Chapter 20

EXTERNALITIES AND PUBLIC GOODS

Externality(外部性)

- An externality occurs whenever the activities of one economic agent affect the activities of another economic agent in ways that are not reflected in market transactions
  - chemical manufacturers releasing toxic fumes
  - noise from airplanes
  - motorists littering roadways

Interfirm Externalities

- Consider two firms, one producing good *x* and the other producing good *y*
- The production of *x* will have an <u>external effect</u> on the production of *y* if the output of *y* depends not only on the level of inputs chosen by the firm but on the level at which *x* is produced

$$y = f(k,l;x)$$

Beneficial Externalities

- The relationship between the two firms can be beneficial
  - two firms, one producing honey and the other producing apples

Externalities in Utility

- Externalities can also occur if the activities of an economic agent directly affect an individual's utility
  - externalities can decrease or increase utility
- It is also possible for someone's utility to be dependent on the utility of another

$$\text{utility} = U_S(x_1,\ldots,x_n;U_J)$$

Public Goods Externalities

- Public goods are nonexclusive
  - once they are produced, they provide benefits to an entire group
  - it is impossible to restrict these benefits to the specific groups of individuals who pay for them

Externalities and Allocative Inefficiency

- Externalities lead to inefficient allocations of resources because market prices do not accurately reflect the additional costs imposed on or the benefits provided to third parties
- We can show this by using a general equilibrium model with only one individual

Externalities and Allocative Inefficiency (skipped)

- Suppose that the individual's utility function is given by

$$\text{utility} = U(x_c, y_c)$$

where x_c and y_c are the levels of x and y consumed

- The individual has initial stocks of x^* and y^*
  - can consume them or use them in production

Externalities and Allocative Inefficiency

- Assume that good *x* is produced using only good *y* according to

$$x_o = f(y_i)$$

- Assume that the output of good *y* depends on both the amount of *x* used in the production process and the amount of *x* produced

$$y_o = g(x_i, x_o)$$

Externalities and Allocative Inefficiency

- For example, y could be produced downriver from x and thus firm y must cope with any pollution that production of x creates
- This implies that $g_1 > 0$ and $g_2 < 0$

Externalities and Allocative Inefficiency

- The quantities of each good in this economy are constrained by the initial stocks available and by the additional production that takes place

$$x_c + x_i = x_o + x^*$$

$$y_c + y_i = x_o + y^*$$

Finding the Efficient Allocation

- The economic problem is to maximize utility subject to the four constraints listed earlier
- The Lagrangian for this problem is

$$\mathbf{L} = U(x_c,y_c) + \lambda_1[f(y_i) - x_o] + \lambda_2[g(x_i,x_o) - y_o] \quad + \lambda_3(x_c + x_i - x_o - x^*) + \lambda_4(y_c + y_i - y_o - y^*)$$

Finding the Efficient Allocation

- The six first-order conditions are

$$\partial \mathbf{L}/\partial x_c = U_1 + \lambda_3 = 0$$

$$\partial \mathbf{L}/\partial y_c = U_2 + \lambda_4 = 0$$

$$\partial \mathbf{L}/\partial x_i = \lambda_2 g_1 + \lambda_3 = 0$$

$$\partial \mathbf{L}/\partial y_i = \lambda_1 f_y + \lambda_4 = 0$$

$$\partial \mathbf{L}/\partial x_o = -\lambda_1 + \lambda_2 g_2 - \lambda_3 = 0$$

$$\partial \mathbf{L}/\partial y_o = -\lambda_2 - \lambda_4 = 0$$

Finding the Efficient Allocation

- Taking the ratio of the first two, we find

$$MRS = U_1/U_2 = \lambda_3/\lambda_4$$

- The third and sixth equation also imply that

$$MRS = \lambda_3/\lambda_4 = \lambda_2 g_1/\lambda_2 = g_1$$

- Optimality in *y* production requires that the individual's *MRS* in consumption equals the marginal productivity of *x* in the production of *y*

Finding the Efficient Allocation

- To achieve efficiency in *x* production, we must also consider the externality this production poses to *y*
- Combining the last three equations gives

$$MRS = \lambda_3/\lambda_4 = (-\lambda_1 + \lambda_2 g_2)/\lambda_4 = -\lambda_1/\lambda_4 + \lambda_2 g_2/\lambda_4$$

$$MRS = 1/f_y - g_2$$

Finding the Efficient Allocation

- This equation requires the individual's *MRS* to equal dy/dx obtained through x production
  - $1/f_y$ represents the reciprocal of the marginal productivity of y in x production
  - g_2 represents the negative impact that added x production has on y output
    - allows us to consider the externality from x production

Inefficiency of the Competitive Allocation

- Reliance on competitive pricing will result in an inefficient allocation of resources
- A utility-maximizing individual will opt for

$$MRS = P_x/P_y$$

and the profit-maximizing producer of *y* would choose *x* input according to

$$P_x = P_y g_1$$

Inefficiency of the Competitive Allocation

- But the producer of *x* would choose *y* input so that

$$P_y = P_x f_y$$

$$P_x/P_y = 1/f_y$$

- This means that the producer of *x* would disregard the externality that its production poses for *y* and will overproduce *x*

Production Externalities

- Suppose that two newsprint producers are located along a river
- The upstream firm has a production function of the form

$$x = 2{,}000 l_x^{0.5}$$

Production Externalities

- The downstream firm has a similar production function but its output may be affected by chemicals that firm *x* pours in the river

$$y = 2{,}000 l_y^{0.5}(x - x_0)^{\alpha} \quad \text{(for } x > x_0\text{)}$$

$$y = 2{,}000 l_y^{0.5} \quad \text{(for } x \leq x_0\text{)}$$

where x_0 represents the river's natural capacity for pollutants

Production Externalities

- Assuming that newsprint sells for $1 per foot and workers earn $50 per day, firm *x* will maximize profits by setting this wage equal to the labor's marginal product

$$50 = p \cdot \frac{\partial x}{\partial l_x} = 1{,}000 l_x^{-0.5}$$

- $l_x^* = 400$
- If $\alpha = 0$ (no externalities), $l_y^* = 400$

Production Externalities

- When firm *x* does have a negative externality ($\alpha < 0$), its profit-maximizing decision will be unaffected ($l_x^* = 400$ and $x^* = 40{,}000$)
- But the marginal product of labor will be lower in firm *y* because of the externality

Production Externalities

- If α = -0.1 and x_0 = 38,000, firm *y* will maximize profits by

$$50 = p \cdot \frac{\partial y}{\partial l_y} = 1{,}000 l_y^{-0.5}(40{,}000 - 38{,}000)^{-0.1}$$

$$50 = 468 l_y^{-0.5}$$

- Because of the externality, l_y^* = 87 and *y* output will be 8,723

Production Externalities

- Suppose that these two firms merge and the manager must now decide how to allocate the combined workforce
- If one worker is transferred from *x* to *y*, output of *x* becomes

$$x = 2{,}000(399)^{0.5} = 39{,}950$$

and output of *y* becomes

$$y = 2{,}000(88)^{0.5}(1{,}950)^{-0.1} = 8{,}796$$

Production Externalities

- Total output increased with no change in total labor input
- The earlier market-based allocation was inefficient because firm *x* did not take into account the effect of its hiring decisions on firm *y*

Production Externalities

- If firm *x* was to hire one more worker, its own output would rise to

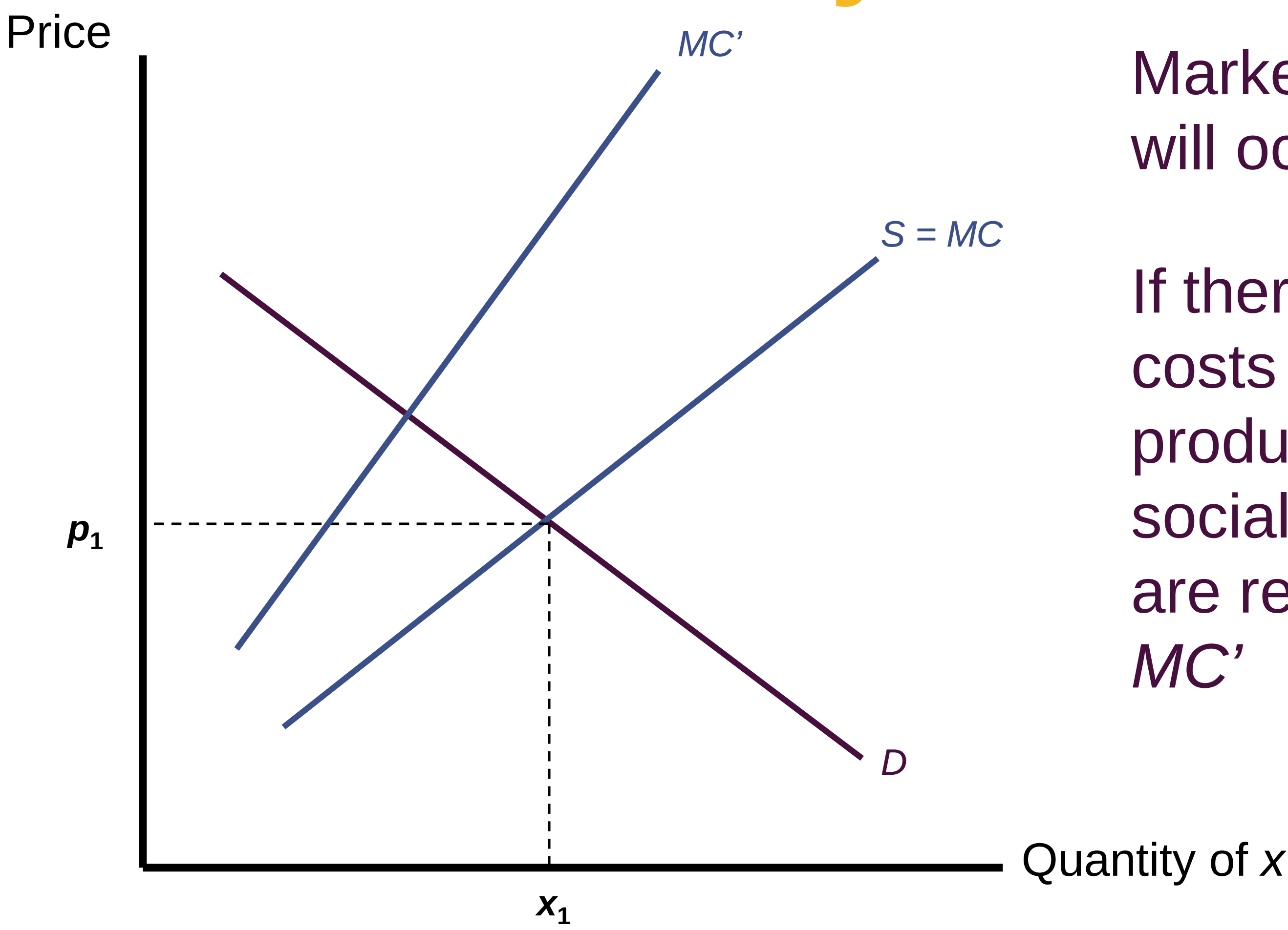
$$x = 2{,}000(401)^{0.5} = 40{,}050$$

  - the private marginal value product of the 401st worker is equal to the wage
- But, increasing the output of *x* causes the output of *y* to fall (by about 21 units)
- The social marginal value product of the additional worker is only $29

Solutions to the Externality Problem

- The output of the externality-producing activity is too high under a market-determined equilibrium
- Incentive-based solutions to the externality problem originated with Pigou, who suggested that the most direct solution would be to tax the externality-creating entity

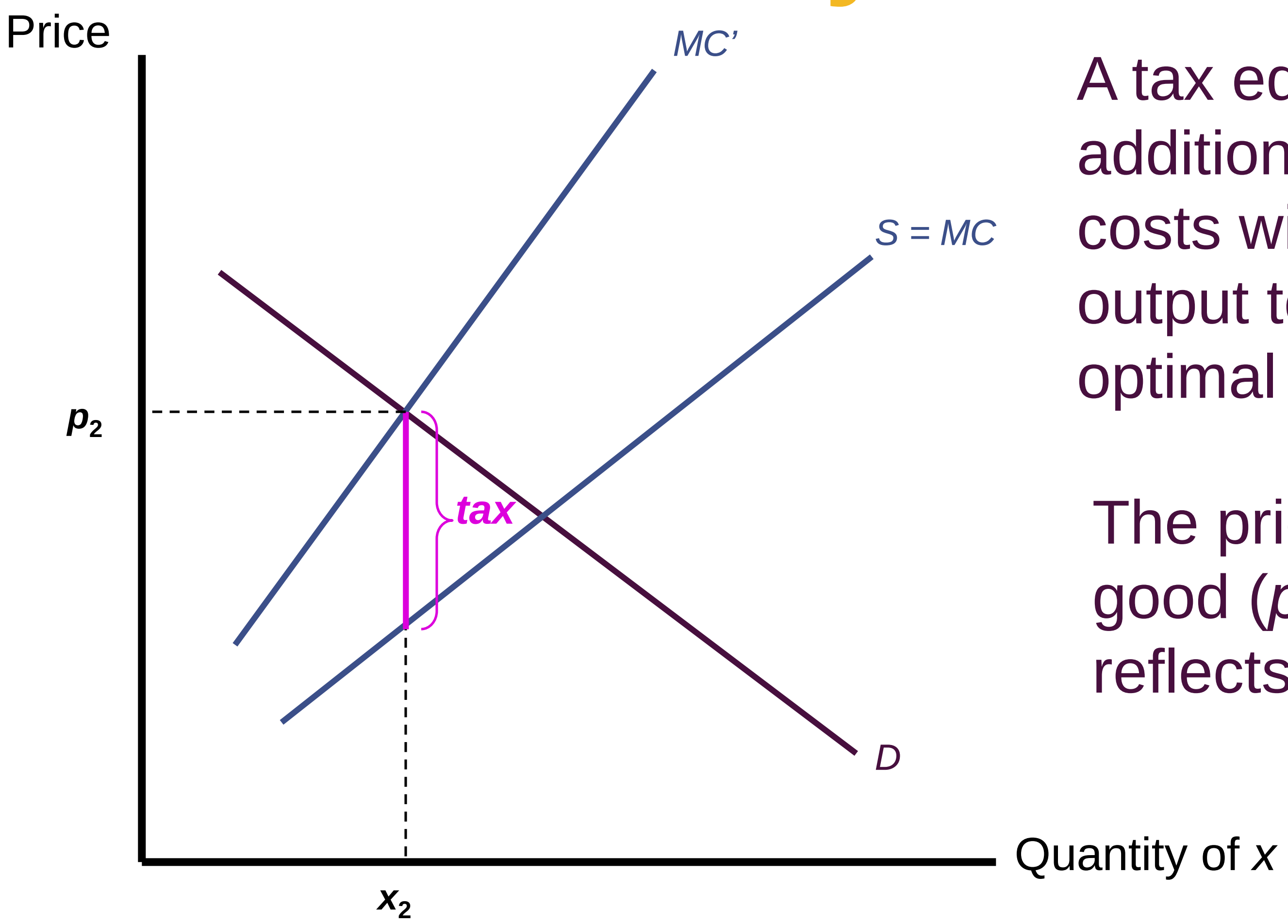
Solutions to the Externality Problem



Market equilibrium will occur at p_1, x_1

If there are external costs in the production of *x*, social marginal costs are represented by *MC'*

Solutions to the Externality Problem



A tax equal to these additional marginal costs will reduce output to the socially optimal level (x_2)

The price paid for the good (p_2) now reflects all costs

A Pigouvian Tax on Newsprint

- A suitably chosen tax on firm x can cause it to reduce its hiring to a level at which the externality vanishes
- Because the river can handle pollutants with an output of $x = 38{,}000$, we might consider a tax that encourages the firm to produce at that level

A Pigouvian Tax on Newsprint

- Output of *x* will be 38,000 if $l_x = 361$
- Thus, we can calculate *t* from the labor demand condition

$$(1 - t)MP_l = (1 - t)1{,}000(361)^{-0.5} = 50$$

$$t = 0.05$$

- Therefore, a 5 percent tax on the price firm *x* receives would eliminate the externality

Taxation in the General Equilibrium Model (skipped)

- The optimal Pigouvian tax in our general equilibrium model is to set $t = -p_y g_2$
  - the per-unit tax on *x* should reflect the marginal harm that *x* does in reducing *y* output, valued at the price of good *y*

Taxation in the General Equilibrium Model

- With the optimal tax, firm x now faces a net price of (p_x - t) and will choose y input according to

$$p_y = (p_x - t)f_y$$

- The resulting allocation of resources will achieve

$$MRS = p_x/p_y = (1/f_y) + t/p_y = (1/f_y) - g_2$$

Taxation in the General Equilibrium Model

- The Pigouvian tax scheme requires that regulators have enough information to set the tax properly
  - in this case, they would need to know firm *y*'s production function

Pollution Rights

- An innovation that would mitigate the informational requirements involved with Pigouvian taxation is the creation of a market for “pollution rights”
- Suppose that firm *x* must purchase from firm *y* the rights to pollute the river they share
  - *x*’s choice to purchase these rights is identical to its output choice

Pollution Rights

- The net revenue that *x* receives per unit is given by p_x - *r*, where *r* is the payment the firm must make to firm *y* for each unit of *x* it produces
- Firm *y* must decide how many rights to sell firm *x* by choosing *x* output to maximize its profits

$$\pi_y = p_y g(x_i, x_o) + r x_o$$

Pollution Rights

- The first-order condition for a maximum is

$$\partial \pi_y / \partial x_o = p_y g_2 + r = 0$$

$$r = -p_y g_2$$

- The equilibrium solution is identical to that for the Pigouvian tax
  - from firm *x*'s point of view, it makes no difference whether it pays the fee to the government or to firm *y*

The Coase Theorem

- The key feature of the pollution rights equilibrium is that the rights are well-defined and tradable with zero transactions costs
- The initial assignment of rights is irrelevant
  – subsequent trading will always achieve the same, efficient equilibrium

The Coase Theorem

- Suppose that firm x is initially given x^T rights to produce (and to pollute)
  - it can choose to use these for its own production or it may sell some to firm y
- Profits for firm x are given by

$$\pi_x = p_x x_o + r(x^T - x_o) = (p_x - r)x_o + rx^T$$

$$\pi_x = (p_x - r)f(y_i) + rx^T$$

The Coase Theorem

- Profits for firm *y* are given by

$$\pi_y = p_y g(x_i, x_o) - r(x^T - x_o)$$

- Profit maximization in this case will lead to precisely the same solution as in the case where firm *y* was assigned the rights

The Coase Theorem

- The independence of initial rights assignment is usually referred to as the Coase Theorem
  - in the absence of impediments to making bargains, all mutually beneficial transactions will be completed
  - if transactions costs are involved or if information is asymmetric, initial rights assignments will matter

Attributes of Public Goods

- A good is exclusive if it is relatively easy to exclude individuals from benefiting from the good once it is produced
- A good is nonexclusive if it is impossible, or very costly, to exclude individuals from benefiting from the good

Attributes of Public Goods

- A good is nonrival if consumption of additional units of the good involves zero social marginal costs of production

Attributes of Public Goods

- Some examples of these types of goods include:

		Exclusive	
		Yes	No
Rival	Yes	Hot dogs, cars, houses	Fishing grounds, clean air
	No	Bridges, swimming pools	National defense, mosquito control

Public Good

- A good is a pure public good if, once produced, no one can be excluded from benefiting from its availability and if the good is nonrival -- the marginal cost of an additional consumer is zero

Public Goods and Resource Allocation

- We will use a simple general equilibrium model with two individuals (*A* and *B*)
- There are only two goods
  - good y is an ordinary private good
    - each person begins with an allocation (y^{A*} and y^{B*})
  - good x is a public good that is produced using y

$$x = f(y_s^A + y_s^B)$$

Public Goods and Resource Allocation

- Resulting utilities for these individuals are

$$U^A[x,(y^{A*} - y_s^A)]$$

$$U^B[x,(y^{B*} - y_s^B)]$$

- The level of *x* enters identically into each person's utility curve
  - it is nonexclusive and nonrival
    - each person's consumption is unrelated to what he contributes to production
    - each consumes the total amount produced

Public Goods and Resource Allocation

- The necessary conditions for efficient resource allocation consist of choosing the levels of y_s^A and y_s^B that maximize one person's (*A*'s) utility for any given level of the other's (*B*'s) utility
- The Lagrangian expression is

$$\mathbf{L} = U^A(x, y^{A*} - y_s^A) + \lambda[U^B(x, y^{B*} - y_s^B) - K]$$

Public Goods and Resource Allocation

- The first-order conditions for a maximum are

$$\partial \mathbf{L}/\partial y_s^A = U_1^A f' - U_2^A + \lambda U_1^B f' = 0$$

$$\partial \mathbf{L}/\partial y_s^B = U_1^A f' - \lambda U_2^B + \lambda U_1^B f' = 0$$

- Comparing the two equations, we find

$$\lambda U_2^B = U_2^A$$

Public Goods and Resource Allocation

- We can now derive the optimality condition for the production of *x*
- From the initial first-order condition we know that

$$U_1^A/U_2^A + \lambda U_1^B/\lambda U_2^B = 1/f'$$

$$MRS^A + MRS^B = 1/f'$$

- The *MRS* must reflect all consumers because all will get the same benefits

Failure of a Competitive Market

- Production of *x* and *y* in competitive markets will fail to achieve this allocation
  - with perfectly competitive prices p_x and p_y, each individual will equate his *MRS* to p_x/p_y
  - the producer will also set $1/f'$ equal to p_x/p_y to maximize profits
  - the price ratio p_x/p_y will be too low
    - it would provide too little incentive to produce *x*

Failure of a Competitive Market

- For public goods, the value of producing one more unit is the sum of each consumer's valuation of that output
  - individual demand curves should be added vertically rather than horizontally
- Thus, the usual market demand curve will not reflect the full marginal valuation

Inefficiency of a Nash Equilibrium (skipped)

- Suppose that individual *A* is thinking about contributing s_A of his initial y endowment to the production of x
- The utility maximization problem for *A* is then

choose s_A to maximize $U^A[f(s_A + s_B), y^A - s_A]$

Inefficiency of a Nash Equilibrium

- The first-order condition for a maximum is

$$U_1^A f' - U_2^A = 0$$

$$U_1^A / U_2^A = MRS^A = 1/f'$$

- Because a similar argument can be applied to *B*, the efficiency condition will fail to be achieved
  - each person considers only his own benefit

The Roommates' Dilemma

- Suppose two roommates with identical preferences derive utility from the number of paintings hung on their walls (x) and the number of granola bars they eat (y) with a utility function of

$$U_i(x,y_i) = x^{1/3}y_i^{2/3} \quad \text{(for } i=1,2\text{)}$$

- Assume each roommate has \$300 to spend and that p_x = \$100 and p_y = \$0.20

The Roommates' Dilemma

- We know from our earlier analysis of Cobb-Douglas utility functions that if each individual lived alone, he would spend 1/3 of his income on paintings ($x = 1$) and 2/3 on granola bars ($y = 1{,}000$)
- When the roommates live together, each must consider what the other will do
  - if each assumed the other would buy paintings, $x = 0$ and utility = 0

The Roommates' Dilemma

- If person 1 believes that person 2 will not buy any paintings, he could choose to purchase one and receive utility of

$$U_1(x,y_1) = 1^{1/3}(1{,}000)^{2/3} = 100$$

while person 2's utility will be

$$U_2(x,y_2) = 1^{1/3}(1{,}500)^{2/3} = 131$$

- Person 2 has gained from his free-riding position

The Roommates' Dilemma

- We can show that this solution is inefficient by calculating each person's *MRS*

$$MRS_i = \frac{\partial U_i / \partial x}{\partial U_i / \partial y_i} = \frac{y_i}{2x}$$

- At the allocations described,

$$MRS_1 = 1{,}000/2 = 500$$

$$MRS_2 = 1{,}500/2 = 750$$

The Roommates' Dilemma

- Since $MRS_1 + MRS_2 = 1{,}250$, the roommates would be willing to sacrifice 1,250 granola bars to have one additional painting
  - an additional painting would only cost them 500 granola bars
  - too few paintings are bought

The Roommates' Dilemma

- To calculate the efficient level of *x*, we must set the sum of each person's *MRS* equal to the price ratio

$$MRS_1 + MRS_2 = \frac{y_1}{2x} + \frac{y_2}{2x} = \frac{y_1 + y_2}{2x} = \frac{p_x}{p_y} = \frac{100}{0.20}$$

- This means that

$$y_1 + y_2 = 1{,}000x$$

The Roommates' Dilemma

- Substituting into the budget constraint, we get

$$0.20(y_1 + y_2) + 100x = 600$$

$$x = 2$$

$$y_1 + y_2 = 2{,}000$$

- The allocation of the cost of the paintings depends on how each roommate plays the strategic financing game

Lindahl Pricing of Public Goods

- Swedish economist E. Lindahl suggested that individuals might be willing to be taxed for public goods if they knew that others were being taxed
  - Lindahl assumed that each individual would be presented by the government with the proportion of a public good's cost he was expected to pay and then reply with the level of public good he would prefer

Lindahl Pricing of Public Goods

- Suppose that individual A would be quoted a specific percentage (α^A) and asked the level of a public good (x) he would want given the knowledge that this fraction of total cost would have to be paid
- The person would choose the level of x which maximizes

$$\text{utility} = U^A[x, y^{A*} - \alpha^A f^{-1}(x)]$$

Lindahl Pricing of Public Goods

- The first-order condition is given by

$$U_1^A - \alpha^A U_2^B (1/f') = 0$$

$$MRS^A = \alpha^A / f'$$

- Faced by the same choice, individual *B* would opt for the level of *x* which satisfies

$$MRS^B = \alpha^B / f'$$

Lindahl Pricing of Public Goods

- An equilibrium would occur when $\alpha^A + \alpha^B = 1$
  - the level of public goods expenditure favored by the two individuals precisely generates enough tax contributions to pay for it

$$MRS^A + MRS^B = (\alpha^A + \alpha^B)/f' = 1/f'$$

Shortcomings of the Lindahl Solution

- The incentive to be a free rider is very strong
  - this makes it difficult to envision how the information necessary to compute equilibrium Lindahl shares might be computed
    - individuals have a clear incentive to understate their true preferences

Important Points to Note:

- Externalities may cause a misallocation of resources because of a divergence between private and social marginal cost
  - traditional solutions to this divergence includes mergers among the affected parties and adoption of suitable Pigouvian taxes or subsidies

Important Points to Note:

- If transactions costs are small, private bargaining among the parties affected by an externality may bring social and private costs into line
  - the proof that resources will be efficiently allocated under such circumstances is sometimes called the Coase theorem

Important Points to Note:

- Public goods provide benefits to individuals on a nonexclusive basis - no one can be prevented from consuming such goods
  - such goods are usually nonrival in that the marginal cost of serving another user is zero

Important Points to Note:

- Private markets will tend to underallocate resources to public goods because no single buyer can appropriate all of the benefits that such goods provide

Important Points to Note:

- A Lindahl optimal tax-sharing scheme can result in an efficient allocation of resources to the production of public goods
  - computation of these tax shares requires substantial information that individuals have incentives to hide