CHAPTER 18 OUTLINE

18.1 EXTERNALITIES

- **externality** Action by either a producer or a consumer which affects other producers or consumers, but is not accounted for in the market price.

Negative externality: the action of one agent imposes a cost to another agent(s)

Positive externality: the action of one agent gives a benefit to another agent(s)

Negative Externalities and Inefficiency

- **marginal external cost** Increase in cost imposed externally as one or more firms increase output by one unit.
- **marginal social cost** Sum of the marginal cost of production and the marginal external cost.

18.1 EXTERNALITIES

Negative Externalities and Inefficiency

Figure 18.1

External Cost

When there are negative externalities, the marginal social cost MSC is higher than the marginal cost MC.

The difference is the marginal external cost MEC.

In (a), a profit-maximizing firm produces at q_1, where price is equal to MC.

The efficient output is q^*, at which price equals MSC.

18.1 EXTERNALITIES

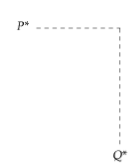
Negative Externalities and Inefficiency

Figure 18.1

External Cost (continued)

In (b), the industry's competitive output is Q_1, at the intersection of industry supply MC^I and demand *D*.

However, the efficient output Q^* is lower, at the intersection of demand and marginal social cost MSC^I.



18.1 EXTERNALITIES

Positive Externalities and Inefficiency

- **marginal external benefit** Increased benefit that accrues to other parties as a firm increases output by one unit.

- **marginal social benefit** Sum of the marginal private benefit plus the marginal external benefit.

18.1 EXTERNALITIES

Positive Externalities and Inefficiency

Figure 18.2

External Benefits

When there are positive externalities, marginal social benefits MSB are higher than marginal benefits *D*.
The difference is the marginal external benefit MEB.
The price P_1 results in a level of repair, q_1.
A lower price, P^*, is required to encourage the efficient level of supply, q^*.

Chapter 18 Externalities and Public Goods

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A model of externalities

Two agents, A and B, consumes good x, respectively in quantities x_A and x_B.

To consume, agent A pays a cost $c(x_A)$ and agent B pays a cost $c(x_B)$ where function $c(.)$ is increasing and convex ($c' > 0$ and $c" \geq 0$)

The consumption of one agent produces an externality on the other agent, i.e.

$u_A(x_A, x_B)$ is the agent A's utility where $\frac{du_A}{dx_A} > 0$ is the marginal benefit and $\frac{du_A}{dx_B}$ is the marginal externality of agent B's consumption on agent A's utility

$u_B(x_B, x_A)$ is the agent B's utility where $\frac{du_B}{dx_B} > 0$ is the marginal benefit and $\frac{du_B}{dx_A}$ is the marginal externality of agent A's consumption on agent B's utility

Selfish agents face the following problems:

Agent A's problem $\max_{\{x_A\}} u_A(x_A, x_B) - c(x_A)$

Agent B's problem $\max_{\{x_B\}} u_B(x_B, x_A) - c(x_B)$

FOCs are $\frac{du_A}{dx_A} = \frac{dc(x_A)}{dx_A} \qquad \frac{du_B}{dx_B} = \frac{dc(x_B)}{dx_B}$

Suppose a social planner that maximizes the sum of the utilities of the two agents. Its problem is

$$\max_{\{x_A, x_B\}} u_A(x_A, x_B) + u_B(x_B, x_A) - c(x_A) - c(x_B)$$

The FOCs are

$$\frac{du_A}{dx_A} = \frac{dc(x_A)}{dx_A} - \frac{du_B}{dx_A} \qquad \frac{du_B}{dx_B} = \frac{dc(x_B)}{dx_B} - \frac{du_A}{dx_B}$$

Selfish agents: FOCs are

$$\frac{du_A}{dx_A} = \frac{dc(x_A)}{dx_A} \qquad \frac{du_B}{dx_B} = \frac{dc(x_B)}{dx_B} \qquad \text{(I)}$$

Social planner: FOCs are

$$\frac{du_A}{dx_A} = \frac{dc(x_A)}{dx_A} - \frac{du_B}{dx_A} \qquad \frac{du_B}{dx_B} = \frac{dc(x_B)}{dx_B} - \frac{du_A}{dx_B} \qquad \text{(II)}$$

If **externality are negative**, i.e. $\frac{du_B}{dx_A} < 0$ and $\frac{du_A}{dx_B} < 0$ the RHS of conditions (II) are bigger respect to the RHS of conditions (I).

This implies that **selfish agents consume more** respect to the social planner solution.

Note that LHS is decreasing, as well as the RHS is increasing

If **externality are positive**, i.e. $\frac{du_B}{dx_A} > 0$ and $\frac{du_A}{dx_B} > 0$ the RHS of conditions (II) are smaller respect to the RHS of conditions (I).

This implies that **selfish agents consume less** respect to the social planner solution.

Example with negative externalities

$u_A(x_A, x_B) = 10x_A - x_B$ and $c(x_A) = {x_A}^2$

$u_B(x_B, x_A) = 10x_B - x_A$ and $c(x_B) = {x_B}^2$

Selfish agents: $x_A = 5 \quad x_B = 5$

Social planner: $x_A = 4.5 \quad x_B = 4.5$

Example with positive externalities

$u_A(x_A, x_B) = 10x_A + x_B$ and $c(x_A) = {x_A}^2$

$u_B(x_B, x_A) = 10x_B + x_A$ and $c(x_B) = {x_B}^2$

Selfish agents: $x_A = 5 \quad x_B = 5$

Social planner: $x_A = 5.5 \quad x_B = 5.5$

18.2 WAYS OF CORRECTING MARKET FAILURE

Figure 18.4

The Efficient Level of Emissions

The efficient level of factory emissions is the level that equates the marginal external cost of emissions MEC to the benefit associated with lower abatement costs MCA. The efficient level of 12 units is *E**.

18.2 WAYS OF CORRECTING MARKET FAILURE

An Emissions Standard

- **emissions standard** Legal limit on the amount of pollutants that a firm can emit.

Figure 18.5

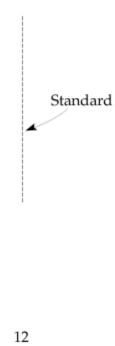
Standards and Fees

Chapter 18 Externalities and Public Goods

The efficient level of emissions at *E** can be achieved through either an emissions fee or an emissions standard.

Facing a fee of $3 per unit of emissions, a firm reduces emissions to the point at which the fee is equal to the marginal cost of abatement.

The same level of emissions reduction can be achieved with a standard that limits emissions to 12 units.



18.2 WAYS OF CORRECTING MARKET FAILURE

An Emissions Fee

- **emissions fee** Charge levied on each unit of a firm's emissions.

Standards versus Fees

Figure 18.6

The Case for Fees

With limited information, a policymaker may be faced with the choice of either a single emissions fee or a single emissions standard for all firms.

The fee of $3 achieves a total emissions level of 14 units more cheaply than a 7-unit-per-firm emissions standard.

With the fee, the firm with a lower abatement cost curve (Firm 2) reduces emissions more than the firm with a higher cost curve (Firm 1).

18.2 WAYS OF CORRECTING MARKET FAILURE

Standards versus Fees

Figure 18.7

The Case for Standards

When the government has limited information about the costs and benefits of pollution abatement, either a standard or a fee may be preferable. The standard is preferable when the marginal external cost curve is steep and the marginal abatement cost curve is relatively flat.

Here a 12.5 percent error in setting the standard leads to extra social costs of triangle *ADE*.

The same percentage error in setting a fee would result in excess costs of *ABC*.

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18.2 WAYS OF CORRECTING MARKET FAILURE

Tradeable Emissions Permits

- **tradeable emissions permits** System of marketable permits, allocated among firms, specifying the maximum level of emissions that can be generated.

Marketable emissions permits create a market for externalities. This market approach is appealing because it combines some of the advantageous features of a system of standards with the cost advantages of a fee system.

EXAMPLE 18.2 Reducing Sulfur Dioxide Emissions in Beijing

Sulfur dioxide emissions produced through the burning of coal for use in electric power generation and the wide use of coal-based home furnaces have caused a huge problem in Beijing as well as other cities in China.

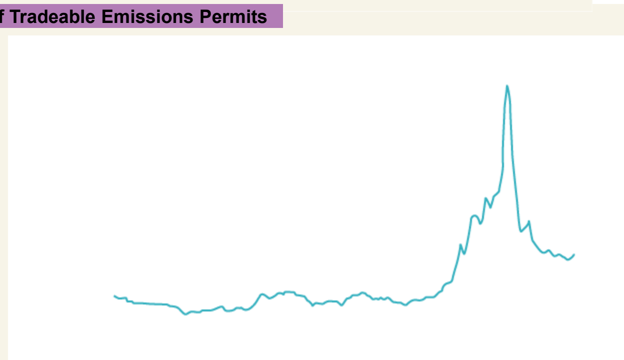
Over the long term, the key to solving Beijing's problem is to replace coal with cleaner fuels, to encourage the use of public transportation, and to introduce fuel-efficient hybrid vehicles.

18.2 WAYS OF CORRECTING MARKET FAILURE

EXAMPLE 18.3 Emissions Trading and Clean Air

Figure 18.8

Price of Tradeable Emissions Permits



The price of tradeable permits for sulfur dioxide emissions fluctuated between $100 and $200 in the period 1993 to 2003, but then increased sharply during 2005 and 2006 in response to an increased demand for permits. Since then, the price has fluctuated around $400 to $500 per ton.

18.2 WAYS OF CORRECTING MARKET FAILURE

Recycling

Figure 18.9

The Efficient Amount of Recycling

As the amount of scrap disposal increases, the marginal private cost, MC, increases, but at a much lower rate than the marginal social cost MSC.

The marginal cost of recycling curve, MCR, shows that as the amount of disposal decreases, the amount of recycling increases; the marginal cost of recycling increases.

18.2 WAYS OF CORRECTING MARKET FAILURE

Recycling

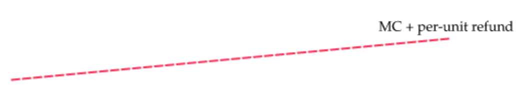
Figure 18.9

The Efficient Amount of Recycling (continued)

The efficient amount of recycling of scrap material is the amount that equates the marginal social cost of scrap disposal, MSC, to the margina cost of recycling, MCR.

The efficient amount of scrap for disposal *m** is less than the amount that will arise in a private market, m_1.

A refundable fee increases the cost of disposal. The individual will reduce disposal and increase recycling to the optimal social level *m**.



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18.2 WAYS OF CORRECTING MARKET FAILURE

Refundable Deposits

Figure 18.10

Refundable Deposits

The supply of virgin glass containers is given by S_v and the supply of recycled glass by S_r.

The market supply S is the horizontal sum of these two curves.

As a result, the market price of glass is P and the equilibrium supply of recycled glass is M_1.

M_1

18.2 WAYS OF CORRECTING MARKET FAILURE

Refundable Deposits

Figure 18.10

Refundable Deposits (continued)

By raising the relative cost of disposal and encouraging recycling, the refundable deposit increases the supply of recycled glass from S_r to S'_r and the aggregate supply of glass from S to S'.

The price of glass then falls to P', the quantity of recycled glass increases to M^*, and the amount of disposed glass decreases.

Note as the quantity of virgin glass reduces

M^*

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18.2 WAYS OF CORRECTING MARKET FAILURE

EXAMPLE 18.4 Regulating Municipal Solid Wastes

Many other countries have made greater efforts to encourage recycling than the United States.

A number of proposals to encourage more recycling in the United States include a refundable deposit, *curbside charge*, and *mandatory separation*. Mandatory separation is perhaps the least desirable of the three alternatives.

A recent case in Perkasie, Pennsylvania, shows that recycling programs can indeed be effective. Prior to implementation of a program combining all three economic incentives just described, the total amount of unseparated solid waste was 2573 tons per year. When the program was implemented, this amount fell to 1038 tons—a 59-percent reduction. As a result, the town saved $90,000 per year in disposal costs.

18.3 STOCK EXTERNALITIES

- **stock externality** Accumulated result of action by a producer or consumer which, though not accounted for in the market price, affects other producers or consumers.

18.3 STOCK EXTERNALITIES

Stock Buildup and Its Impact

How does the stock of a pollutant change over time?
With ongoing emissions, the stock will accumulate, but some fraction of the stock, *δ*, will dissipate each year. Thus, assuming the stock starts at zero, in the first year, the stock of pollutant (*S*) will be just the amount of that year's emissions (*E*):

$$S_1 = E_1$$

In general, the stock in any year t is given by the emissions generated that year plus the nondissipated stock from the previous year:

$$S_t = E_t + (1-\delta)S_{t-1}$$

If emissions are at a constant annual rate *E*, then after *N* years, the stock of pollutant will be

$$S_N = E[1+(1-\delta)+(1-\delta)^2+\cdots+(1-\delta)^{N-1}]$$

As *N* becomes infinitely large, the stock will approach the long-run equilibrium level *E*/*δ*.

18.3 STOCK EXTERNALITIES

Stock Buildup and Its Impact

Numerical Example Table 18.1 shows how the stock builds up over time. Note that after 100 years, the stock will reach a level of 4,337 units. (If this level of emissions continued forever, the stock will eventually approach E/δ = 100/.02 = 5,000 units.)

TABLE 18.1 Buildup in the Stock of Pollutant

Year	*E*	S_t	Damage ($ Billion)	Cost of *E* = 0 ($ Billion)	Net Benefit ($ Billion)
2010	100	100	0.100	1.5	–1.400
2011	100	198	0.198	1.5	–1.302
2012	100	296	0.296	1.5	–1.204
. . .	. . .	. . .	. . .	. . .	. . .
2110	100	4,337	4.337	1.5	2.837
. . .	. . .	. . .	. . .	. . .	. . .
∞	100	5,000	5.000	1.5	3.500

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18.3 STOCK EXTERNALITIES

Stock Buildup and Its Impact

To determine whether a policy of zero emissions makes sense, we must compare the present value of the annual cost of $1.5 billion with the present value of the annual benefit resulting from a reduced stock of pollutant.

$$\text{NPV} = (-1.5 + .1) + \frac{(-1.5 + .198)}{1 + R} + \frac{(-1.5 + .296)}{(1 + R)^2} + \cdots + \frac{(-1.5 + 4.337)}{(1 + R)^{99}}$$

TABLE 18.2 NPV of "Zero Emissions" Policy

		Discount Rate, R				
		.01	.02	.04	.06	.08
Dissipation Rate, δ	.01	108.81	54.07	12.20	−0.03	−4.08
	.02	65.93	31.20	4.49	−3.25	−5.69
	.04	15.48	3.26	−5.70	−7.82	−8.11

Note: Entries in table are NPVs in $billions. Entries for δ = .02 correspond to net benefit numbers in Table 18.1.

Table 18.2 shows the NPV as a function of the discount rate. It also shows how the NPV of a "zero emissions" policy depends on the dissipation rate, δ. If δ is lower, the accumulated stock of pollutant will reach higher levels and cause more economic damage, so the future benefits of reducing emissions will be greater.

18.3 STOCK EXTERNALITIES

- **social rate of discount** Opportunity cost to society as a whole of receiving an economic benefit in the future rather than the present.

In principle, the social rate of discount depends on three factors: (1) the expected rate of real economic growth; (2) the extent of risk aversion for society as a whole; and (3) the "rate of pure time preference" for society as a whole.

Chapter 18 Externalities and Public Goods

18.3 STOCK EXTERNALITIES

EXAMPLE 18.5 Global Warming

Emissions of carbon dioxide and other greenhouse gases have increased dramatically over the past century, which has in turn led to an increase in atmospheric concentrations of greenhouse gases, or GHGs.

The problem is that the costs of reducing GHG emissions would occur today but the benefits from reduced emissions would be realized only in some 50 or more years.

Does this emissions-reduction policy make sense? To answer that question, we must calculate the present value of the flow of net benefits, which depends critically on the discount rate. Economists disagree about what rate to use, and as a result, they disagree about what should be done about global warming

18.3 STOCK EXTERNALITIES

EXAMPLE 18.5 Global Warming (continued)

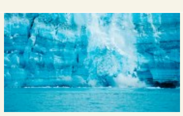


TABLE 18.3 Reducing GHG Emissions

	"Business as Usual"				Emissions Reduced by 1% per Year					
Year	E_t	S_t	ΔT_t	Damage	E_t	S_t	ΔT_t	Damage	Cost	Net Benefit
2010	50	430	0°	0	50	430	0°	0	0.65	-0.65
2020	55	460	0.5°	0.54	45	460	0.5°	0.43	0.83	-0.72
2030	62	490	1°	1.38	41	485	1°	1.11	1.07	-0.79
2040	73	520	1.5°	2.66	37	510	1.4°	2.13	1.36	-0.83
2050	85	550	2°	4.54	33	530	1.8°	3.63	1.75	-0.84
2060	90	580	2.3°	6.77	30	550	2°	5.81	2.23	-1.27
2070	95	610	2.7°	9.91	27	550	2°	7.44	2.86	-0.38
2080	100	640	3°	14.28	25	550	2°	9.52	3.66	1.10
2090	105	670	3.3°	20.31	22	550	2°	12.18	4.69	3.44
2100	110	700	3.7°	28.59	20	550	2°	15.60	6.00	7.00
2110	115	730	4°	39.93	18	550	2°	19.97	7.68	12.28

Notes: E_t is measured in gigatonnes (billions of metric tons) of CO_2 equivalent (CO_2e), S_t is measured in parts per million (ppm) of atmospheric CO_2e, the change in temperature ΔT_t is measured in degrees Celsius, and costs, damages, and net benefits are measured in trillions of 2007 dollars. Cost of reducing emissions is estimated to be 1 percent of GDP each year. World GDP is projected to grow at 2.5% in real terms from a level of $65 trillion in 2010. Damage from warming is estimated to be 1.3% of GDP per year for every 1 °C of temperature increase.

Table 18.3 shows GHG emissions and average global temperature change for two scenarios. Also shown is the annual net benefit from the policy, which equals the damage under the "business as usual" scenario minus the (smaller) damage when emissions are reduced minus the cost of reducing emissions.

18.4 EXTERNALITIES AND PROPERTY RIGHTS

Property Rights

- **property rights** Legal rules stating what people or firms may do with their property.

Bargaining and Economic Efficiency

Economic efficiency can be achieved without government intervention when the externality affects relatively few parties and when property rights are well specified.

TABLE 18.4 Profits under Alternative Emissions Choices (Daily)

	Factory's Profit ($)	Fishermen's Profit ($)	Total Profit ($)
No filter, no treatment plant	500	100	600
Filter, no treatment plant	300	500	800
No filter, treatment plant	500	200	700
Filter, treatment plant	300	300	600

The efficient solution maximizes the joint profit of the factory and the fishermen. Maximization occurs when the factory installs a filter and the fishermen do not build a treatment plant.

18.4 EXTERNALITIES AND PROPERTY RIGHTS

Bargaining and Economic Efficiency

If the factory and the fishermen agree to split this gain equally by having the fishermen pay the factory $250 to install the filter, this bargaining solution achieves the efficient outcome.

TABLE 18.5 Bargaining with Alternative Property Rights

No Cooperation	Right to Dump ($)	Right to Clean Water ($)
Profit of factory	500	300
Profit of fishermen	200	500
Cooperation		
Profit of factory	550	300
Profit of fishermen	250	500

- **Coase theorem** Principle that when parties can bargain without cost and to their mutual advantage, the resulting outcome will be efficient regardless of how property rights are specified.

18.4 EXTERNALITIES AND PROPERTY RIGHTS

Costly Bargaining—The Role of Strategic Behavior

Bargaining can be time-consuming and costly, especially when property rights are not clearly specified.

Bargaining can break down even when communication and monitoring are costless if both parties believe they can obtain larger gains.

Another problem arises when many parties are involved.

A Legal Solution—Suing for Damages

A suit for damages eliminates the need for bargaining because it specifies the consequences of the parties' choices. Giving the party that is harmed the right to recover damages from the injuring party ensures an efficient outcome. (When information is imperfect, however, suing for damages may lead to inefficient outcomes.)

18.5 COMMON PROPERTY RESOURCES

- **common property resource** Resource to which anyone has free access.

Figure 18.11

Common Property Resources

When a common property resource, such as a fishery, is accessible to all, the resource is used up to the point F_c at which the private cost is equal to the additiona revenue generated.

This usage exceeds the efficient level F^* at which the marginal social cost of using the resource is equal to the marginal benefit (as given by the demand curve).

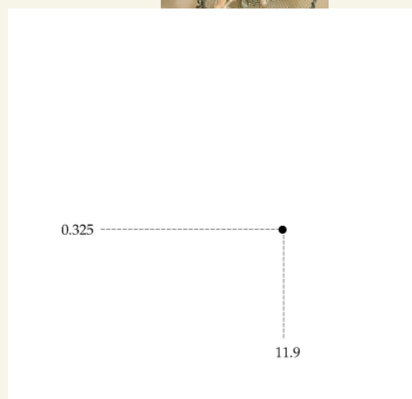
18.5 COMMON PROPERTY RESOURCES

EXAMPLE 18.7 Crawfish Fishing in Louisiana

Figure 18.12

Crawfish as a Common Property Resource

Because crawfish are bred in ponds to which fishermen have unlimited access, they are a common property resource.
The efficient level of fishing occurs when the marginal benefit is equal to the marginal social cost.
However, the actual level of fishing occurs at the point at which the price for crawfish is equal to the private cost of fishing.
The shaded area represents the social cost of the common property resource.



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Example: The problem of the Commons

n farmers in a village graze their goats on the village green.

g_i is the number of goats of the i^{th} farmer

The total number of goats is denote by $G = g_1 + ... + g_n$

c is the cost of a goat

Value of a goat is $v(G)$ where

$v' < 0$, $v'' < 0$ and $v(G) > 0$ if $G < G_{max}$.

During the spring farmers simultaneously choose how many goats to own.

Normal form game representation

Players: n farmers

Strategies:

i^{th} player's set of strategy is $S_i=[0, \infty)$ i.e. $s_i = g_i$

Payoff:

i^{th} player's payoff is $\pi_i = g_i V(G) - c\, g_i$

Solution: Nash Equilibrium

$\left(g_1^*,....g_n^*\right)$ is a Nash equilibrium if every g_i^* is the solution to the following farmer's problem:

$$\max_{\{g_i\}} g_i \cdot v\left(g_1^* + ... + g_i + ... + g_n^*\right) - g_i \cdot c$$

The FOC are:

$$v\left(g_1^* + ... + g_i + ... + g_n^*\right) + g_i \cdot v'\left(g_1^* + ... + g_i + ... + g_n^*\right) - c = 0$$

Then in a Nash equilibrium must be:

$$v\left(g_1^* + ... + g_i^* + ... + g_n^*\right) + g_i \cdot v'\left(g_1^* + ... + g_i^* + ... + g_n^*\right) - c = 0$$

for all i.

Denoting by G* the total number of goats in equilibrium, for every *i* the FOC is written as:

$$v(G^*) + g_i \cdot v'(G^*) - c = 0$$

Summing up all *n* FOCs we have

$$n \cdot v(G^*) + G^* \cdot v'(G^*) - n \cdot c = 0$$

$$v(G^*) + \frac{G^*}{n} \cdot v'(G^*) - c = 0$$

The social optimum G^{**} is given by the solution of the following problem:

$$\max_{\{G\}} G \cdot v(G) - G \cdot c$$

The FOC is:

$$v(G^{**}) + G^{**} \cdot v'(G^{**}) - c = 0$$

Then in The Nash equilibrium farmers choose to buy more goats that the social optimum.

Numerical example with two farmers

$v(G) = 100 - G^2$ where $G = g_1 + g_2$ and $c = 2$

Farmer 1's problem:

$$\max_{g_1} g_1(100 - (g_1 + g_2)^2) - g_1 c$$

The FOC is:

$$100 - (g_1 + g_2)^2 - 2g_1(g_1 + g_2) - \mathrm{c} = 0$$
$$100 - G^2 - 2g_1 G - \mathrm{c} = 0$$

The FOCs for both players are:

$100 - G^2 - 2g_1 G - \mathrm{c} = 0$ and $100 - G^2 - 2g_2 G - \mathrm{c} = 0$

Summing up we get:

$$200 - 2G^2 - 2G(g_1 + g_2) - 2\mathrm{c} = 0$$
$$200 - 4G^2 - 2\mathrm{c} = 0$$

Replacing c=2 and solving by G

$$G = 7$$

Social optimum

The problem is

$$\max_{G} G(100 - G^2) - Gc$$

FOC:

$$(100 - G^2) - 2G^2 - c = 0$$
$$3G^2 = 100 - c = 98$$
$$G = \sqrt{\frac{98}{3}} < 7$$

18.6 PUBLIC GOODS

- **public good** Nonexclusive and nonrival good: the marginal cost of provision to an additional consumer is zero and people cannot be excluded from consuming it.
- **nonrival good** Good for which the marginal cost of its provision to an additional consumer is zero.
- **nonexclusive good** Good that people cannot be excluded from consuming, so that it is difficult or impossible to charge for its use.

18.6 PUBLIC GOODS

Efficiency and Public Goods

Figure 18.13

Efficient Public Good Provision

When a good is nonrival, the social marginal benefit of consumption, given by the demand curve *D*, is determined by vertically summing the individual demand curves for the good, D_1 and D_2.

At the efficient level of output, the demand and the marginal cost curves intersect.

18.6 PUBLIC GOODS

Public Goods and Market Failure

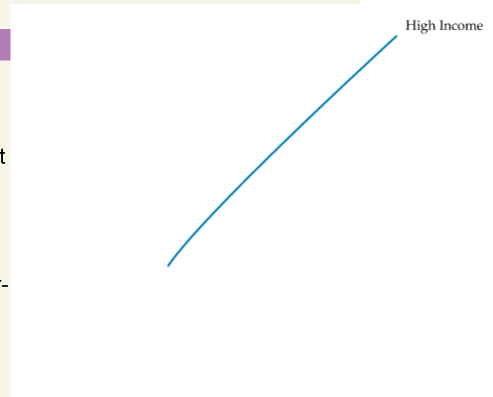
- **free rider** Consumer or producer who does not pay for a nonexclusive good in the expectation that others will.

EXAMPLE 18.8 The Demand for Clean Air

Figure 18.14

The Demand for Clean Air

The three curves describe the willingness to pay for clean air (a reduction in the level of nitrogen oxides) for each of three different households (low income, middle income, and high income).
In general, higher-income households have greater demands for clean air than lower-income households. Moreover, each household is less willing to pay for clean air as the level of air quality increases.



Chapter 18 Externalities and Public Goods

Public good game

N subjects denoted by $i \in \{1, 2, \ldots\ldots, N\}$ are endowed by e_i

They contribute simultaneously to a public good. The contribution of subject i is denoted by c_i. The amount of public good is the sum of the contributions: $G = \sum_{i=1}^{N} c_i$

The utility of subject i is given by:

$$u(G) + e_i - c_i$$

where $u' > 0$ and $u" < 0$ and

it exist a G^* such that:

$u' = 1$ for $G = G^*$ and $u' < 1$ for all $G < G^*$, greater than 1 otherwise.

The problem of subject i is:

$$\max_{c_i} u(G) + e_i - c_i$$

FOCs: $u'(G) - 1 = 0$ for all subjects i

Then the best response is to contribute an amount to reach an amount G^* of public good

FOCs: $u'(G) - 1 = 0$ for all subjects i

Then the best response is to contribute an amount to reach an amount G^* of public good

Then all combinations of contributions such that

$$G^* = \sum_{i=1}^{N} c_i$$

Represent a Nash equilibrium

Note that if $G^* = 0$ the unique Nash equilibrium is when all contributions are equal to zero

What is the social optimum?

Suppose a social planner that maximizes the sum of the utilities of all subjects.

The problem of the social planners is:

$$\max_{c_i} n \cdot u(G) + \sum_{i=1}^{N} e_i - G$$

FOC: $\mathrm{n} \cdot u'(G) - 1 = 0$

Then the best response is an amount that satisfy

$$u'(G) = \frac{1}{n}$$

By this amount is larger than G^* because u' is decreasing ($u" < 0$) and $\mathrm{u}(G^*) = 1$

Numerical example I: $u(G) = \ln(G)$

The problem of the social planners is:

$$\max_{c_i} n \cdot \ln(G) + \sum_{i=1}^{N} e_i - G$$

FOC: $\mathrm{n} \cdot \frac{1}{G} - 1 = 0$ → $G = n$

The problem of subject i is:

$$\max_{c_i} \ln(G) + e_i - c_i$$

FOC: $\frac{1}{G} - 1 = 0$ for all subjects i → $G = 1$

Numerical example II

Note, suppose $u(G) = \ln(G + 2)$, the FOC of the subject I's problem is: $\frac{1}{G+2} - 1 < 0$ for all values of G

Then in equilibrium contributions are all equal to zero

The social optimum is $G = n - 2$

18.7 PRIVATE PREFERENCES FOR PUBLIC GOODS

Figure 18.15

Determining the Level of Educational Spending

The efficient level of educational spending is determined by summing the willingness to pay for education (net of tax payments) of each of three citizens.

Curves W_1, W_2, and W_3 represent their willingness to pay, and curve *AW* represents the aggregate willingness to pay.

The efficient level of spending is \$1200 per pupil. The level of spending actually provided is the level demanded by the median voter. In this particular case, the median voter's preference (given by the peak of the W_2 curve) is also the efficient level.