient?

Externalities

- An **externality** occurs when actions taken by one affect someone else in a way that is not accounted for by the market price

- An externally imposed benefit is a **positive externality**

- An externally imposed cost is a **negative externality**

Examples of Negative Externalities

- Pollution (Water/Air)
- Second-hand cigarette smoke
- Loud parties next door
- Increased insurance premiums due to alcohol/tobacco/sugar consumption

Examples of Positive Externalities

- A well-maintained property next door that raises the market value of your property
- Improved driving habits that reduce accident risks
- A scientific advancement
- An NUS graduate wins the Nobel Prize

Externalities and Efficiency

- Externalities may cause inefficiency
- Typically
  - too much resource allocated to activity with negative externality
  - too little resource allocated to activity with positive externality
- Both cases represent **market failures**
  - (*Market fails* when it does not allocate resources efficiently)

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Production Externalities

An example:

- A steel mill produces jointly steel (s) and pollution (x)
- The pollution adversely affects a nearby fishery, which catches fish (f)
- p_S is the market price of steel
- p_F is the market price of fish
- Both firms are price-takers

The Steel Firm's Problem

- $c_s(s, x)$ is the steel firm's cost of producing s units of steel jointly with x units of pollution
- The steel firm's profit function is $\pi_s(s, x) = p_s s - c_s(s, x)$
- Steel firm chooses *s* and *x* to maximize its profit. The first-order profit-maximization conditions are:

$$p_s = \frac{\partial c_s(s, x)}{\partial s}, \quad 0 = \frac{\partial c_s(s, x)}{\partial x}$$

The Steel Firm's Problem

- Suppose $c_s(s,x) = s^2 + (x-4)^2$ and $p_s = 12$. Then $\pi_s(s,x) = 12s - s^2 - (x-4)^2$

- The first-order profit-maximization conditions are

$$\frac{\partial \pi_s(s,x)}{\partial s} = 12 - 2s = 0, \quad \frac{\partial \pi_s(s,x)}{\partial x} = -2(x-4) = 0$$

$$\Longrightarrow \; s^* = 6, \quad x^* = 4, \quad \pi^* = 36$$

Production Externalities

- Let $c_f(f,x)$ represent the cost to the fishery of catching f units of fish when the steel mill emits x units of pollution. If $c_f(f,x)$ increases with x, the steel firm inflicts a negative externality on the fishery

- The fishery's profit function is $\pi_f(f,x) = p_f f - c_f(f,x)$

- Fishery chooses f to maximize its profit. The first-order profit-maximization condition is:

$$p_f = \frac{\partial c_f(f,x)}{\partial f}$$

- *(Differentiate with respect to x too?)*

Production Externalities

- Suppose $c_f(f,x) = f^2 + xf$ and $p_f = 10$
- External cost inflicted on the fishery by the steel firm is *xf*
- Since fishery has no control over *x*, it takes steel firm's choice of *x* as a given. The fishery's profit function is thus

$$\pi_f(f,x) = 10f - f^2 - xf$$

- Given *x*, the first-order profit-maximization condition is

$$\frac{\partial \pi_f}{\partial f} = 10 - 2f^* - x = 0 \implies \quad f^* = 5 - 0.5x$$

- Fishery produces less, and earns less profit, as pollution increases

Production Externalities

- Given that $f^* = 5 - 0.5x$ and $x^* = 4$, the fishery's profit-maximizing output level is $f^* = 3$
- The fishery's profit is $\pi_f(f, x) = 10f^* - f^{*2} - x^* f^* = \$9$
- Notice that the external cost is \$12
- When the steel firm ignores the external costs of its choices, the sum of the two firm's profits is \$36 + \$9 = \$45
- Is \$45 the largest total profit possible?

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Merger and Internalization

- Suppose the two firms merge to become one. What is the highest profit this new firm can achieve?

$$\pi^m(s, f, x) = 12s + 10f - s^2 - (x-4)^2 - f^2 - xf$$

- The first-order conditions are

$$\frac{\partial \pi^m}{\partial s} = 12 - 2s = 0$$

$$\frac{\partial \pi^m}{\partial f} = 10 - 2f - x = 0 \qquad \Longrightarrow \quad s^m = 6, f^m = 4, x^m = 2$$

$$\frac{\partial \pi^m}{\partial x} = -2(x-4) - f = 0$$

Merger and Internalization

- The merged firm's profit is \$48
- This exceeds \$45, the sum of the non-merged firms
- On its own, the steel firm produced $x^m = 2$. Within the merged firm, pollution is $x^* = 4$
- So merger has caused an increase in profit and less pollution

Merger and Internalization

- The steel firm's profit function is $\pi_s(s,x) = 12s - s^2 - (x-4)^2$
- Note that at $x^* = 4$, $-(x^*-4)^2 = 0$
- Its private marginal cost of pollution is $2(x-4)$
- In the merged firm the profit function is $\pi^m(s,f,x) = 12s + 10f - s^2 - (x-4)^2 - f^2 - xf$
- The "social" marginal cost of pollution is $2(x-4) + f > 2(x-4)$

Merger and Internalization

- Merged firm's marginal cost of pollution is larger
  - because it faces the full cost of its own pollution
  - it would produce less pollution than the steel firm would

- Merger internalizes an externality and induces economic efficiency

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Coase Theorem and Externalities

- Is merger the only solution?
- Can market solve the problem?

- **Coase Theorem**: If (1) property rights of an externality are clearly defined, (2) there are no transaction costs, then bargaining will lead to an efficient outcome no matter how property rights are initially allocated

Ronald Coase

- 1910–2013
- Hugely influential in Law & Economics
- Best known for two articles:
  - "The Nature of the Firm" (1937)
  - "The Problem of Social Cost" (1960)

Coase Theorem and Externalities

- Coase argues that the externality exists because neither the steel firm nor the fishery owns the water being polluted
- Suppose the property right to the water is created and assigned to one of the firms. Does this induce efficiency?

Coase Theorem and Externalities

- Suppose the fishery owns the water

- It can **sell** pollution rights, in a competitive market, at \$$p_x$ each

- The fishery's profit function becomes $\pi_f(f, x) = p_f f - f^2 - xf + p_x x$

- Given p_f and p_x , how many fish and how many rights does the fishery wish to produce?

- (*Notice that x is now a choice variable for the fishery*)

Coase Theorem and Externalities

$$\pi_f(f,x) = p_f f - f^2 - xf + p_x x$$

The profit-maximum conditions are

$$\frac{\partial \pi_f}{\partial f} = p_f - 2f - x = 0$$

$$\frac{\partial \pi_f}{\partial x} = -f + p_x = 0$$

$\implies f^* = p_x$ (fish supply)

$x_s^* = p_f - 2p_x$ (pollution right supply)

Coase Theorem and Externalities

- The steel firm's profit function is $\pi_s(s, x) = p_s s - s^2 - (x-4)^2 - p_x x$

- The profit-maximum conditions are

$$\frac{\partial \pi_s}{\partial s} = p_s - 2s = 0$$

$$\frac{\partial \pi_s}{\partial x} = -2(x-4) - p_x = 0$$

$\Longrightarrow \; s^* = 0.5 p_s$ (steel supply)

$x_d^* = 4 - 0.5 p_x$ (pollution right demand)

Coase Theorem and Externalities

$f^* = p_x$ (fish supply)

$x_s^* = p_f - 2p_x$ (pollution right supply)

$s^* = 0.5p_s$ (steel supply)

$x_d^* = 4 - 0.5p_x$ (pollution right demand) (4 equations, 7 unknowns)

- Since p_s = 12 and p_f = 10,

$$\implies s^* = 6, \quad p_x = 4, \quad f^* = 4, \quad x_d^* = x_s^* = 2$$

- This is the efficient outcome

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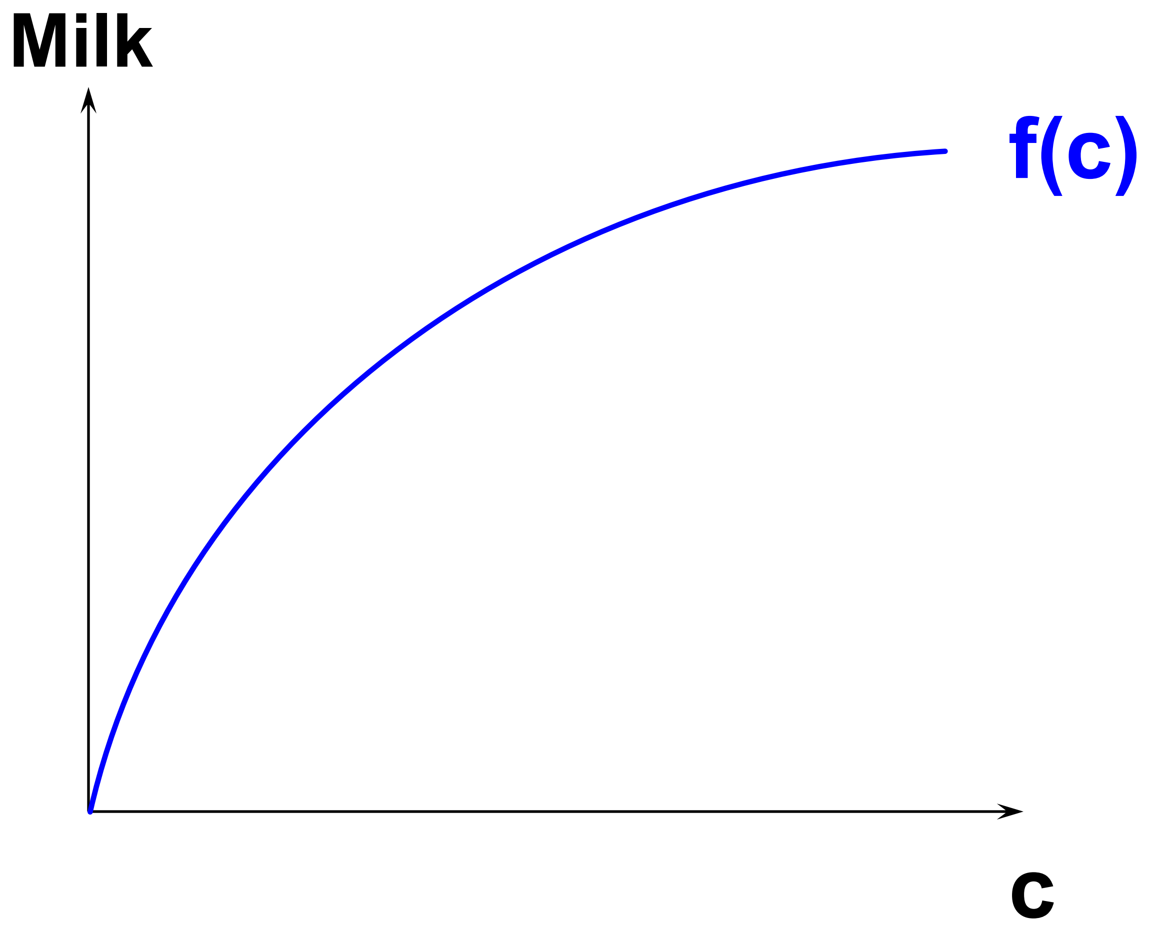
The Tragedy of the Commons

- Consider a grazing area owned “in common” by all members of a village
- Villagers graze cows on the common
- When c cows are grazed, total milk production is $f(c)$, where $f' > 0$ and $f'' < 0$
- e.g., $f(c) = c^{0.5}$, so $f' = 0.5c^{-0.5} > 0$, $f'' = -0.25c^{-1.5} < 0$
- How should the villagers graze their cows so as to maximize their overall income?

The Tragedy of the Commons



The Tragedy of the Commons

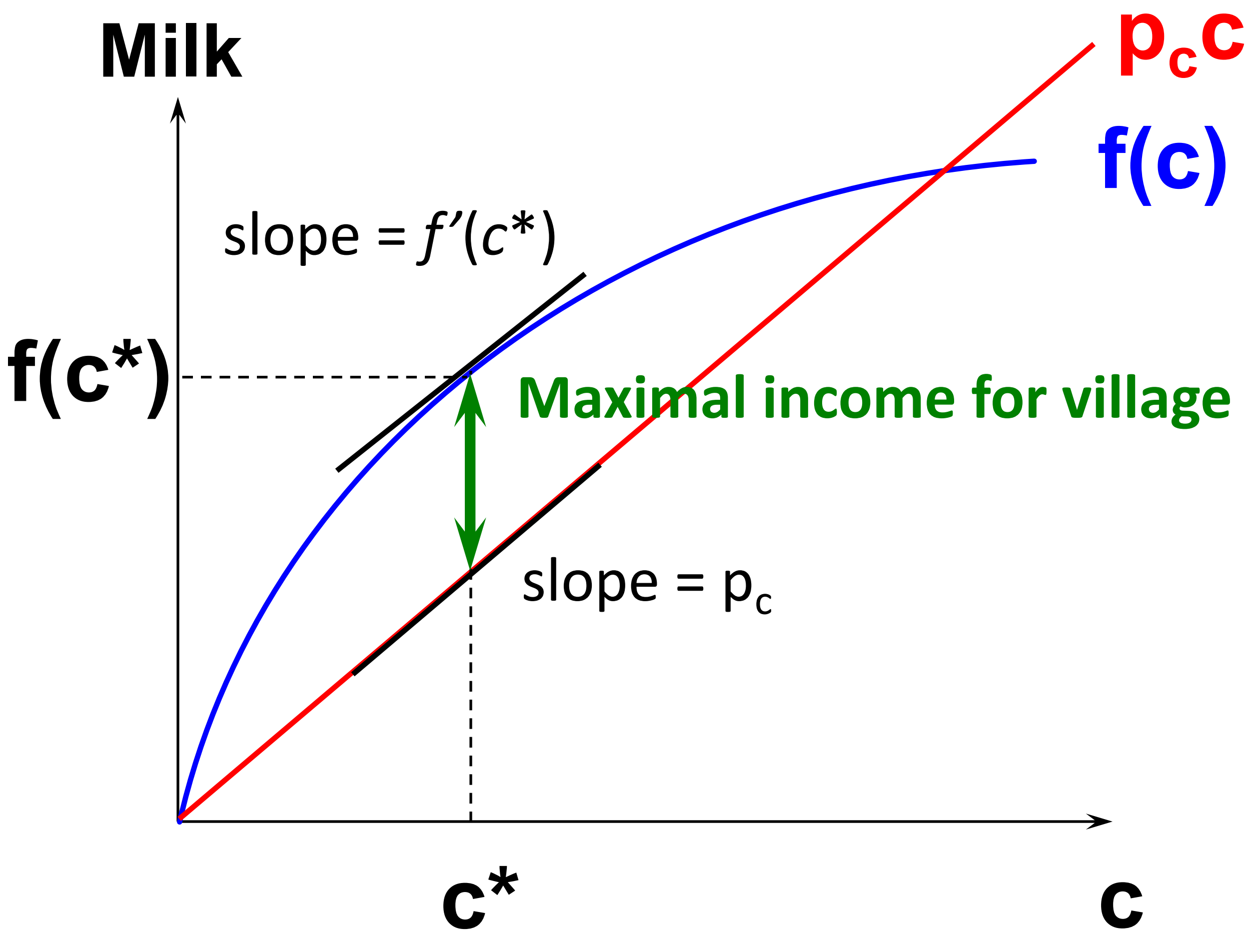
- Suppose price of milk is \$1 and let the relative cost of grazing a cow be \$$p_c$. Then the profit function for the entire village is $\Pi(c) = f(c) - p_c c$

- If the village behaves like a rational individual, its profit maximizing number of cows to graze, c^*, satisfies $f'(c) = p_c$

- i.e. the marginal revenue product from the last cow grazed must equal the marginal cost of grazing it

- (marginal revenue product = marginal product since price of milk is \$1)

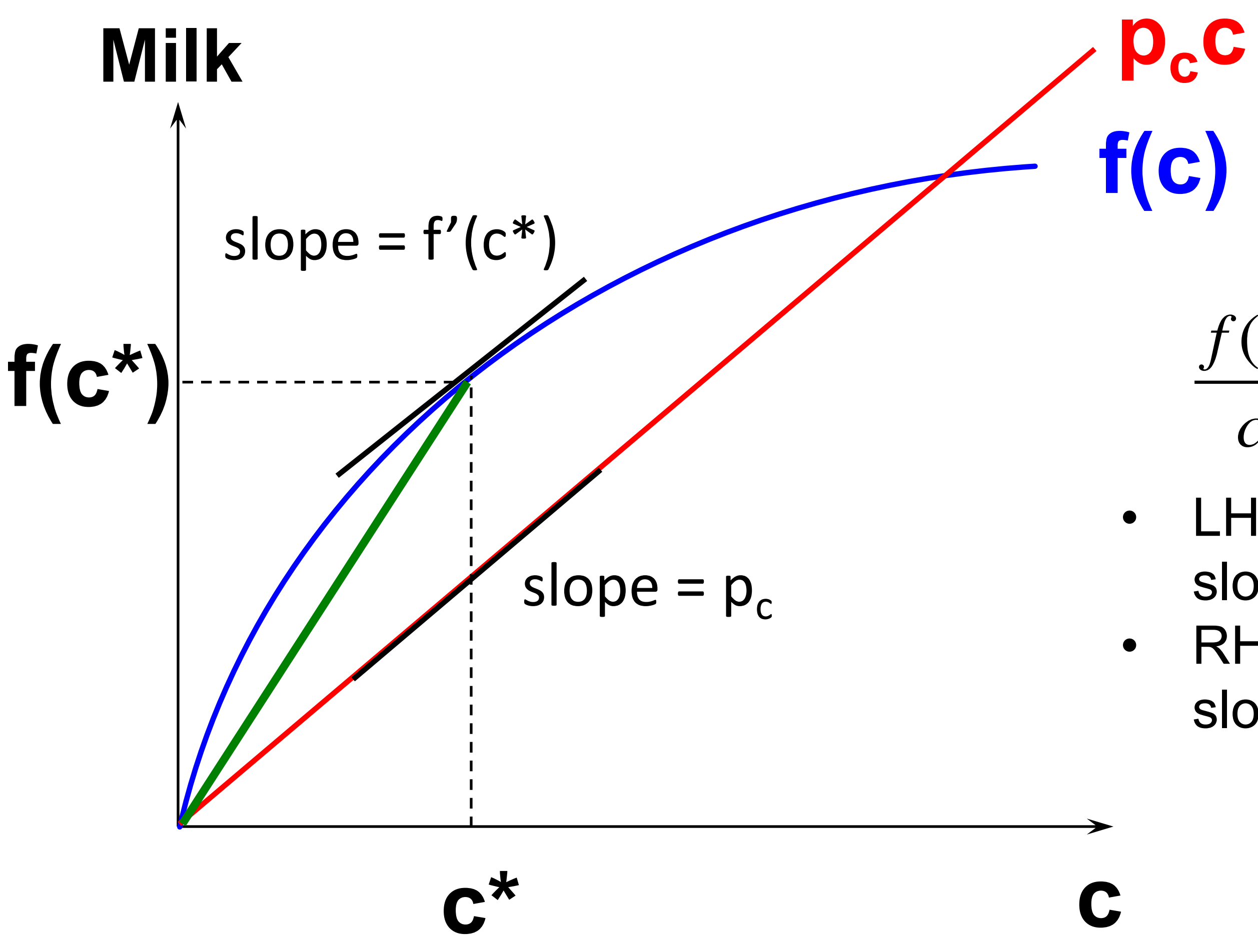
The Tragedy of the Commons



The Tragedy of the Commons

- But the village does not think like a rational individual, even though it is made up of rational individuals
- Suppose $c = c^*$, and you are considering whether to graze an additional cow
- The private cost for you to do so is p_c
- The private benefit for you to do so is $\approx \frac{f(c^*)}{c^*}$
- (Because your cow has the same “productivity”, or average product, as other existing cows)

The Tragedy of the Commons



$$\frac{f(c^*)}{c^*} > p_c$$

- LHS of inequality is slope of green line.
- RHS of inequality is slope of red line

The Tragedy of the Commons

- You should graze that additional cow since $\dfrac{f(c^*)}{c^*} > p_c$

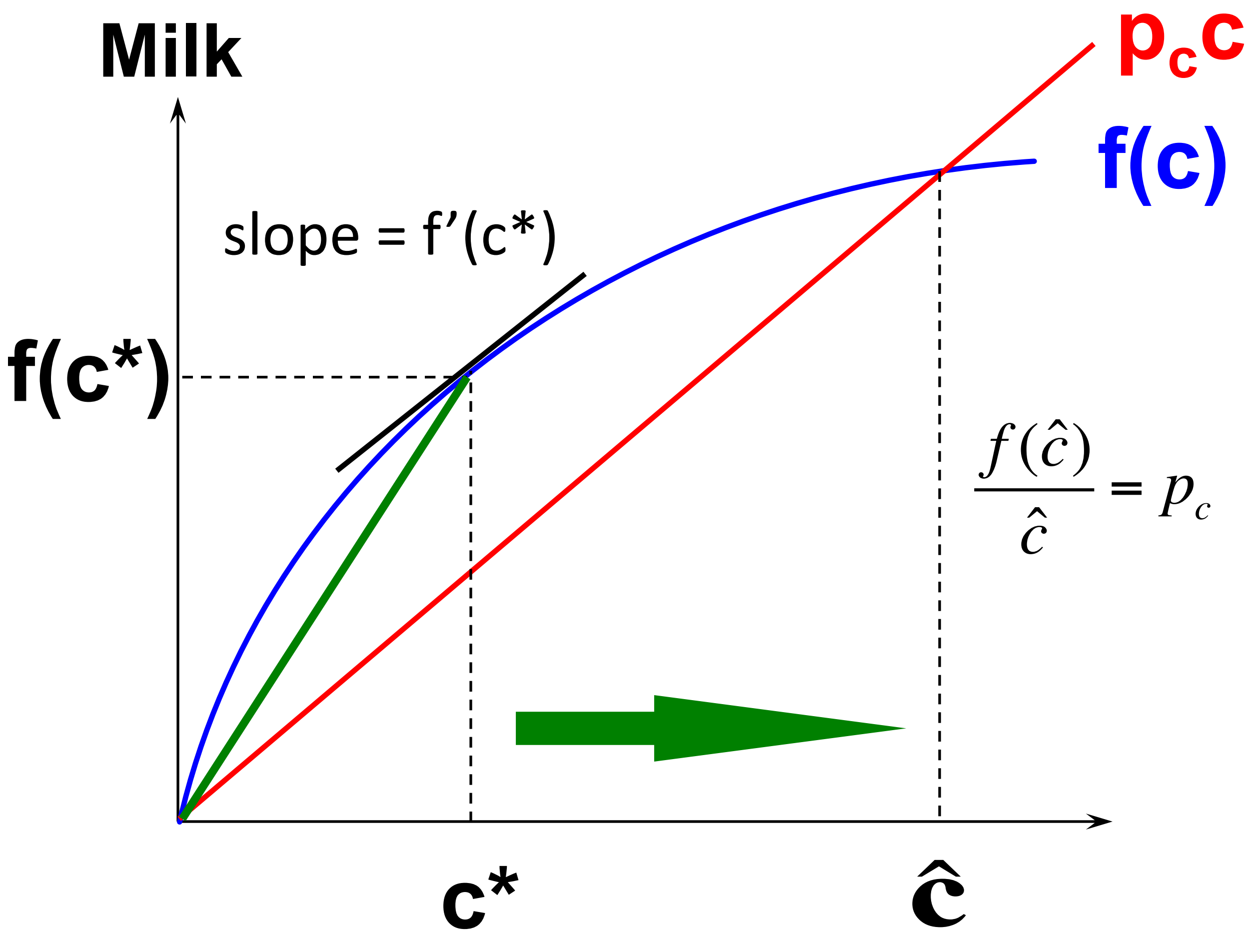
- Since *f"*<0, grazing the additional cow will lower the average product of every existing cow

- But you take no account of the cost inflicted upon the rest of the village

- Now, if everyone thinks the same way, the number of cows will increase until

$$\frac{f(\hat{c})}{\hat{c}} = p_c \Rightarrow f(\hat{c}) - p_c\hat{c} = 0 \Rightarrow \Pi(\hat{c}) = 0$$

The Tragedy of the Commons



The commons are over-grazed, tragically

The Tragedy of the Commons

- Modern-day “tragedies of the commons”
  - over-fishing the high seas
  - over-logging forests on public lands
  - over-intensive use of public parks
  - urban traffic congestion

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Public Goods - Definition

- A good is **purely public** if it is non-excludable and non-rivalrous
  - **Non-excludable**: Once produced, it is impossible to exclude people from using the good
  - **Non-rivalrous**: one person's consumption of the good doesn't diminish the ability of other people to consume it

Public Goods and Others

	Excludable	Non-excludable
Rivalrous	Pizza	Ocean fish; “Commons”
Non-rivalrous	Satellite television; Computer Software	National Defence; Clean air; Lighthouse

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Private Provision of a Public Good

- Suppose there are two individuals: A and B
- The cost of producing a public good is c
- A and B derive utilities r_A and r_B from the public good
- Suppose $r_A > c$ and $r_B < c$
- Then A would supply the good even if B made no contribution
- B then enjoys the good for free; free-riding

Private Provision not always feasible

- Suppose $r_A < c$ and $r_B < c$
- Then neither A nor B will supply the good alone
- But if $r_A + r_B > c$, then it is Pareto-improving for the good to be supplied
- A and B may try to free-ride on each other, causing no good to be supplied

Free-Riding

- Suppose A and B each have two actions to choose from: individually supply a public good, or not
- Cost of supply c = \$100
- Payoff to A from the good = \$80
- Payoff to B from the good = \$65
- \$80 + \$65 > \$100, so supplying the good is Pareto-improving

Free-Riding

		Player B: Buy	Player B: Don't Buy
Player A	Buy	-\$20, -\$35	-\$20, \$65
	Don't Buy	\$80, -\$35	\$0, \$0

- (Don't Buy, Don't Buy) is the unique NE
- But (Don't Buy, Don't Buy) is inefficient
- (Efficient if one and only one of them buys)

Free-Riding

- Now allow A and B to make contributions to supplying the good
- E.g. A contributes \$60 and B contributes \$40
- Payoff to A from the good = \$80 - \$60 = \$20 > \$0
- Payoff to B from the good = \$65 - \$40 = \$25 > \$0

Free-Riding

- So allowing contributions makes possible supply of a public good when no individual will supply the good alone

- But free-riding can persist even with contributions
  - If voluntary, one is tempted to underreport valuation of good to pay less
  - Market provision would likely lead to under-provision
  - Some form of coercion might be necessary

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How much Public Good to provide?

- Our concern is not just whether to provide a public good, but also how much to produce
- E.g. how many broadcast TV programs, or how big a national park
- Consider the following
  - $\$c(G)$ is the production cost of G units of public good
  - Two individuals, A and B
  - Endowed with $\$w_A$ and $\$w_B$ respectively;
  - Private consumptions are x_A and x_B;
  - Set $p_x = 1$
  - Budget allocations must satisfy $x_A + x_B + c(G) = w_A + w_B$

How much Public Good to provide?

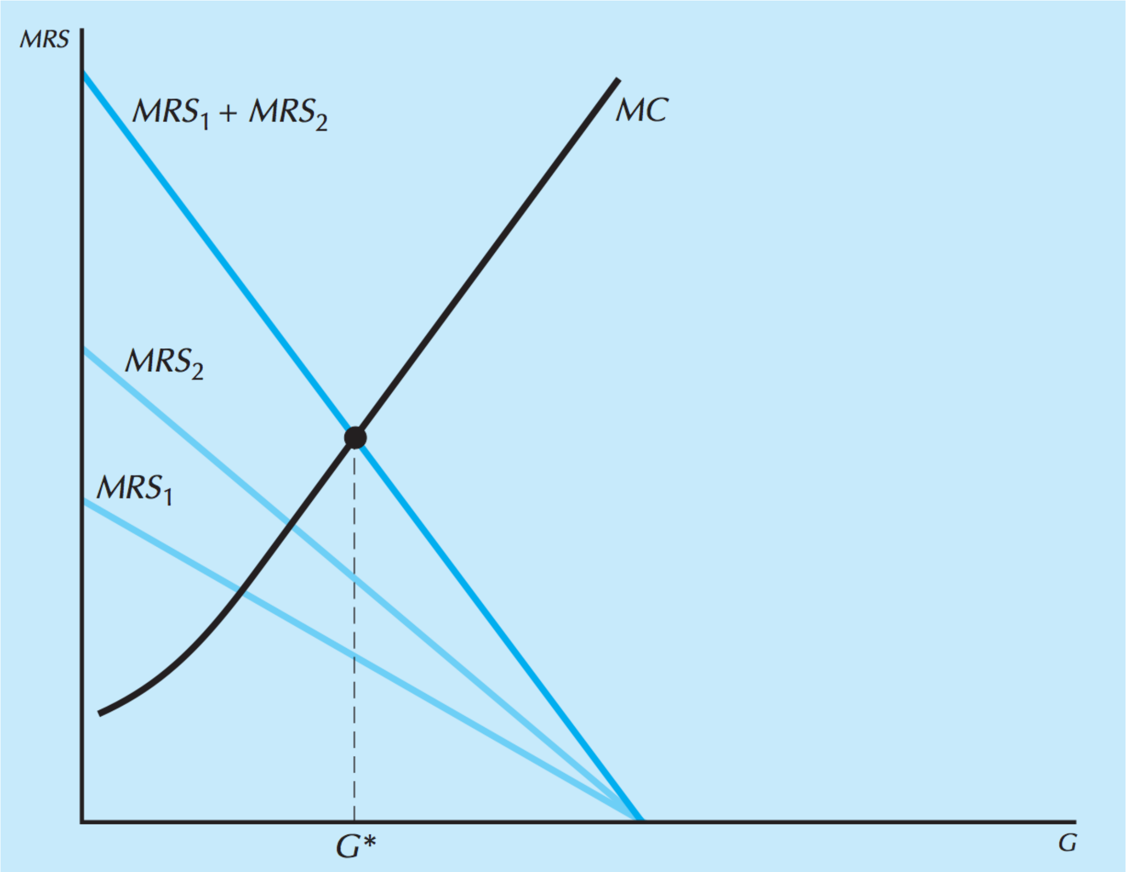
- MRS_A and MRS_B are A & B's marginal rates of substitution between the private and public goods

- Pareto efficiency condition for public good supply is

$$MRS_A + MRS_B = MC(G)$$

- Why?
  - The public good is non-rivalrous in consumption, so 1 extra unit of public good is fully consumed by both A and B

How much Public Good to provide?



- Should reduce G if $MRS_A + MRS_B < MC(G)$
- Should increase G if $MRS_A + MRS_B > MC(G)$

Note the difference

- If G is a private good, efficiency requires $$\left[\frac{MU_G}{MU_X}\right]_A = \left[\frac{MU_G}{MU_X}\right]_B = \frac{P_G}{P_X} = \frac{MC(G)}{1}$$

$$\Longrightarrow MRS_A = MRS_B = MC(G)$$

- Efficient **public** good production requires $$MRS_A + MRS_B = MC(G)$$

- If there are n consumers; *i* = *1*,…,*n*. Then efficient public good production requires

$$\sum_{i=1}^{n} MRS_i = MC(G)$$