Chapter 7 (Part II)

Public Goods

Contents:

Excludable Public Goods

We have seen that with non-excludable public goods, the free-rider problem may lead to the inefficient provision of public goods by the private market. With **excludable public goods**, private markets may either provide the efficient level or inefficient level of public goods. Two key issues determine whether the private market will provide the efficient level of public goods:

- heterogeneity of consumer demand, and
- the ability of private providers to price discriminate.

However, in every case, the distribution of welfare among producers and consumers under private provision of public goods varies significantly from the distribution of welfare among these groups under public (government) provision of public goods.

The Socially-Optimal Level of an Excludable Public Good

The socially optimal level of provision of an excludable public good is the same as it is for a non-excludable public good, namely, X*.

When public goods are excludable, a private firm can build some kind of barrier to prevent consumers from free riding. Let's call this barrier a "fence." With excludable public goods, the private owner of the resource will build a fence and charge each consumer their willingness to pay (area under the individual demand curve). Different cases arise depending on whether consumers are homogeneous or heterogeneous. We will first consider the case of homogeneous individuals.

Excludable Public Goods with Homogeneous Consumers

A private firm will build a fence and attempt to act as a monopoly by charging each individual their maximum willingness to pay (area under the individual demand curve). The sum of willingness to pay across all individuals is the monopoly Total Revenue function:

$$TR(X) = \int_0^X n\, D(X)\, dx$$

The monopolist maximizes profits:

$$\underset{X}{Max.}\left\{\pi = \int_0^X nD(x)dx - \int_0^X MC(x)dx\right\}$$

When nD(X) = n(a - bX) and MC(X) = c + d X, as in the social problem, the FOC is:

$$nD(X) = MC(X) \qquad \text{or} \qquad n(a - bX) = c + dX$$

Solving for Xm, we get:

$$X_m = (na - c)/(nb + d)$$

and find, comparing X_m with X*, that X_m = X*.

Thus, in the case of homogeneous consumers, we get the surprising result that the monopolist provides the optimal level, X*. Of course, the distribution of welfare between consumers and the monopolist is very different from the case of public provision of the public good. When the monopolist provides the public good, the monopolist gets all of the benefits. This is the case of first-degree price discrimination.

The monopolist would set the entry fee, E_m, equal to the maximum willingness to pay of each individual (i.e., the area under the demand curve) at X*. With identical consumers, he would receive a total revenue of n*E_m. E_m can be found using conventional methods of integration on individual demand,

$$E_m = \int_0^{X_m} D(x)dx = aX - \frac{bX^2}{2}$$

then substituting in for X = X* to get:

$$E_m = \frac{(na - c)(anb + 2ad + bc)}{2(nb + d)^2}$$

Alternatively, for the monopoly owner who deplores integration, we could,

1) First find the shadow price associated with X*, λ = MC (X*) = D(X*):

$$\lambda = D(X^*) = a - b\left(\frac{na - c}{nb + d}\right)$$
$$= \frac{ad + bc}{nb + d},$$

Then, recognizing "a" as the choke price (where individual demand hits the price-axis, (i.e., D(0) = a - 0 = a), we can use the area formula for a triangle, Area = (λ)(base)(height) and add this amount to the rectangle λX* to get:

$$E_m = \lambda X^* + \frac{(a-\lambda)X^*}{2}$$
$$= \frac{(na-c)(anb+2ad+bc)}{2(nb+d)^2}$$

Examples of Private Provision of Excludable Public Goods

A familiar example is a movie theater. If the person showing the movie could not prevent individuals from seeing and hearing the movie, then the person showing the movie would not be able to charge for tickets, and thus have no incentive to provide movie services. Because the owner of a movie theater can control access to the (relatively non-rival) theater by showing the film within a building and controlling access, movie services are provided by the private market.

Another case is the provision of Biological Technology (or Bio-Tech). For example, seed companies have developed hybrid seeds that capture profits associated with high yield technologies by contracting farmers and charging them "entry fees" for access.

Pay-per-view television and cable TV service are other examples of the private provision of an excludable public good, although imperfect, since subscribers to Pay-per-view events are not likely to watch these events alone.

Government Provision of Excludable Public Goods

By developing access barriers to public goods, the government can make public goods excludable and therefore self-financing (also known as "budget-balancing") or even moneymaking enterprises. If entrance can be controlled, public (i.e., government) provision of public goods can be financed through entry fees. For example, entrance fees to national parks can be used to finance the government provision of the public good aspects of the parks, such as preventing soil erosion or stocking fish. Other examples of entrance fees include road tolls and docking fees for ships.

With excludable public goods, the government can build a fence and charge an entry fee to cover costs:

$$E_{gov} = TC(X)/n = \frac{(na-c)(2cnb+and+cd)}{2n(nb+d)^2}$$

Note that each consumer will now receive a welfare surplus from entry which can be calculated using the shadow price of X* in the previous example:

$$CS_{gov} = \frac{(a-c)X^*}{2n} = \frac{(a-c)(na-c)}{2n(nb+d)}$$

Concessionaire Provision of Excludable Public Goods

Alternatively, access barriers established by the government may make it profitable for private firms to provide public goods. For example, television commercials provide an example of a mechanism used to finance the provision of public goods (television broadcasts) made excludable by government action. The government makes television broadcasts excludable by auctioning off the rights to broadcast and by preventing the entry of competing broadcasters into the market.

The government can grant a license to a private firm (the "concessionaire") to build a fence, provide the public good, and charge an entry fee. However, the government regulates the level of the entry fee to ensure a more equitable distribution of welfare between consumers and the private firm than that which occurs in the monopoly outcome. (Note that in order to induce the private firm to provide the public good, the government must allow the concessionaire to make "competitive profits," or else the concessionaire would undertake some other project in the private sector). One measure of the level of competitive profits is the producer surplus the firm would make if the public good were in fact a private good with market demand nD(X) and the private good were produced and sold at level X*.

This outcome would allow the concessionaire to charge the unit price, P = MC(X*) = λ, which is the shadow price of providing the public good.

$$PS(X^*) = \lambda X^* - TC(X^*)$$

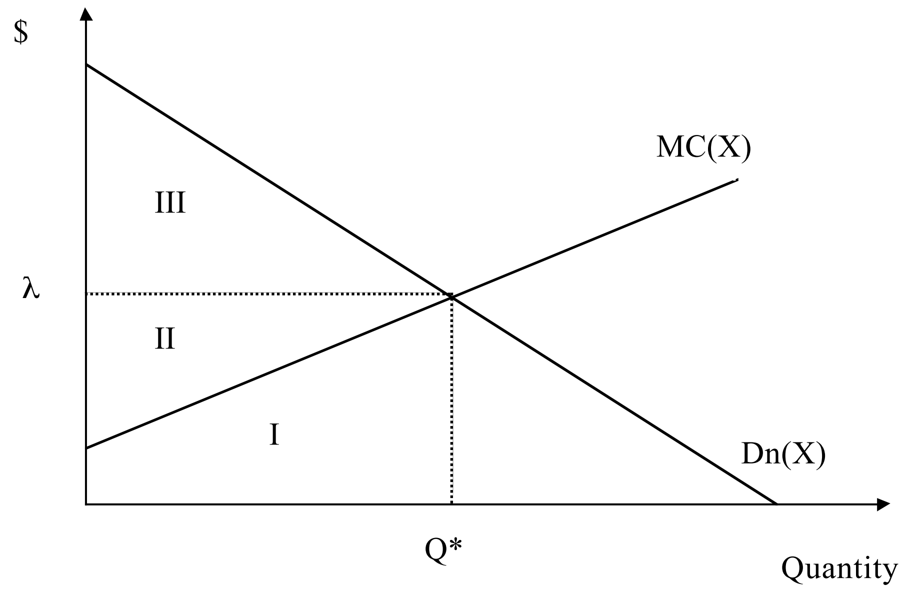
For the private firm to make PS(X*) in profits, the government must allow the firm to charge each consumer an entry fee, E_c, where:

$$E_c = \frac{\lambda X^*}{n} = \frac{(ad+bc)(na-c)}{n\left(nb+d\right)^2}$$

Graphically,

- A Benevolent Government charges the entry fee, $E_{gov} = \dfrac{I}{n}$
- A Concessionaire charges the entry fee, $E_c = \dfrac{I + II}{n}$
- The Monopolist charges the entry fee, $E_m = \dfrac{I + II + III}{n}$

Figure 7.1



Heterogeneous Demand for a Public Good

If firms are heterogeneous, two cases arise:

- private firms can price discriminate among the different types of consumers
- or, private firms cannot.

Suppose you work with the Environmental Protection Agency in the Kansas Air Quality District and there are two people in your district with different (heterogeneous) marginal benefits from improved air quality. You have determined that the marginal willingness to pay for improved air quality is:

$p_1 = 100 - 10Q$ for the first person, and
$p_2 = 40 - 2Q$ for the second person.

Here Q refers to the level of air quality, measured, for example, as reductions in SO_2 concentration from the current level, in grams per cubic-meter, and p is the price in dollars per unit of concentration [$/(gram/m^3)] that each individual is WTP.

Finding the Aggregate Demand for a Public Good with Heterogeneous Consumers

To find the aggregate demand for reductions in SO_2 by this small society, you must add the individual demand curves vertically. Person 1 is willing to pay positive amounts for Q up to 10 units of improved air quality and person 2 is willing to pay for improvements up to 20 units. Therefore the aggregate demand for improved air quality is

(1) $p = p_1 + p_2 = 140 - 12Q$ for $0 \leq Q < 10$
(2) $p = p_2 = 40 - 2Q$ for $10 < Q \leq 20$

Notice that the aggregate demand has a **kink** in it.

Calculating the Socially-Optimal Level of a Public Good with Heterogeneous Consumers

You estimate that the marginal cost of providing improved air quality is given by

$$MC = \$68/(g/m^3),$$

and you want to calculate the efficient level of air quality. To find the efficient level of air quality you need to look for the quantity Q for which the marginal cost of providing improved air quality is just equal to the marginal benefit to this small society, as indicated by the aggregate demand for improved air quality. Since the aggregate demand is kinked, you have to look at both segments of the demand curve separately. One segment will give you an answer that is logically inconsistent, while the other will give you the correct Q*.

Setting (1) equal to the MC curve:

$$MC = 68 = 140 - 12Q^* = p \qquad \text{for } 0 \leq Q \leq 10,$$

which solves for

$$Q^* = (140 - 68)/12 = 6$$

which is consistent with the range $0 \leq Q \leq 10$. This is the correct value.

Setting (2) equal to the MC curve:

$$MC = 68 = 40 - 2Q^* = p \qquad \text{for } 10 < Q \leq 20,$$

which solves for

$$Q^* = (68-40)/-2 = -14,$$

which is clearly outside the range $10 < Q \leq 20$ (and thus doesn't make any sense!). Therefore, $Q^* = 6$ is the efficient level of air quality improvement to provide (you can check this graphically).

Given that the two individuals value clean air differently, it is efficient to charge them different amounts for the cleanup. Each person should be charged an amount such that, for them, the marginal benefits of air quality improvement just equal the marginal costs that is charged to them (such an policy is referred to as a **Lindahl Tax**). Person 1's marginal demand for air quality improvements at the efficient level is

$$p1^* = 100 - 10(6) = \$40 \text{ per unit of cleanup.}$$

Person 2's marginal demand is

$$p2^* = 40 - 2(6) = \$28 \text{ per unit of cleanup.}$$

If you charge them these amounts, the receipts will be

$$(6 \text{ units})(\$40/\text{unit} + \$28/\text{unit}) = 408,$$

which just covers the total cost, which is the area under the MC curve.

$$TC = (6 \text{ units})(\$68/\text{unit}) = \$408.$$

The Case of Increasing Marginal Costs

Now suppose you believe that the marginal cost of obtaining improved air quality increases as the air quality improves, say the marginal cost is

$$MC = 7 + 7Q,$$

and you want to solve for the new efficient level of cleanup.

Guessing that you should use segment (1) of the aggregate demand curve again instead of segment (2), you set:

$$MC = 7 + 7Q^* = 140 - 12Q^* = p$$

which solves for

$Q^* = (140-7)/(7+12) = 7$ units (which is consistent with the assumed region).

Person 1 should be charged

$$p1^* = 100 - 10(7) = \$30/\text{unit},$$

while person 2 should be charged

$$p2^* = 40 - 2(7) = \$26/\text{unit}.$$

Receipts will be: (7 units)($30/unit +$26/unit) = $392.

Now, because marginal costs are increasing, the total cost of cleaning up this amount (the area under the MC curve between 0 and 7) will be less than this. The total cost is:

$$(1/2)(\$56/\text{unit}-\$7/\text{unit})(7 \text{ units}) + (\$7/\text{unit})(7 \text{ units}) =$$
$$\$171.50 + \$49 = \$220.50.$$

Heterogeneity and Exclusion from the Market

Suppose there are three individuals:

- Two rich with $D_i(X) = 20 - X$, $i = 1, 2$.
- One poor with $D_3(X) = 10 - X$.

$$\text{Total Demand} = \begin{cases} 50 - 3X & \text{for } X \leq 10 \\ 40 - 2X & \text{for } X > 10 \end{cases}$$

If Marginal Cost = 5X, then, at the social optimum, 50 - 3x = 5X, which implies, X*= 6.25 (Note: this value is in the correct range, $0 \leq X^* \leq 10$), and a shadow price = $P_3^* = 50 - 3(6.25) = 31.25$.

Thus, we have the following policy conclusions:

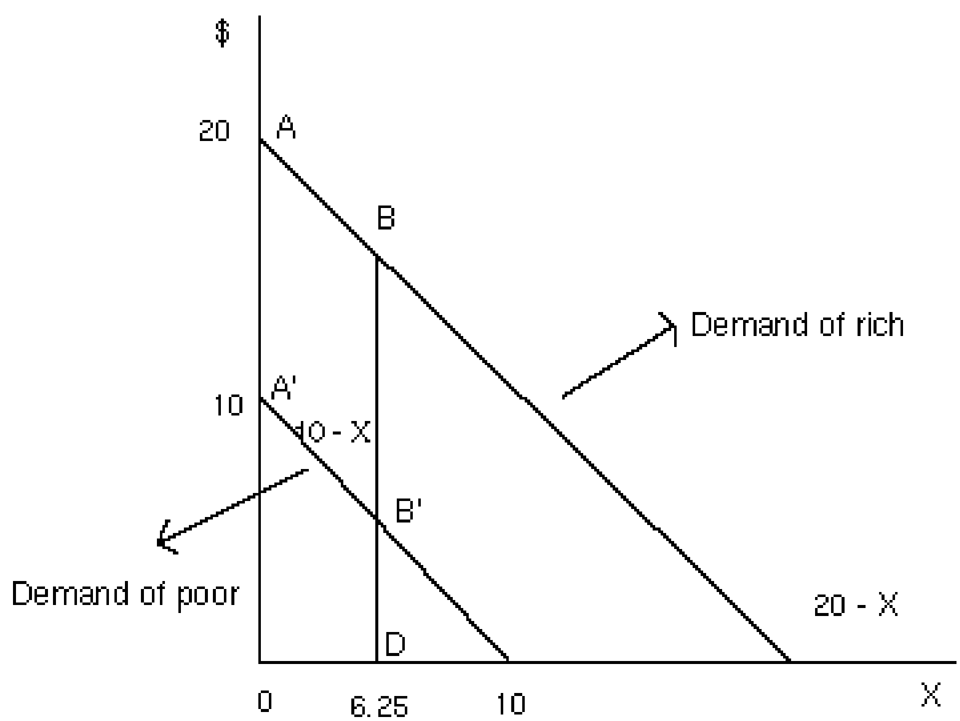
- If there is open access, government should provide X* = 6.25 and collect revenues by assessing taxes, or, Lindahl taxes, where possible.
- If access can be closed, government may regulate against monopoly pricing.
- The Entry Fees:

<u>Benevolent Government</u>: $E_{gov} = \dfrac{TC(X^*)}{3} = \dfrac{5(X^*)^2}{2(3)} = \dfrac{97.65}{3} = \$32.55$

<u>Concessionaire</u>: $E_c = X^* (P_3^0/3) = (6.25)(31.25)/3 = \$65.10$

<u>Figure 7.2</u>

Public Goods with Exclusion



An individual will pay an entry fee only if the benefits from consuming X are greater than the fee.

Benefits of a rich person = area of 0ABD
[20 - 6.25] * 6.25+0.5*6.25*6.25 = $105.47 > 65.10.

Benefit of poor people = area of 0A'B'D
[10 - 6.25] * 6.25+0.5*6.25*6.25 = $42.97 < 65.104.

Poor people may not pay the entry fee since their total benefit (consumer surplus) may be less than the fee. In this case, the poor person will not pay to enjoy the excludable public good, as the highest entry fee the poor person will pay is approximately $43.

However, an entry cost of $32.55 will cover the government's variable costs and will still be affordable to the poor. Yet we can see that the outcomes may differ depending on whether the government or a concessionaire provides the public good.

Say fixed cost = 53, so that the total cost = 97 + 53 = 150. In this case, even a fee affordable to the poor will not cover total cost.

What Can We Learn From This Example? Two Important Messages:

1) Policy cannot be formulated based on aggregate data alone. Say the Government provides the excludable public good in this example. The Government might solve the problem based on aggregate demand for the public good, as we did above. But, if the regulator does not check to verify that the consumer surplus of low-demand individuals is not sufficient to cover entry, *expected revenue may fall short of the cost of provision*.

2) It may be politically difficult to exclude people if there is no marginal cost of allowing an additional person inside (costs only occur from the aggregate level of the good that is provided). The government would like to be able to allow the poor people to enter and gain enjoyment from the public good, and since the marginal cost of letting another person in is zero (without congestion costs), it seems economical to let the poor person pay any positive amount they can afford. Such a policy is referred to as *cross-subsidization*. Yet, if the regulator cannot discriminate between rich people and poor people, then letting poor individuals access the public good for what they can afford, say for $42, invites all individuals to say they are poor when purchasing entry.

Public Goods, Environmental Amenities and Nonuse Benefits:

Environmental amenities provide both use and nonuse benefits. Nonuse benefits reflect benefits that are derived from the simple existence, rather than use, of certain environmental goods (such as a species or ecosystem).

Nonuse benefits are examples of a pure public good. They are non-rival and non-excludable. There are likely to be market failures in their provision.

For example, we all benefit from maintaining a healthy rainforest, since the rainforest ecosystem is critical to maintaining a healthy atmosphere, and also because much of the new medicine that is developed is derived from tropical plant species. Yet, these are nonuse values, because they do not depend on us ever visiting the rainforest.

As we have seen, use benefits can sometimes be provided by the private sector in cases where entry can be controlled. Even then, however, regulation is needed to prevent monopolistic outcomes or else cross-subsidization may be required to make environmental amenities accessible to low income individuals.

Access to many environmental amenities can be restricted by travel cost. Even when physical entry is free, transaction cost prevents many from enjoying faraway environmental amenities.

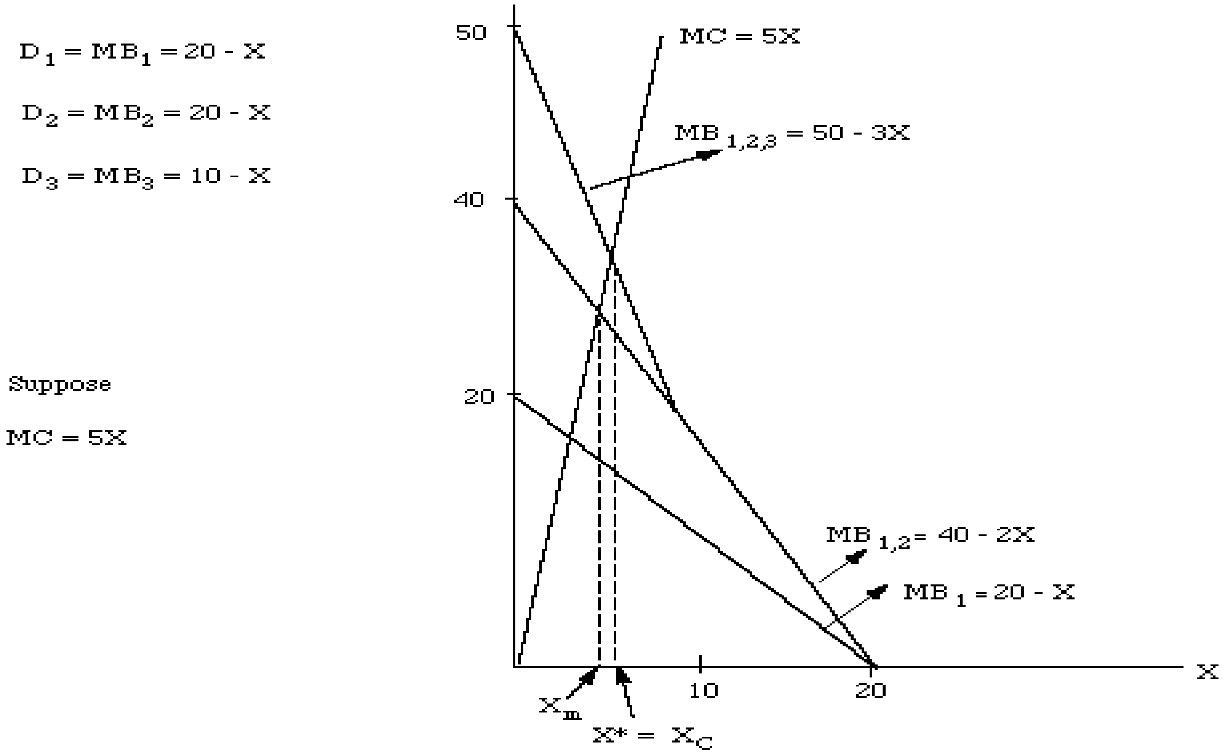
Some Important Research Questions

- To what extent should the government provide or protect such amenities that provide use benefits enjoyed by the few (and many times the rich) because of high transaction costs involved in using them?

- Is diversion of public money to provide such amenities regressive from an income distribution perspective?

- How should society provide and finance environmental amenities in ways that are efficient and equitable?

<u>Heterogeneous Demand for a Public Good</u>



Aggregate demand is kinked:
(1) MB = 50 - 3X, $0 \leq X \leq 10$
(2) MB = 40 - 2X, $10 < X \leq 20$

Government's Problem:

The government chooses an X* such that MB = MC.

Since demand is kinked, we must look at both segments of the demand curve separately. One segment will provide an INCONSISTENT answer, while the other will provide the correct X*.

(1)	MB = 50 -3X $0 \leq X \leq 10$	(2)	MB = 40 - 2X $10 < X \leq 20$
	MB = MC =>		MB = MC =>
	50 - 3X = 5X		40 - 2X = 5X
	8X = 50		7X = 40
	X* = 6.25		X* = 5.71
	$0 \leq 6.25 \leq 10$		5.71 is not between 10 and 20
	$\boxed{X^* = 6.25}$ is correct		INCONSISTENT

The government will charge an entry fee that just covers costs, E_G, i.e.,

$$E_G = \frac{TC(X^*)}{3}$$

Recall: $MC = 5X$

$$TC = \int 5X = \tfrac{5}{2} X^2$$

$$E_G = \frac{5(X^*)^2}{3(2)} = \frac{5(6.25)^2}{2(3)} = \$32.55: \quad \boxed{E_G = 32.55}.$$

Now let's see if the two consumers are willing to pay this amount:

Rich person's MB = 20 - X and TB = $\int MB \Rightarrow$

$$TB = \int_0^{6.25} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{6.25} = 105.47 > E_G.$$

The rich person will enter.

Poor person's MB = 10 - X and TB = $\int MB \Rightarrow$

$$TB = \int_0^{6.25} 10 - X = 10X - \tfrac{1}{2}X^2 \Big|_0^{6.25} = 42.97 > E_G.$$

The poor person will also enter.

Concessionaire's Problem:

She also provides X*: i.e., $X_C = X^*$

$$\Rightarrow \boxed{X_C = 6.25}$$

$X_C = 6.25$ => a shadow price λ* = 50 - 3 (6.25) = 31.25.

Concessionaire's entry fee, E_C

$$E_C = \frac{X^* \lambda^*}{3} = \frac{31.25(6.25)}{3} = \$65.10: \quad \boxed{E_C = 65.10}.$$

Recall the rich person's benefit from X = 6.25.

$105.45 > E_C$: rich person will enter.

Recall the poor person's benefit from X = 6.25.

$42.97 < E_C$: poor person will not enter.

∴ Concessionaire's provision is inefficient because it is never economically efficient to exclude an individual from consuming a public good.

Monopolist's Problem

The monopolist knows that the poor consumer cannot afford to enter so he provides the level X_m of the public good where the marginal benefit of the rich consumers equal the MC: $MB_{1,2} = MC$.

$$MB_{1,2} = 40 - 2X = MC = 5X \Rightarrow 40 - 2X = 5X$$

$$7X = 40$$

$$\boxed{X_m = 5.71}.$$

Note: $X_m < X_c = X^*$, the monopolist under-provides the public good.

The monopolist will charge each of the rich consumers their total benefit from consuming X_m:

$$E_m = \int MB = \int_0^{5.71} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{5.71} = \$97.90 \; \boxed{E_m = 97.90}.$$

Rich person's benefit

$$TB = \int_0^{5.71} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{5.71} = 97.90$$

The rich person will enter.

Poor person's benefit:

$$TB = \int_0^{5.71} 10 - X = 10X - \tfrac{1}{2}X^2 \Big|_0^{5.71} = 40.80 < E_m$$

The poor person will not enter.

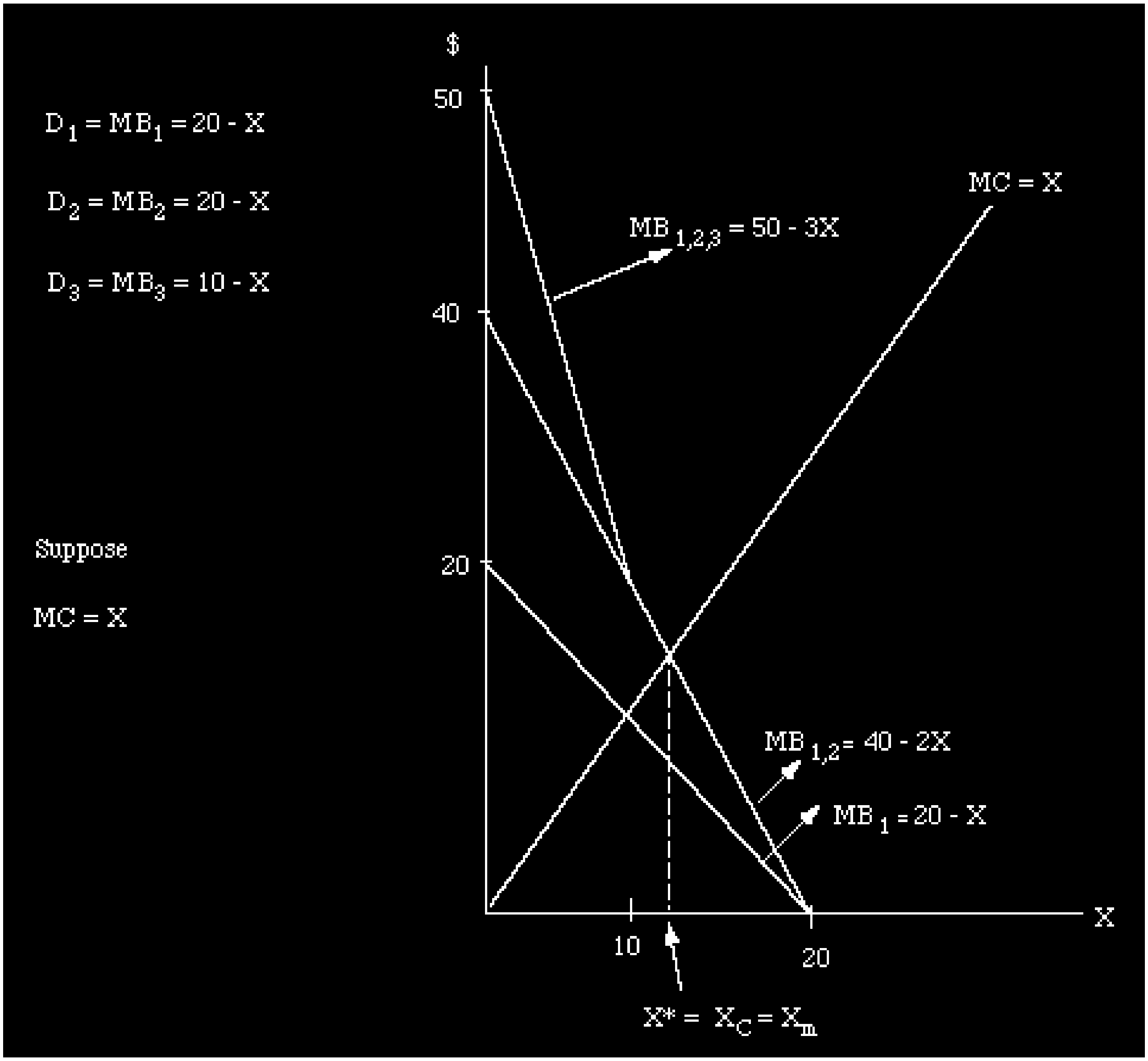
$\therefore$ Monopoly provision is inefficient for two reasons:

(1) Exclusion from public good is never efficient.
(2) Monopoly under-provides the public good,

$$X_m < X^*.$$

This happens because the monopolist knows that its output affects price and, therefore, restricts its provision. Note that if the monopolist could price discriminate he could increase his profits compared to what we obtained above, and both poor and rich persons would be able to enter. We would have the socially efficient level of provision of the public good.

Lower Marginal Cost of Provision



Aggregate demand is kinked:
(1) MB = 50 - 3X $\quad 0 \leq X \leq 10$
(2) MB = 40 - 2X $\quad 10 < X \leq 20$

Government's Problem:

The government chooses an X* such that MB = MC.

Again, we must examine both segments of the demand curve.

(1) MB = 50 -3X $\quad 0 \leq X \leq 10$
MB = MC =>
50 - 3X = X
4X = 50

(2) MB = 40 - 2X $\quad 10 < X \leq 20$
MB = MC =>
40 - 2X = X
3X = 40

$X^* = 12.25$
INCONSISTENT
12.5 is not between 0 and 10

$X^* = 13.33$
$10 \le 13.33 \le 20$
$\boxed{X^* = 13.33}$ is correct

The government will charge an entry fee that just covers costs, E_G, i.e.,

$$E_G = \frac{TC(X^*)}{3}$$

Recall: $MC = X$

$$TC = \int X = \tfrac{1}{2} X^2$$

$$E_G = \frac{(X^*)^2}{2(3)} = \frac{(13.33)^2}{6} = \$29.61: \quad \boxed{E_G = 29.61}.$$

Now let's see if the two consumers are willing to pay this amount:

Rich person's MB = 20 - X and TB = $\int MB \Rightarrow$

$$TB = \int_0^{13.33} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{13.33} = 177.75 > E_G.$$

The rich person will enter.

Poor person's MB = 10 - X and TB = $\int MB \Rightarrow$

$$TB = \int_0^{13.33} 10 - X = 10X - \tfrac{1}{2}X^2 \Big|_0^{13.33} = 44.55 > E_G.$$

The poor person will also enter.

Concessionaire's Problem:

She also provides X*: i.e., $X_C = X^*$

$$\Rightarrow \boxed{X_C = 13.33}$$

$X_C = 13.33$ => a shadow price X* = 40 - 2 (13.33) = 13.34.

Concessionaire's entry fee, E_C

$$E_C = \frac{X^* \lambda^*}{3} = \frac{(13.33)(13.34)}{3} = \$59.27: \quad \boxed{E_C = 59.27}.$$

Recall the rich person's benefit from X = 13.33.
$177.75 > E_C$: rich person will enter.

Recall the poor person's benefit from X = 13.33.

$44.55 < E_C$: poor person will not enter.

∴ Concessionaire's provision is inefficient because the poor person is excluded from consumption.

Monopolist's Problem

Again, the monopolist knows that the poor consumer cannot afford to enter. He provides the level X_m of the public good where the marginal benefit of the rich consumers equals the MC: $MB_{1,2} = MC$.

$$MB_{1,2} = 40 - 2X = MC = X \quad => \quad 40 - 2X = X$$

$$3X = 40$$

$$\boxed{X_m = 13.33}.$$

Note: In this case, the monopoly provides the socially optimal amount of the public good.

The monopolist will charge each of the rich consumers their total benefit from consuming X_m:

$$E_m = \int MB = \int_0^{13.33} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{13.33} = \$177.75 \ \boxed{E_m = 177.75}.$$

Rich person's benefit

$$TB = \int_0^{13.33} 20 - X = 20X - \tfrac{1}{2}X^2 \Big|_0^{13.33} = 177.75$$

The rich person will enter.

Poor person's benefit:

$$TB = \int_0^{13.33} 10 - X = 10X - \tfrac{1}{2}X^2 \Big|_0^{13.33} = 44.46 < E_m$$

The poor person will not enter.

∴ Monopoly provision is inefficient because the poor person is excluded from consumption.

Note: In the case of "low MC," all three providers provide the optimal amount of the public good,

$$X^* = X_c = X_m.$$

Of course, the concessionaire and monopolist are still inefficient because they exclude the poor consumer.