Chapter #7: Public Goods

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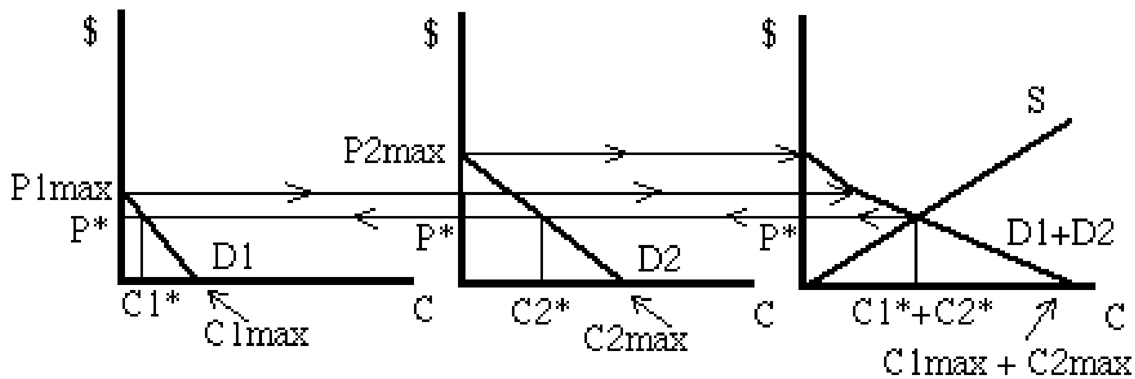
General Overview

Public Goods are goods or services that can be consumed by several individuals simultaneously without diminishing the value of consumption to any one of the individuals. This key characteristic of public goods, that multiple individuals can consume the same good without diminishing its value, is termed **non-rivalry**. Non-rivalry is what most strongly distinguishes public goods from private goods. A Pure Public Good also has the characteristic of **non-excludability**, that is, an individual cannot be prevented from consuming the good whether or not the individual pays for it. For example, *Fresh air, a Public Park, a Beautiful View, National Defense*.

Graphically, non-rivalry means that if each of several individuals has a demand curve for a public good, then the individual demand curves are summed **vertically** to get the **aggregate demand curve** for the public good (see Figure 7.2). This is in contrast to the procedure for deriving the aggregate demand for a private good, where individual demands are summed **horizontally** (see Figure 7.1).

Figure 7.1: Deriving Aggregate Demand for Private Good
(Coffee, chicken sandwich, etc.)

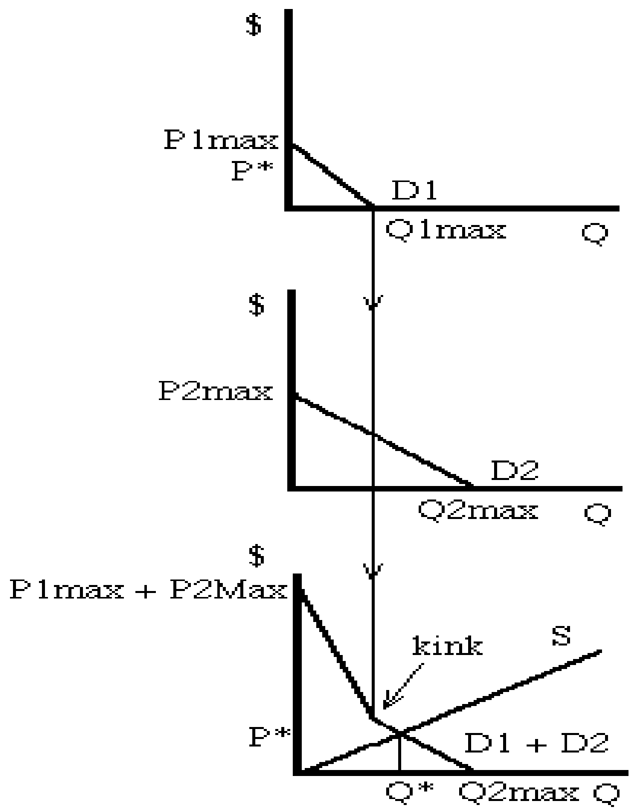


Why Private Goods Are Summed Horizontally:

• Exclusive: once you buy it, you own it and can consume it as you please.
• Rival: A good taken off the shelf it isn't there for other people to consume.

We sum private goods horizontally, because consumers cannot consume the same units. Rivalry in consumption is what makes the market pricing system so incredibly effective; why the invisible hand hypothesis can work. A price is a per unit charge for a good, so that, when goods are consumed away due to rivalry between consumers, supply shortages will tend to correct the market by driving up prices as consumers compete for the few remaining goods. Similarly, a supply surplus will cause firms to lower the price of the good until an equilibrium is met that will clear the market**. Public goods, however, cannot be so easily and efficiently priced.**

Figure 7.2: Deriving Aggregate Demand for Public Good (Recreational Demand for Water Quality at Mono Lake)



Aggregate demand in the economy for a public good is the vertical sum of individual demand curves. Demand is summed vertically, because the same unit of water quality at Mono Lake can be enjoyed by all individuals. Therefore, for each marginal unit of water quality:

aggregate demand = the sum of individual value for the unit

Almost no good or service is completely non-rival. On the other hand, many goods are not completely rival either. Hence, non-rivalry as a characteristic of a public good is a relative, not an absolute concept. However, for the purpose of discussion, we often use the notion of a **pure public good**. A pure public good is a good or service that is *both* non-rival and non-excludable. **Knowledge** and **National Defense** are perhaps the best known examples of relatively pure public goods.

A number of environmental amenities have public good characteristics. For example, we will discuss the socially-optimal level of provision of **regional air quality**, a relatively pure public good. We will also discuss **non-use values**, which are types of environmental benefits that are also public goods.

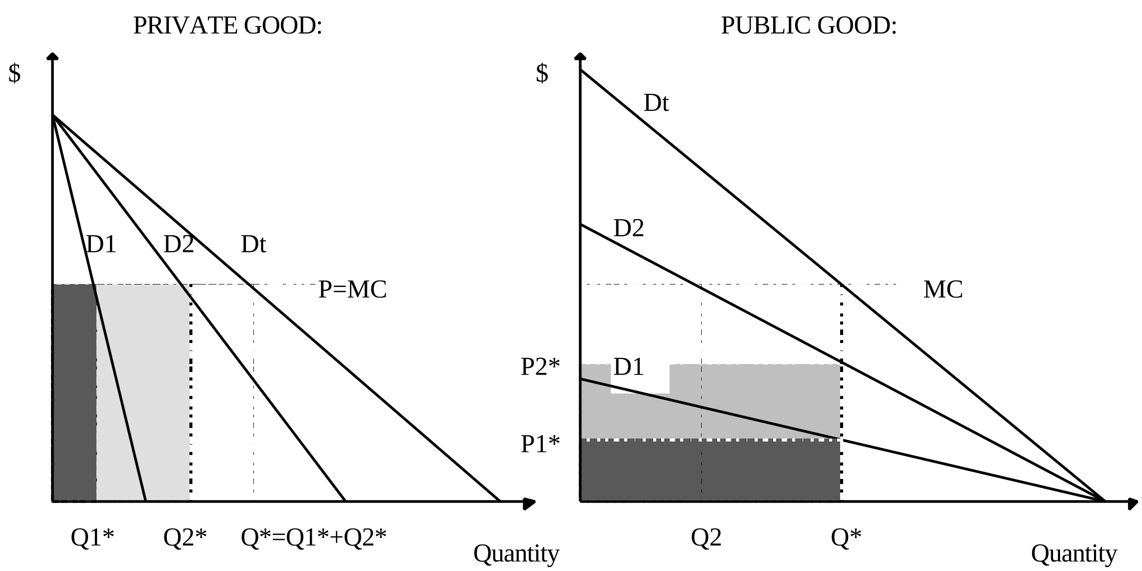
Many environmental issues can be thought of in terms of public goods. For example, the reason the Coase Theorem may not work can be thought of in terms of public goods; if air and water resources were private goods, they could be traded efficiently in a market. We will now show why inefficiencies can arise in the provision of public goods.

Heterogeneity, Non-Rivalry and Market Failure

Consider Two Goods with Identical Aggregate Demand:

- The first good is a private good, (i.e., Chicken Sandwiches)
- The second good is a public good, (i.e., Water Quality at Mono Lake)

Figure 7.3



Private Good: Notice that the market price is an efficient mechanism.

- The equilibrium price of a chicken sandwich is P=MC, so that each chicken sandwich costs \$P. Consumers *compete* for the consumption of sandwiches, and, at a price of \$P, will self-select socially optimal quantities. Consumer 1 eats Q1* sandwiches, consumer 2 eats Q2* sandwiches and Q1* + Q2* = Q*, the aggregate efficient level. The total revenue paid by each individual is shown by the shaded regions.

Public Good: Notice that the market price is no longer an efficient mechanism, because the stock of a public good is never “consumed away”.

- The equilibrium price of water quality cannot be P=MC, because then consumer 1 would not pay for any water quality improvements, consumer 2 would pay for only Q2, and, since Q2 < Q*, the efficient level of water quality would not be met. To see what we would like to do, note the analogy to the case of the private good, recognizing that public goods are the mirror image. Thus, the social optimal solution would be to provide Q* and then charge each consumer a unit price equal to the individuals’ marginal value at Q*, or, P1* and P2*. As in the case of private goods, the high demand individual will pay a larger area in total revenue (shown as the shaded regions). Yet, such a solution may not be possible.

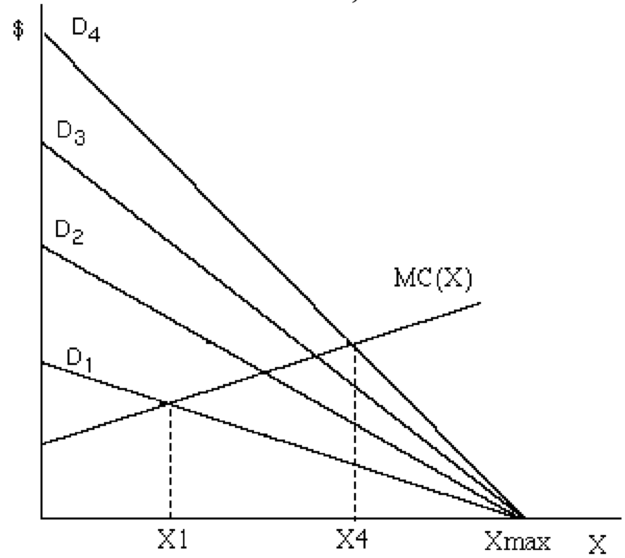
The reason inefficiency arises in providing public goods is that, unlike price, quantity is not an effective market mechanism:

- For a given quantity, individuals will not automatically self-select their optimal price, but will instead wish to pay the lowest price possible when they cannot be excluded from consuming the good.

Non-Excludability and Market Failure

Public goods are a special concern to economists because there can be "market failure" in the private market provision of both pure and impure public goods. The primary cause of market failure involving public goods is **non-excludability**. Non-excludability means that the producer of a public good cannot prevent individuals from consuming it. Non-excludability is a relative, not an absolute, characteristic of most public goods. A good is usually termed non-excludable if the costs of excluding individuals from consuming the good are very high. Private markets often under-provide non-excludable public goods because individuals have the incentive to **free ride**, or to not pay for the benefits they receive from consuming the public good. With a free-rider problem, private firms cannot earn sufficient revenues from selling the public good to induce them to produce the socially optimal level of the public good.

Figure 7.4: Optimal Provision of a Non-excludable Public Good, The Free-Rider Problem, and Market Failure



D1 = Demand of one individual for public good X.
D2 = Total Demand of two individuals for public good X.
D3 = Total Demand of three individuals for public good X.
D4 = Total Demand of four individuals for public good X.
MC = Marginal cost of providing the public good X.

The socially-optimal level of public good X with four consumers is X4. (Note that the optimal level of the public good with a very large number of individuals ("n" individuals) is Xmax.) Because of non-excludability, markets may fail to provide X4. Under private markets, each individual may wait for the others to purchase the public good so that he/she can "free-ride." In this case, no public good may be provided by the private market, because no one is willing to purchase it. For example, if individual 1 decides to purchase (and the others free-ride), the private market will provide a level of the public good equal to X1, where the marginal benefit of the purchasing individual equals the marginal cost of providing the public good. Notice that this is much less than the optimal level of provision of the public good, X4.

The Socially-Optimal Level of Provision of a Public Good with n Homogeneous Individuals

X = level of provision of a public good
n = number of homogeneous individuals in a society

(Inverse) demand of one individual: Di(X) = a - bX.

(Inverse) demand of n homogeneous individuals ("aggregate demand"):

Dn(X) = n(a - bX) = na - nbX. ==> TBn(X) = $\int$ Dn(x) dx

(Inverse) Supply:

MC(X) = c + d X ==> TC(X) = $\int$ MC(x) dx

The socially-optimal level of provision of X occurs where TBn(X) - TC(X) is maximized, which is given by the solution to the problem:

$$\underset{X}{Max.}\left\{ W(X) = \int_0^X Dn(x)dx - \int_0^X TC(x)dx \right\}$$

The FOC for this problem is:

Dn(X) = MC(X), or na - nbX = c + dX

Solving the FOC for X:

$$X^* = \frac{na - c}{nb + d}$$

Note that as n becomes very large, X* approaches the value a/b, which is the X intercept of aggregate demand (draw a little supply/demand graph and see how the intersection of supply and demand causes the optimal level of X to approach the value of a/b as the n becomes very large). For public goods, the X intercept of aggregate demand is the level of provision of the public good at which the marginal benefit to any individual of providing an additional unit of the public good is zero.

Numerical Example:

- Suppose a = 10, b = 1, c = 0, and d = 5.

- This gives us: $D1(X) = 10 - X$ and $MC(X) = 5X$.

Examine what happens to X* as n increases:

$n = 1 \Longrightarrow D1(X) = 10 - 1X$. $D1(X) = MC(X) \Longrightarrow$ $\underline{X1^* = 1.66}$

$n = 5 \Longrightarrow D5(X) = 50 - 5X$. $D5(X) = MC(X) \Longrightarrow$ $\underline{X5^* = 5}$

$n = 10 \Longrightarrow D10(X) = 100 - 10X$. $D10(X) = MC(X) \Longrightarrow$ $\underline{X10^* = 6.66}$

$n = 100 \Longrightarrow D100(X) = 1{,}000 - 100X$. $D100(X) = MC(X) \Longrightarrow$ $\underline{X100^* = 9.5}$

Private Market Outcome for a Non-excludable Public Good

Private providers will provide public goods up to the point where the marginal benefit of one individual (the other individuals free ride) equals the marginal cost of providing the public good. Private providers charge one total price for all of the units of the public good consumed. Basically, the private provider is deciding how large to build a single public good, or what quality of a single public good to provide. The private provider charges a price equal to the willingness to pay (the area under the demand curve) of a single purchasing individual. The private provider solves the following problem:

$$\max \ f(X) = TB1(X) - TC(X)$$

The FOC for this problem is:

$$D1(X) = MC(X), \quad \text{or} \quad a - bX = c + dX$$

Solving for the level of the public good provided by the private market:

$$X^{Comp.} = \frac{a - c}{b + d}$$

Comparing X^{comp} with X^*, we find that $X^{comp} < X^*$. Hence, *the private market under-provides the public good.*

Mechanisms for Providing the Socially-Optimal Level of Public Goods

In those cases where the private market fails to provide the efficient level of public goods, provision of public goods requires **collective action**. People need to realize that a public goods situation exists and either raise contributions from private individuals to fund the public good or let the government provide the public good. Mechanisms to provide public goods include:

(1) Civic responsibility, individual volunteerism, private fund raising and donation (Examples: donations to the "Arts" for symphony halls, volunteer fire departments, nature reserves financed by groups such as the Nature Conservatory)

(2) Private provision of excludable public goods (Examples: movies, music concerts)

(3) Public provision of excludable public goods through the use of entrance fees (Example: entrance fees for a National Park)

(4) Public provision of non-excludable public goods through the use of general government tax revenues (Example: taxes earmarked for National Defense)

(5) Religious beliefs (Examples: church services are a public good; during the ceremony a basket is passed around for collections. Religion can prevent free-riding by convincing people that "God is watching".

The Relationship Between Wealth and Public Good Provision

One of the beneficial aspects of an unequal income distribution is that some rich people have the ability to finance public goods through donation, volunteering and charity. Of course, this is not necessarily what happens. In order for voluntary donation to occur, members of society, especially rich individuals, need to have community spirit and a sense of moral obligation (which they may lack). However, there are many historical examples where the rich have financed the provision of public goods:

- Music and the Arts were financed by kings and knights.
- The rich educated themselves—collected books and preserved knowledge.
- The rich can buy expensive early versions of new products, hence generating incentives for R&D oriented towards innovation due to larger monetary incentives.

- The Church introduced mechanisms for public goods provision.
  - -Monks, nuns, priests serve as a "public good."
  - -Religious beliefs provided incentives to public good provisions.
  - -Education.

Government Provision of Non-Excludable Public Goods Through Taxes

The government can correct market failure and provide the socially-optimal level of a public good by financing the provision of public goods with tax revenue. Public financing of public goods may be the only option in cases where the public good is non-excludable and, therefore, entry fees cannot be charged (we cover the entry fee case later). In fact, one could argue that the only role for government in a society is to provide non-excludable public goods such as National Defense, Public Education, and other Social Welfare Programs.

Let us now look at the Government's problem in this context. We will simplify the situation by assuming that there is only one public good. If the government seeks to provide the public good in a budget-balancing, or revenue-neutral manner, then the government needs to collect total tax revenue equal to the total cost of providing the public good. If there are n individuals in the society, then:

$$\text{Total Tax} = TC(X^*) = \int_0^{X^*} MC(X)\, dx$$

so that the tax per individual = TC(X*)/n.

<u>The Specification of Congestion Costs in Public Goods Models</u>

Of course, most public goods are not pure public goods. For example, although roads are used simultaneously by many people, and are public goods, an increasing number of users can reduce the benefits to each individual due to **congestion costs**. Congestion costs, or *negative congestion externalities*, are a type of externality that can occur with public goods. Congestion costs can be a problem for several environmental amenities and natural resources. For example, the benefits to each viewer of a scenic vista may be reduced if the overlook site becomes crowded (i.e., if the site becomes congested). Similarly, if too many fishing boats crowd together over a school of fish, then the costs to each fisher of catching the fish may increase due to accidental collisions, inefficiently short trawling runs, nets damaged by other boat's propellers, etc.

Congestion can also create benefits in some cases. *Positive congestion externalities* occur often in the provision of information networks. For example, consider the "information highway". When the first individual subscribes to email, the value of the service is equal to zero, since there is no one out there to send messages to. As subscription to the service increases, however, the value of email increases due to the positive congestion externality.

In an economic model, the existence of a negative congestion externality means that the benefit each individual gains from consuming a public good decreases with the number of individuals consuming the public good. For example, if X is the level of provision of a public good, N is the number of people consuming the public good, and Bi(X,N) is the benefit to an individual associated with consuming a public good at a level of X when N individuals are using the public good, then the existence of congestion costs implies that:

$$dBi/dN < 0$$

that is, the benefit to an individual of consuming the public good decreases as the number of individuals consuming the public good increases. Note the contrast to a pure public good, where dBi/dN=0 due to non-rivalry.

Hence, when building an economic model involving congestable public goods, the functional form we choose to represent the benefits to an individual of consuming a public good should have the property that the benefits to an individual decrease as the number of individuals consuming the public good increases. For example, consider the following functional form for the benefits to an individual of consuming a congestable public good:

$$Bi(X,N) = \frac{a + bX - cX^2}{N},$$

where the parameters a,b,c > 0.

When we maximize Benefits with respect to N, we find that:

$$\frac{dBi}{dN} = \frac{-(a + bX - cX^2)}{N^2},$$

Since the expression is negative, this implies a negative congestion externality.

But what about the fishing example, where we noted that congestion led to increased costs rather than to decreased benefits? If we simply redefine the benefits from fishing as the *net* benefits, or profits, from fishing, then we can note that the profits from fishing decrease as the costs of fishing increase, and $dBi/dN < 0$ would still be a necessary condition for the presence of congestion costs.

Excludable Public Goods

We have seen that with non-excludable public goods, the free-rider problem may lead to the inefficient under-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 his/her 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:

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

The monopolist maximizes profits:

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

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

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

Solving for Xm, we get:

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

and find, comparing Xm with X*, that Xm = 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, Em, equal to the maximum willingness to pay of each individual (i.e., the area under the demand curve) at X*. X* can be found using conventional methods of integration on individual demand,

$$Em = \int_0^{Xm} Di(x)dx = aX - \frac{bX^2}{2}$$

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*) = Di(X*):

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

Then, recognizing “a” as the choke price (where individual demand hits the price-axis, (i.e., Di(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:

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

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 money-making 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:

Egovt = TC(X)/n

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

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

It is easy to show that Em > E, since,

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

for any a, n, b > 0. The difference Em - E is consumer surplus.

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 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 Dn(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.

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

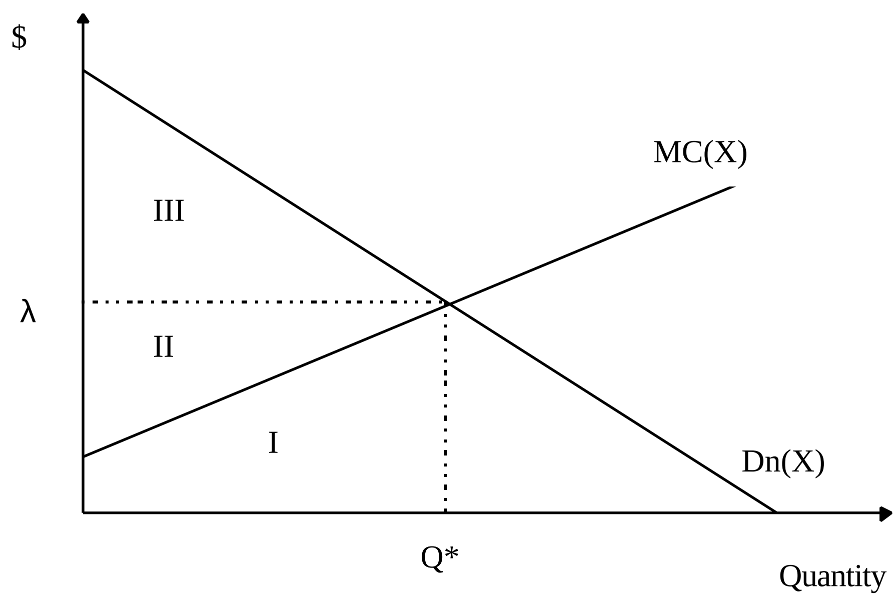
For the private firm to make PS(X*) in profits, the government must allow the firm to charge each consumer an entry fee, Ec, where:

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

Graphically,

- A Benevolent Government charges the entry fee, $E = \frac{I}{n}$
- A Concessionaire charges the entry fee, $Ec = \frac{I + II}{n}$
- The Monopolist charges the entry fee, $Em = \frac{I + II + III}{n}$

Figure 7.5



Club Provision of Public Goods:

A club is an organization that provides access to a public good to a restricted number of members. The key decisions in design of a club is the amount of public goods provided and membership size. The objective function of the club is:

$$\underset{n,X}{Max.}\{nB(n,X) - C(X)\},$$

where B(n, X) is the individual total benefit function from the public good. The FOCs are:

$$(1)\ n\frac{dB(n,X)}{dn} + B(n,X) = 0, \text{ and}$$

$$(2)\ n\frac{dB(n,X)}{dX} - \frac{dC(X)}{dX} = 0.$$

Equation (1) states that the optimality condition for club size. Since the marginal congestion cost of adding another member is $-B_n(n,X) > 0$, and the incremental benefit of an additional member is $B(n,X)$, the equation states that members should be added to the club until the marginal benefit to current members of an adding an additional member is equal to the marginal congestion cost of adding an additional member.

Equation (2) states the marginal condition for the level of public good provision, X. The marginal benefit of providing a greater quantity of the public good is the representative individuals' MB from the level of the public good multiplied by the total number of identical individuals who enjoy it, $nB_x(n, X)$. The equation states that the marginal cost of providing the public good is equal to the marginal benefit received by all of its members.

There is an optimal number of members and optimal level of provision of the public good that can be solved by combining equations (1) and (2). The larger the membership size, the greater X is.

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

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 EPA 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 $0 \le Q \le 10$

(2) $p = p_2 = 40 - 2Q$ for $10 \le Q \le 20$

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 which is logically inconsistent, while the other will give you the correct Q*.

Setting (1) equal to the MC curve:

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

which solves for

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

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

Setting (2) equal to the MC curve:

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

which solves for

$$Q^* = (68\text{-}40)/\text{-}2 = \text{-}14,$$

which is clearly outside the range $10 \leq Q \leq 20$ (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

$p_1^* = 100 - 10(6) = \$40$ per unit of cleanup.

Person 2's marginal demand is

$p_2^* = 40 - 2(6) = \$28$ per unit of cleanup.

If you charge them these amounts, the receipts will be

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

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

TC = (6 units)(\$68/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
$p_1^* = 100 - 10(7) = \$30$/unit,

while person 2 should be charged
$p_2^* = 40 - 2(7) = \$26$/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/unit-\$7/unit)(7 units) + (\$7/unit)(7 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 $D_3(X) = 10 - X$.

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

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 = $P_3^* = 50 - 3(6.25) = 31.25$.

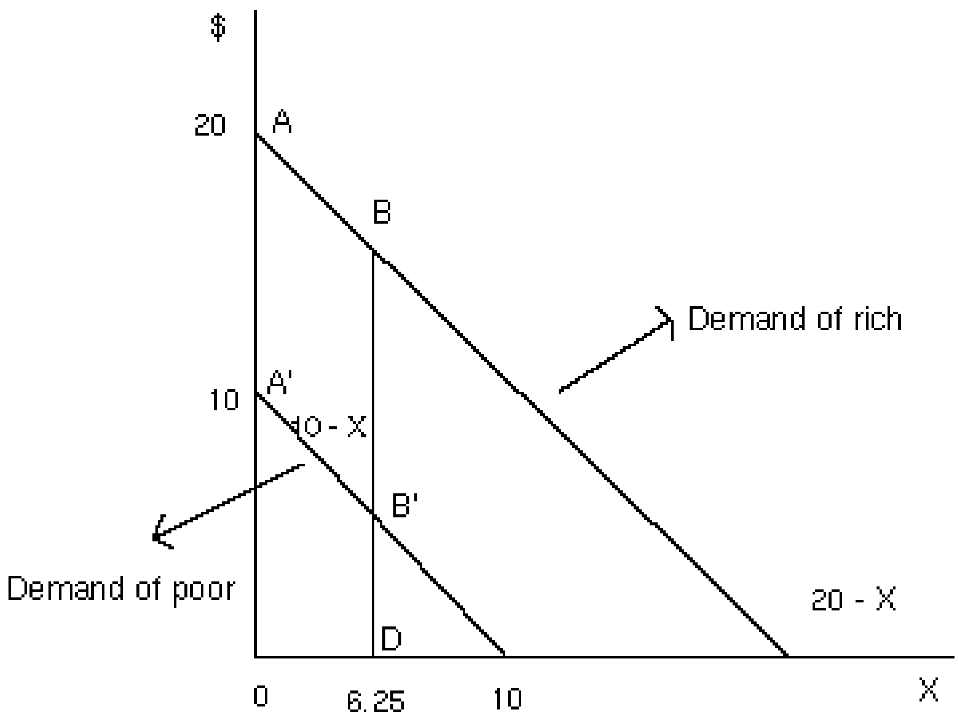
Thus, we have the following policy conclusions:
- If there is open access, government should provide $X^* = 6.25$ and collect revenues by assessing taxes, or, Lindahl taxes, where possible.
- If access can be closed, government may regulate against monopoly pricing.

• The Entry Fees:

Benevolent Government: $E = \frac{TC(X^*)}{3} = \frac{5(X^*)^2}{2(3)} = \$32.55$

Concessionaire: $Ec = X^* (P_3^0/3) = (6.25)(31.25)/3 = \$65.10$

Figure 7.6: Public Goods with Exclusion



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

Benefits of a rich person = area of 0ABD
$[20 + (20 - 6.25)] \cdot 6.25/2 = \$105.47 > 65.10.$

Benefit of poor people = area of 0A'B'D
$[10 + (10 - 6.25)] \cdot 6.25/2 = \$42.97 < 65.104.$

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 still be affordable to 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.

- 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*.

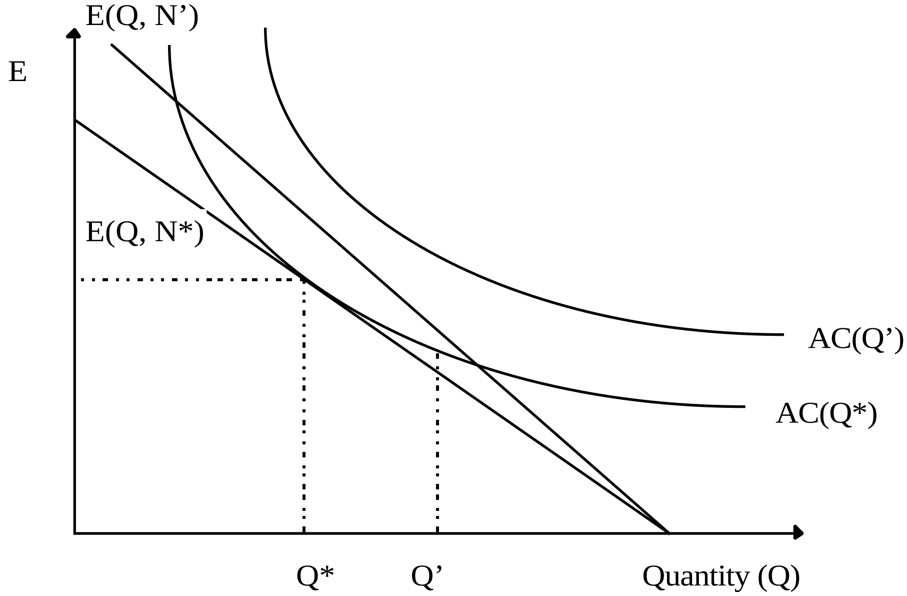
- Second, it may be politically difficult to exclude people, there is no marginal cost of allowing an additional person inside (costs only occur from the aggregate level of the good that is provided). The government would like to be able to allow the poor person to enter and gain enjoyment from the public 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.

The Second-Best Problem of Balanced-Budget Provision

Consider the case in which low-demand individuals are not able to afford the Benevolent Government's Entry Fee for access to an excludable public good. The idea is that the regulator must choose the level of provision subject to the balanced-budget constraint that the sum of revenue from entry fees equals the Average Cost of provision. The regulator is unable to discriminate between high- and low-demand individuals by assessing different Entry Fees for different groups.

Imagine a continuum of individuals, ordered from highest to lowest demand for the public good. Notice that the *y-axis* does not give a unit price, but gives the marginal entry fee per unit of output supplied, or the *Marginal Revenue collected by government*.

Figure 7.7: The Simultaneous Choice of Q* and N*



The graphical solution to the problem is shown above. The regulator begins with the lowest demand individuals and, provided Average Costs can not be recovered through Entry Fees for all individuals, begins to discard them from the market. Each time, the regulator re-calculates the residual demand with a smaller and smaller group, until finally, at point Q*, the highest quantity of provision is found for which entry fees can just cover the Average Cost of providing the good.

Note that the level Q* is a second-best solution, and not an optimal outcome. The optimal outcome, or first-best, involves a larger provision of the good, but also cross-subsidization from high-demand to low-demand individuals.

Discrete vs. continuous public goods: Most public goods assume many values and are represented by continuous variables. However, some variables are represented by variables, which assume discrete values (0 or 1), such as: Freedom or slavery of a group, or Survival or extinction of a species.

<u>Public Goods, Environmental Amenities and Nonuse Benefits:</u>

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. There 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 moneys 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?

Heterogeneous Demand for a Public Good

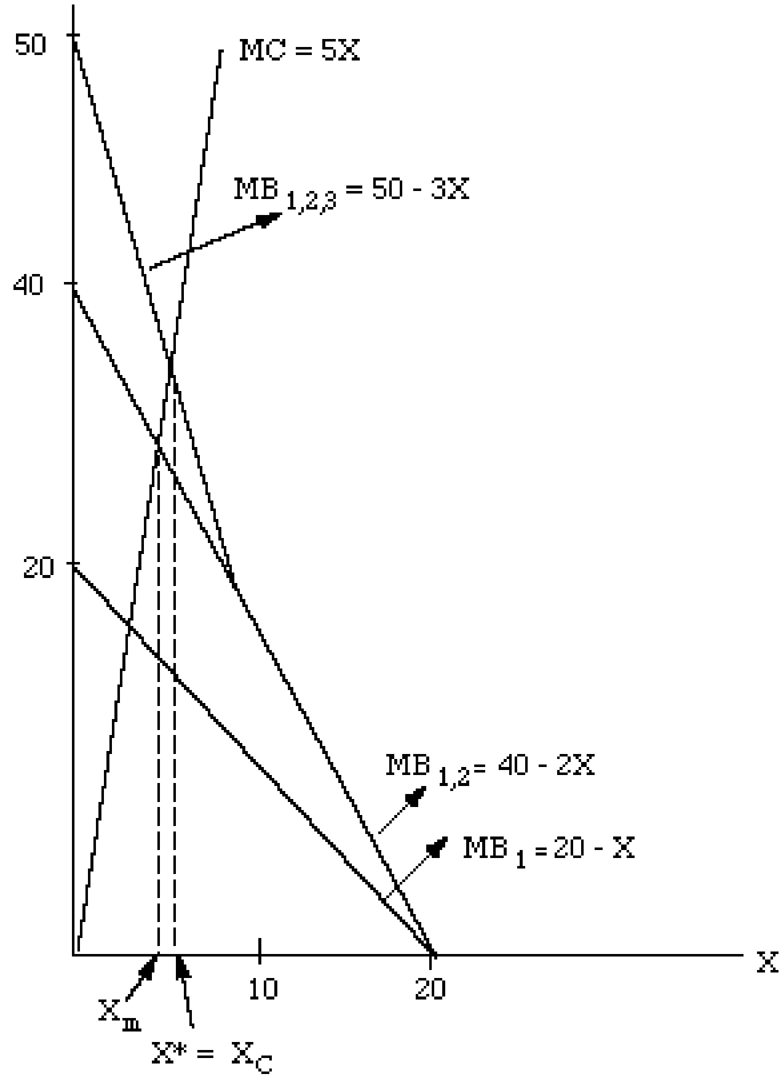
$D_1 = MB_1 = 20 - X$

$D_2 = MB_2 = 20 - X$

$D_3 = MB_3 = 10 - X$

Suppose

$MC = 5X$



Aggregate demand is kinked:

(1) $MB = 50 - 3X, \qquad 0 \le X \le 10$

(2) $MB = 40 - 2X, \qquad 10 \le X \le 20$

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) $MB = 50 - 3X \quad 0 \le X \le 10$

$MB = MC \Rightarrow$

$50 - 3X = 5X$

$8X = 50$

$X^* = 6.25$

$0 \le 6.25 \le 10$

$\boxed{X^* = 6.25}$ is correct

(2) $MB = 40 - 2X \quad 10 \le X \le 20$

$MB = MC \Rightarrow$

$40 - 2X = 5X$

$7X = 40$

$X^* = 5.71$

5.71 is not between 10 and 20

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 = $\int MB$

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

The rich person will enter.

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

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

The poor person will also enter.

Concessionaire's Problem:

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

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

$X_C = 6.25 \Rightarrow$ a shadow price $\lambda^* = 50 - 3\,(6.25) = 31.25$.

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: $MB_{1,2} = MC$.

$$MB_{1,2} = 40 - 2X = MC = 5X \Rightarrow 40 - 2X = 5X$$
$$7X = 40$$
$$\boxed{X_m = 5.71}.$$

<u>Note</u>: $X_m < X_c = X^*$, 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.

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.

Lower Marginal Cost of Provision

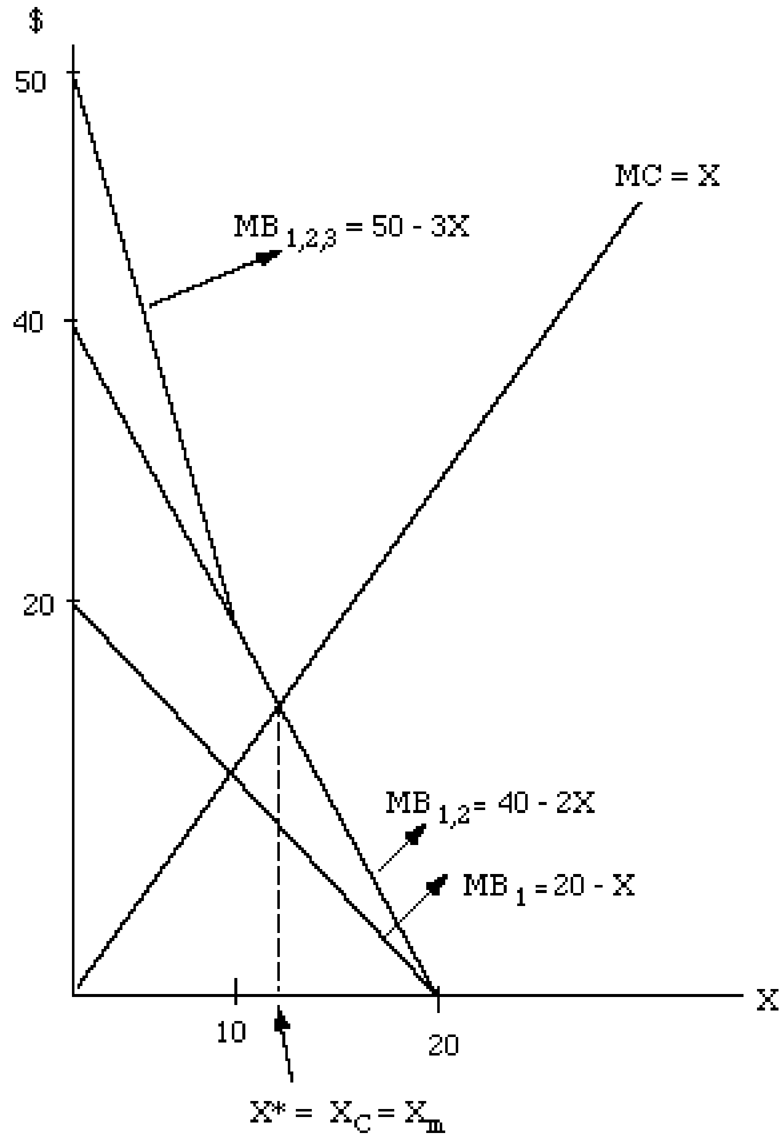
$D_1 = MB_1 = 20 - X$

$D_2 = MB_2 = 20 - X$

$D_3 = MB_3 = 10 - X$

Suppose

$MC = X$



Aggregate demand is kinked:

(1) $MB = 50 - 3X \quad 0 \le X \le 10$

(2) $MB = 40 - 2X \quad 10 \le X \le 20$

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 $0 \le X \le 10$

MB = MC =>

50 - 3X = X

4X = 50

X* = 12.25

INCONSISTENT

12.5 is not between 0 and 10

(2) MB = 40 - 2X $10 \le X \le 20$

MB = MC =>

40 - 2X = X

3X = 40

X* = 13.33

$10 < 13.33 \le 20$

$\boxed{X^* = 13.33}$ 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 = $\int MB$

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

The rich person will enter.

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

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

The poor person will also enter.

Concessionaire's Problem:

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

=> $\boxed{X_C = 13.33}$

X_C = 13.33 => a shadow price _* = 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: $MB_{1,2} = MC$.

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

$$3X = 40$$

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

<u>Note:</u> 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.