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Lectures 19 and 20

<u>Natural Resources</u>

Analysis of natural resources requires an understanding of behavior over time. A useful distinction is between:

<u>Nonrenewable resources</u> (mineral, fossil water, remnants of ancient civilizations, old growth forest, "dead things") and

<u>Renewable resources</u> (fisheries, forests, grasslands, water systems, "living things").

Many renewable resources and most nonrenewable ones are exhaustible. Analysis of natural resources requires indicators of their situation. They are in the form of "state variables" that measure resource stocks, for example, the size of fish populations.

There is a significant gap between conceptual and empirical analyses of natural resource systems, as measurement of, say, fish populations is quite challenging. Understanding of biology is also crucial for useful analysis.

A Generic Model

Let x be he amount of resource harvested in a period. The resource provides benefit $B(x)$ where $MB = \partial B / \partial x$ in the demand curve.

Three categories of costs are associated with resource harvesting or mining:

(1) Mining cost. Defined as $NC(x)$. This is the extraction cost carried by the firm that supplies the resource. It plays the same role as the "private cost" in our externality analysis. We will define marginal mining cost as:

$$MNC(x) = \frac{\partial NC}{\partial x}.$$

(2) Future cost. Defined as *FC*. For nonrenewable resources, the amount mined today will not be available in the future. The future cost represents the opportunity cost of mining resources at the present. It is affected by the discount rate (which reduces *FC*) and by the expected benefits and costs of the future use of the resources. For renewable resources, the future cost is affected by the growth pattern of the resource. Catching a pregnant female fish today will not avail her and her offsprings tomorrow. However, the food it consumes may enable the growth of other fish. Let marginal future cost be denoted by

$$MFC(x) = \frac{\partial FC(x)}{\partial x}.$$

(3) Externality cost. This is denoted by *EC*. In the case of fisheries, they include elements such as bycatch. For nonrenewable resources such as fossil fuels, they include contribution to climate change. The marginal externality cost is

$$MEC(x) = \frac{\partial EC(x)}{\partial x}$$

Figure 1 denotes equilibrium outcomes.

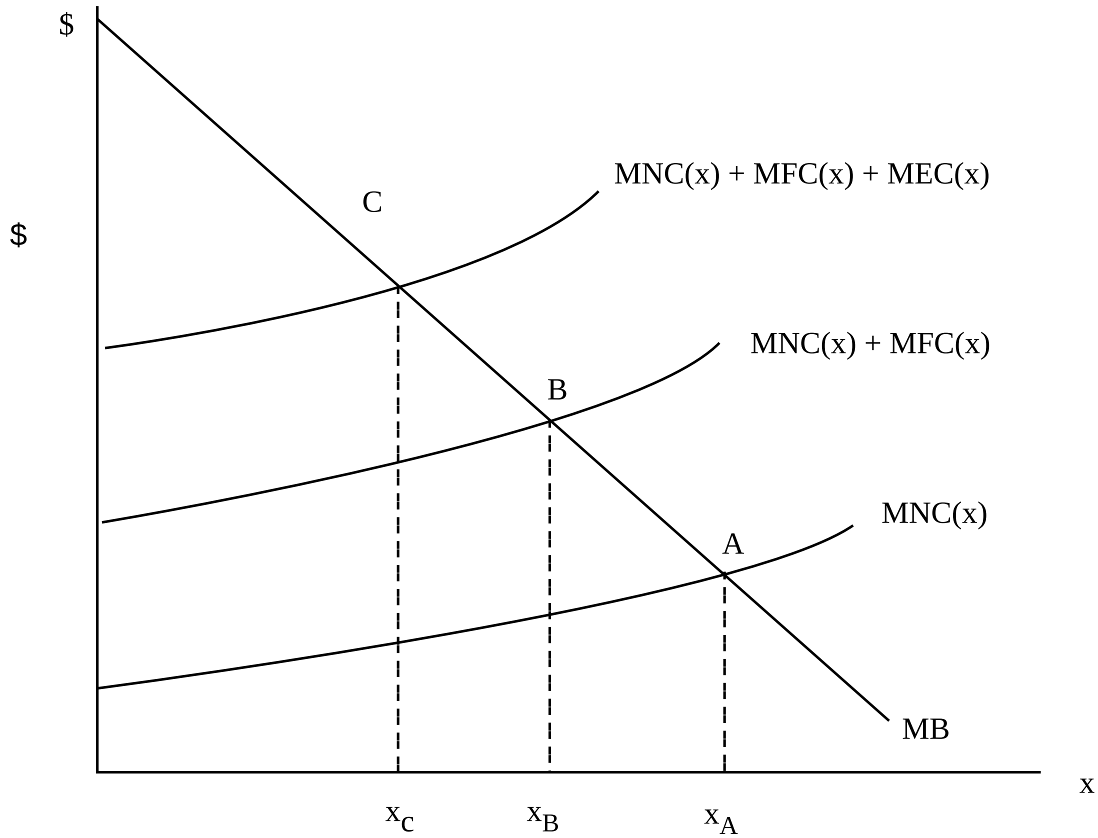

Figure 1. Equilibrium Outcomes

Optimal allocation occurs at *C*. In cases of

(i) *No regulation* and

(ii) *Open access* to the resource, private firms will not consider future cost and the outcome will be at *A*..

Excessive harvesting occurs under open access and no externality control. However, even in situations such as the one in point B, with closed access but no externality control, we again have excessive extraction.

Elements of a Resource Policy

(1) Establishing private prosperity for the resource. This prevents the open access problem and moves from point A to point B in Figure 1.

(2) Externality control. This is a form of tax on the resource and leads to a transition from point B to C. Reality is complex and a wide variety of policy solutions exist for various situations.

Fishery Issues

(1) International water. There are international agreements and evolving "laws of the sea." Yet, open access problems are as severe as the seas. Some of these problems have been addressed by establishing territorial water along 200 miles of shoreline in various countries and by protecting specific species (ban on fishing whale species).

(2) Monitoring problems. Countries establish transferable fishing permits and divide them among their fishermen or set quotas for recreational fishing. They are monitored by random inspection in the sea and at the processing and wholesaling facilities.

(3) Regulation of timing. To control overfishing, the size and number of boats and, particularly, duration of fishing may be regulated.

Regulation of duration is suboptimal because:

(i) It leads to overinvestment in equipment.

(ii) Frozen fish are inferior to fresh ones.

The transition to tradable permits increases efficiency; yet, it may be accompanied by restrictions on fishing at breeding grounds during breeding seasons.

(4) Role of technologies. Some fishing techniques (use of explosive, fishing with fine mesh nets) may increase both future and externality costs. They may prevail in open-access fisheries. Fishing technologies may be regulated through bans on explosives or especially damaging fishing equipment in addition to fines against violators and taxation of bycatch.

Taxation of the actual fish caught or imposing fishing quotas may not provide sufficient incentives to modify current fishing methods. Fishing needs more direct regulation of harvest technologies.

(5) Aquaculture and marine culture. These techniques, which feed and breed fish and seafood, augment or provide alternative sources of fish. If the price of fish produced by aquaculture is P_a^1, then that sets an upper bound on the cost of harvesting. As Figure 2 suggests, reduction of the price of fish from aquaculture from P_a^0 to P_a^1 will reduce fishing and is a solution to overfishing.

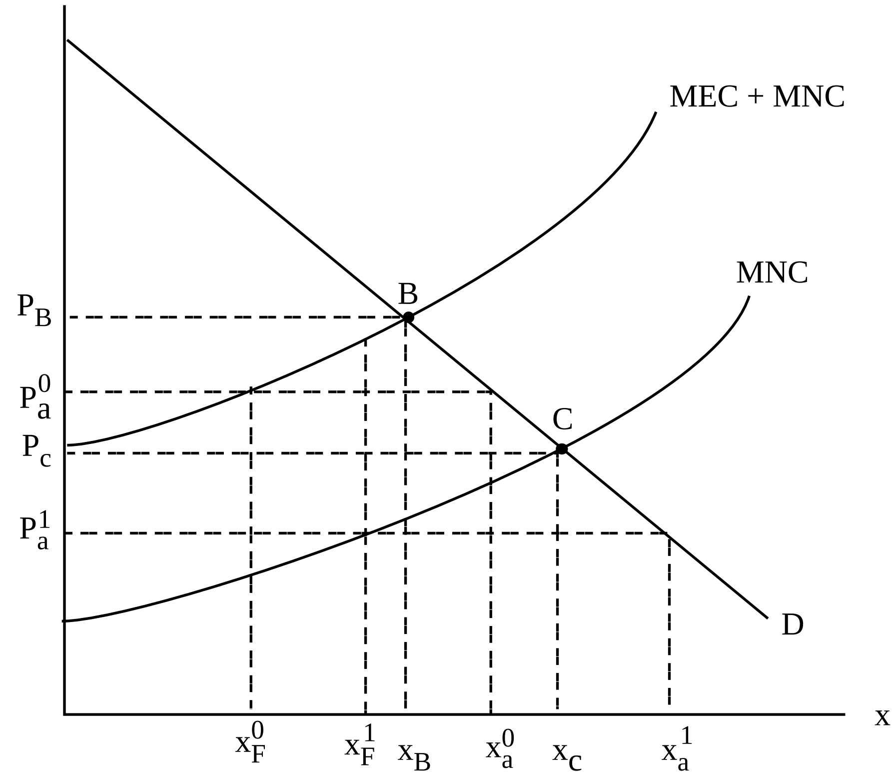

Figure 2

Suppose we only have externality cost. Without aquaculture and regulation, fishing will be at C, and the price of fish is P_c. With regulation, the optimal solution without aquaculture is at B. If the price of aquaculture is P_a^0, it will not affect the outcome if fishing is not regulated. However, if it is regulated, the fish of price will drop to P_a^0, consumption will be at x_a^1, and fishing will be at x_F^0. Now if the price of aquaculture declines to P_a^1, production without regulation increases to x_a^1 and fishing declines from x_A to x_F^1.

The transition from fishing to aquaculture in essence is similar to the transition from hunting to farming. Hunting and gathering rely on nature to control breeding and feeding and human concentration on harvesting. As the human population grows and animal population declines, the benefits of systems where humans are responsible for all stages of the production processes—breeding, feeding, and harvesting—increase. With learning, new technologies are available, increase yield per acre, and reduce the requirements for land and other resources for food.

Agricultural intensification that increases yield per acre reduces the need for expansion in the land base as populations grow. That is likely to be the impact of aquacultre in the future (once the negative side effects of aquculture and mariculture systems are corrected).

Price Dynamics

Here we will consider the basic relationship depicting the dynamics of prices of both nonrenewable and renewable resources. Suppose a person considers whether to mine and sell a resource at time 0 or keep it and mine it at period 1.

Let P_0 = price at period 0

P_1 = price at period 1

r = interest rate

C = per unit extraction cost at period 1.

In a two-period world, the person will compare discounted net benefits in each period deciding whether to mine or wait.

She will mine in period 0 if

$$P_0 - C_0 > \frac{P_1 - C_1}{1+r} \quad P_0 > C_0 .$$

She will mine and keep the resource in period 1 if

$$\frac{P_1 - C_1}{1+r} > P_0 - C_0 \ , \ P_1 - C_1 > 0 .$$

She will not mine if $P_0 < C_0$ and $P_1 < C_1$.

In an equilibrium situation, when resources are being mined constantly, prices will adjust so that individuals will be indifferent to when mining should be done.

$$\frac{P_1 - C_1}{1+r} = P_1 - C_0$$

$$P_1 - C_1 = \left(P_0 - C_0\right)(1+r).$$

The rent for the mineral (price – extraction cost, $P_1 - C_i$) <u>increases</u> over time since the delay in mining results in loss of interest earnings. Suppose $C_1 = C_0$.

(1) $$\frac{P_1 - P_0}{P_0} = r\left[1 - \frac{C_0}{P_0}\right].$$

The increase in the price over time is dependent on the interest rate. When $C_0 - 0$ and there is no mining cost, $P_1 - P_0 / P_0 = r$ and the resource price increases at the rate of interest. Equation (1) suggests that higher mining costs reduce the increase in resource price over time.

Figure 3 depicts optimal price of resource over time when $C = 0$.

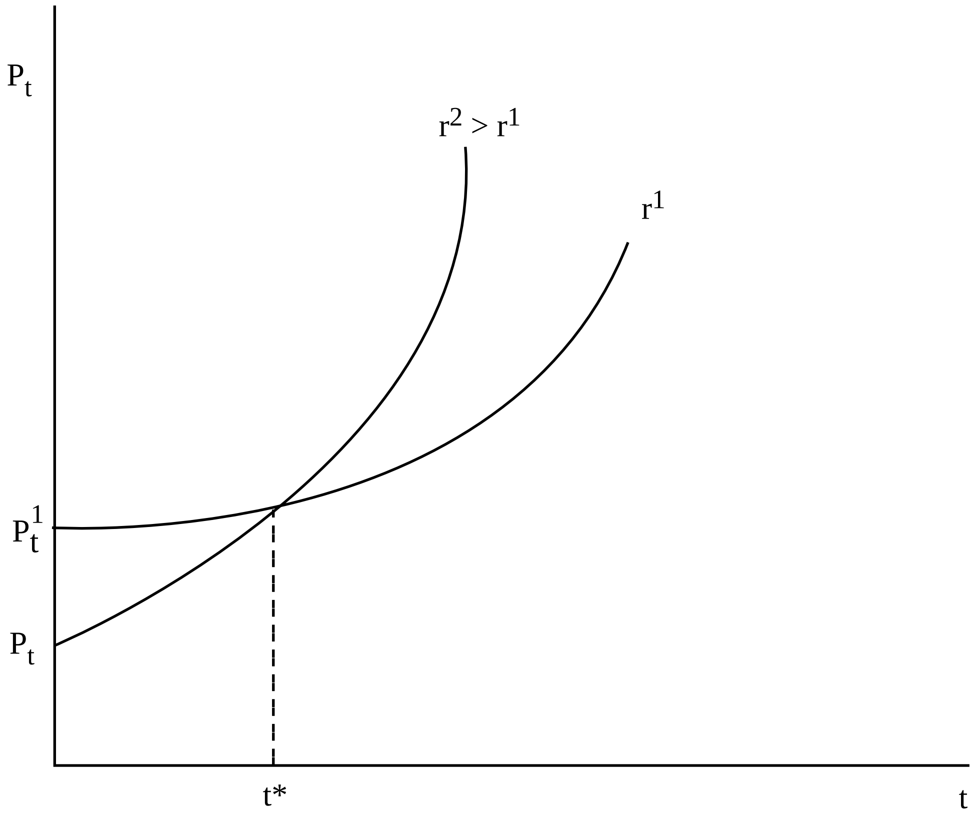

Figure 3

Higher interest rates lead to a higher rate of growth in the price of the resource over time and lower initial prices. In Figure 3 $r_2 > r_1$ and when $t < t*$ at the early period $P_t^2 < P_t^1$. That results in more mining under higher interest rates in earlier periods and less mining beyond $t = t*$ (see Figure 4).

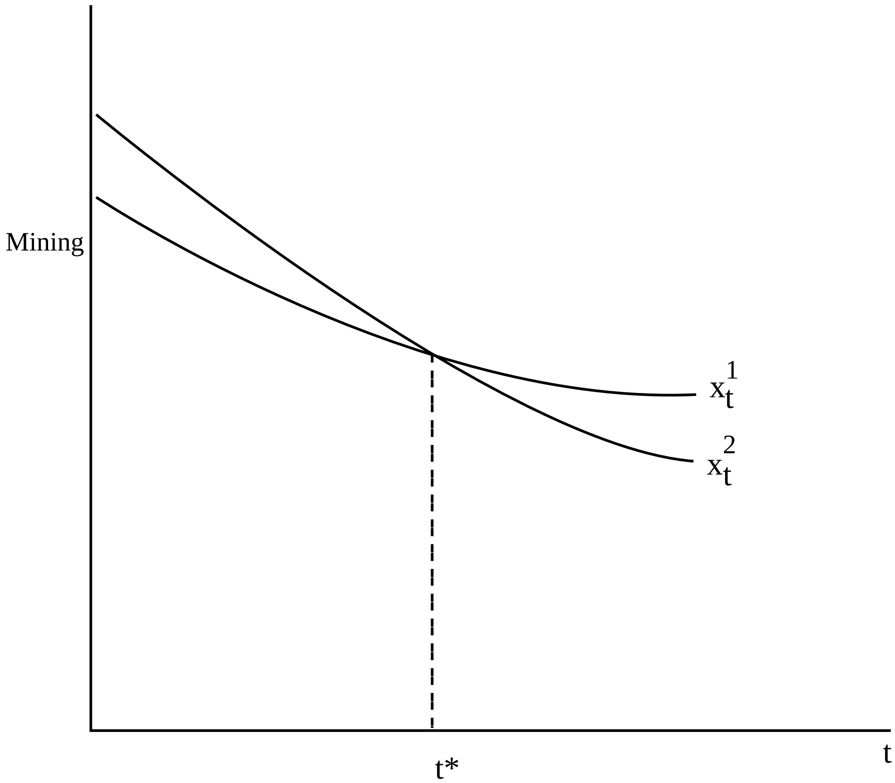

Figure 4

Myopic behavior (or open-access mining) when $P_t = C$, without concern to future periods, will result in a faster depletion of nonrenewable resources.

This may also be the case with renewable resources. If constant harvesting is larger than population growth after a finite amount of time, populations are decimated. That occurred with the buffaloes in the West.

Mining costs are likely to increase as populations decline, which may save some species since at some point the demand price was below the extraction cost.

Price Dynamics for Renewable Resources

For renewable resources, when deciding whether or not to catch a fish or leave it, one takes into account the growth of the fish (or offspring). One unit of resource in period 0 will result in 1 + g units in period 1 when g is the rate of growth or resource stock.

Thus, the decision whether to harvest at 0 or 1 compares $P_0 - C_0$ with

$$\frac{(P_1 - C_1)(1+g)}{1+r}.$$

If harvesting is continuous,

$$P_0 - C_0 = \frac{(P_1 - C_1)(1+g)}{1+r},$$

which suggests

$$P_1 - P_0 = rP_0 - gP_1 + C_1(1+g) - C_0(1+r)$$

or

(2) $$\frac{P_1 - P_0}{P_0} = r - g\frac{P_1}{P_0} + \frac{C_1(1+g) - C_0(1+r)}{P_0}.$$

In the case where $C_1 = C_0 = C$,

$$\frac{P_1 - P_0}{P_0} = r - g\frac{P_1}{P_0} + \frac{C(g-r)}{P_0} = r\left[1 - \frac{C}{P_0}\right] - g\left[\frac{P_1}{P_0} - \frac{C}{P_0}\right].$$

The rate of the price change is affected by

(i) The discount rate, which tends to increase price over time.

(ii) Population growth, which tends to reduced price over time (as supply increases).

(iii) Extraction cost factor which dampens the other two.

With renewable resources, we may have steady states with constant prices and extraction that is equal to growth. In this case, $gS^* = x^*$, when S is the resource stock in steady state and x^* is the harvest.

Issues in Nonrenewable Resources

The economics of nonrenewable resources is affected by the following phenomena:

(1) Backstop technologies. Alternative technologies that either replace the need for renewable resources—for example, solar energy that may one day replace fossil fuel—or increase their efficiency use**.** Expectations of new technologies will reduce the future costs of mining and, thus, will lead to increased mining at the present and reduce the price of resources. Thus, increased likelihood of discovering alternative sources of energy or a new engine that will increase the efficiency of cars or other uses of fossil fuels is likely to reduce prices and increase energy use. A similar phenomenon is:

(2) New discoveries. We haven't yet discovered all the reservoirs of oil, coal, and other minerals. New discoveries tend to reduce the future cost of mining and thus tend to increase extraction and reduce energy pricing. Of course, discovery efforts are economic activities, and they become intensified during periods of high energy prices and perception of future shortages. Thus, we may see cycles in the energy and mineral pricing. High prices and shortages will trigger new discovery efforts that will result in reduction of prices and slowly reduce the incentives for further discovery efforts. During the energy prices of 1970s, new discovery efforts led to increased supply that resulted in an abundance of oil in the 1980s and 1990s. Low prices during the last two decades might have reduced the incentive for further discovery and contributed to the perception of growing scarcity at the present.

(3) Cartels and monopolies. Thus far, the analyses have assumed competitive behavior. As we know, oil producers form a cartel (OPEC), which is more effective in

some periods than in others. Energy pricing has increased and production is curtailed when the cartel is more effective. As we know from the externality discussion, monopolization tends to reduce supply, and sometimes it can be a substitute for government intervention in forms of taxes and transferable quota.

While monopoly pricing may move resource allocations associated with mining towards social optimum, it has a significant distributional effect as it increases the wealth of monopolists. The main advantage of energy prices is that they may reach the same outcome as a monopolist while transferring resources to the government. With low elasticity of demand for natural resources such as oil, many countries introduced significant energy prices both for the externality and also to provide an alternative source of finance for the public sector.