Environment

And Resources

Economies

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The Economic Problem
Scarcity and Choice

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The Economic Problem Scarcity and Choice[1]

What gets produced? How is it produced? Who gets it? Why? Is it good or bad? Can it be improved?

This chapter explores these questions further, in a sense, this entire chapter is the definition of economics. It lays out the central problems addressed by the discipline of economics and provide the framework that will guide you through the rest of the book.

Human wants are unlimited, but resources are not limited, or scarce, resources force individuals and societies to choose. The Central Function of any economy, no matter how simple or how complex is to transform resources into useful from in accordance with those choices. The process by which this transformation takes place is called production.

The term resource is very broad. Some resources are the product of nature: land, wildlife, minerals, timber, energy, even the rain and wind. At any given time, the resources available to a society also

[1] - Kael. E Case and Ray C. fair. Principles of Economics" Second Edition, prentice Hall, U.S.A, 1992, PP.34 – 56.

include those things that have been produced by previous generations, such as building and equipment. Things that are produced and then used to produce other valuable goods or services later on are called capital resources, or simply Capital, Buildings, Machinery, equipment, tables, roads, bridges, and knowledge- are also an important part of a nation's resources.

Producers are those who take resources and transform them into usable products, or outputs, private manufacturing firms purchase resources and produce products for the market. Governments do so as well. National defense, the justice system, police and fire protection, and sewer services are all examples of outputs produced by the government, which is sometimes called the public sector.

Individual households often produce products for themselves. A household that owns its own home is in essence using land and a structure (capital) to produce its own housing services" that it consumes itself. The Boston symphony Orchestra is no less a producer than General Motors. An orchestra takes capital resources – a building, musical instruments, lighting fixtures, musical scores, and so on and combines them with land and highly skilled labor to produce performances.

Scarcity and Choice in a One – Person Economy:

The simplest economy is one in which a single person lives alone on an island where no one has ever been before. Consider Bill, the survivor of a plane crash, who finds himself cast ashore in such a place. Here, individual and society are one; there is no distinction between social and private. Nonetheless, nearly all of the basic decisions that characterize complex economies must be made. Bill must decide how to allocate the resources of the island, what to produce, and how and when to produce it.

First, Bill must decide what he wants, what to produce. Notice that the word needs does not appear here. Needs are absolute requirements, but beyond just enough water, basic nutrition, and shelter to survive, they are very difficult to define. What is an “absolute necessity” for one may not be for another. In any case, Bill must put his wants in some order of priority and make some choices.

Next he must look at the possibilities. What can he do to satisfy his wants, given the limits of the island? In every society, no matter how simple or complex, no matter how rich, or poor, wants are constrained in some way. In this society of one, Bill's wants are constrained by time, his physical condition, his knowledge, his skills, and the resources and climate of the island.

Given that resources are limited, or scarce, Bill must decide how to use them best to satisfy his hierarchy of wants, Food would probably come close to the top of his list. Should he spend his time simply gathering natural fruits and berries? Should he hunt for game? Should he clear a field and plant seeds? Notice that the planting option involves more time than the other two. If bill takes time away from gathering food today, he will have less to eat today, but he may have more to eat tomorrow. Clearly, the answers to these questions depend on the character of the island, its climate, its flora and fauna (are there any fruits and berries); the extent of his skills and knowledge (does he know anything about farming technology?), and his preferences (he may be a vegetarian).

Scarcity, and Choice in an Economy of Two Or More

Now, suppose that another survivor of the crash, colleen, appears on the island. Now that Bill is not alone things are more complex, and some new decisions must be made. Bill's and colleen's preferences about what things to produce are likely to be different. They will probably not have the same knowledge or skills Perhaps Colleen is very good at tracking animals, while Bill has a knack for building things. How should they split the work that needs to be done? Once things are produced, they decide how to divide them. How should their products be distributed?

The mechanism for answering these fundamental questions is clear when Bill alone is on the island. The "central plan" is his; he simply decides what he wants he wants and what to do about it. The minute someone else possible. One or the other may take charge, in which case that person will decide for both of them. The two may agree to cooperate, with each having an equal say, and come up with a joint plan. Or they may agree to split the planning, as well as the production duties. Finally, they may go off to alone at opposite ends of the island.

Even if they live apart, however, they may take advantage of each other's presence by specializing and trading.

Opportunity Cost:

The concepts of constrained choice and scarcity are central to the discipline of economics. They can be applied when discussing the behavior of Individuals like Bill, or Bill and colleen together, and when analyzing the behavior of large groups of people in complex societies.

Given the scarcity of time and resources, Bill has less time to gather if he chooses to hunt- he trades more meat for less fruit. There is trade-off between food and shelter, too. If Bill likes to be comfortable, he may work on building a nice place to live, but that may require giving up the food he might have produced, we call that which we forgo when we make a choice the opportunity cost of the choice.

Bill and Colleen may occasionally decide to rest, to lie on the beach and enjoy the sun in one sense, that benefit is free – they don't have to pay for the privilege. In reality, however, it does have a cost, an opportunity cost. Lying in the sun means using time that otherwise could have been spent doing something else. The true cost of that leisure is the value to Bill and Colleen of the other things they could have produced, but did not, during the time they spent on the beach.

In the 1960s, the United States decided to put a man on the moon. to do so required devoting enormous resources to the space program, resources that could have been used to produce other things. The opportunity cost of placing a man on the moon was the total value of all the other things that those resources could have produced. Among other possibilities, taxes might have been lower. That would have meant more income for all of us to spend on goods and services. Those same resources could also have been used for medical research, for aid to education, to build a bridge, or to support the arts.

In making everyday decisions it is sometimes helpful to think about opportunity costs. Should I go to the dorm party or not? First, it costs $4 to get in. when I pay out money for anything, I give up the other things that I could have bought with that money. Second, it costs two or three hours clearly, time is a valuable commodity for a college student. I have exams next week and I need to study. I could go to a movie. I could go to another party. I could sleep. Just as Bill and Colleen must weigh the value of sunning on the beach against more food or better housing, so I must weigh the value of the fun I may have at the dorm party against everything else I might otherwise do with the time and money.

Weighing Present and Expected Costs and Benefits:

Very often we find ourselves weighing benefits available today against benefits available tomorrow. Here too the notion of opportunity cost is helpful.

Bill had to choose between cultivating a field and just gathering wild nuts and berries. Gathering nuts and berries provides food now; gathering seeds and clearing a field for planting will yield food tomorrow, if all goes well. Using today's time to farm may well be worth the effort if doing so will yield more food than Bill would otherwise have in the future. By planting Bill is trading present value for future values. Working to gather seeds and clear a field has an opportunity cost– the present leisure he might consume and the value of the berries he might gather if he not works the field.

The simplest example of trading present for future benefits is the common act of saving. When I put income aside today for use in the future, I give up some things that I could have had today in exchange for something tomorrow. The saver must weigh the value of what that income can buy today against what it might be expected to buy later. Since nothing is certain, some judgment about future events and expected values must be made. What are interest rates likely to be? What will my income be in ten years? How long am I likely to live?

We trade off present and future benefits in small ways all the time. If you decide to study rather than go to the dorm party, you are trading present fun for the expected future benefits of higher grades. If you decide to go outside on a very old day and run five miles, you are trading discomfort in the present for being in better shape later on.

Capital Goods and Consumer Goods:

A society trades present for expected future benefits when it devotes a portion of its resources to research and development or to investment in capital. As we said earlier, capital in its broadest definition is anything that is produced that will be used to produce other goods or services over time.

Building capital means trading present benefits for future ones. Bill and colleen might trade lying in the sun for a nicer house in the future, or for a boat. In a modern society, resources used to produce capital goods could have been used to produce consumer goods, that is, for present consumption. Heavy industrial machinery does not directly satisfy the wants of anyone, but producing it requires resources that could instead have into producing food, clothing, toys, golf clubs, and so forth.

Capital is everywhere. A road is capital. Once built, we can drive on it or transport goods and services over it for many years to come. The benefits of producing it will be realized over many years. A house is also capital. When it is built, the builder presumes that it will provide shelter and valuable services for a long time. Before a new manufacturing firm can start up, it must put some capital in place. The buildings, equipment, and inventories that it owns are its capital. As it contributes to the production process, this capital yields valuable services through time.

Capital need not be tangible. When you spend time and resources developing skills or getting an education, you are investing human capital− your own human capital− that will continue to exist and yield benefits to you for years to come. A computer program produced by a software company may come on a tangible disk that costs 75$ to make, but its true intangible value comes from the ideas embodied in the program itself, which will continue to drive computers to do valuable tasks over time. It too is capital.

The process of using resources to produce new capital is called investment. (in everyday language, the term investment is often used to refer to the act of buying a share of stock or a bond, as in “I invested in some Treasury bonds. in economics, however, investment always refers to the creation of capital: the purchase or putting in place of buildings, equipment, roads, houses, and the like.) A wise investment in capital is one that yields future benefits that are more valuable than the present cost.

When you send money for a house, for example, presumably you value its future benefits; that is you expect to gain more from living in it than would from the things you could buy today with the same money.

Capital is able to generate future benefits in excess of cost by increasing the productivity of labor. A person who has to dig a hole can dig a bigger hole with a shovel than without a shovel. A computer can do in several seconds what it took hundreds of bookkeeper's hours to do

15 years ago. This increased productivity makes it less costly to produce products.

The Production Possibility Frontier

A simple graphical device called the production possibility frontier (ppf) illustrates the principle of constrained choice and scarcity. The ppf is a graph that shows all the combinations of goods and services that can be produced if all of society's resources are used efficiently. Figure (No.1) shows a ppf for a hypothetical economy.

On the Y axis we measure the quantity goods (k) produced, and on the X axis, the quantity of consumption goods (c). all points below and to the left of the curve (the shaded area) represent combinations of capital and consumption goods that are possible for the society given the resources available and existing technology. Points above and to the right of curve, such as point G, represent combinations that cannot be reached. If an economy were to end up at point A on the graph, it would be producing no consumption goods at all; all resources would be used for the production of capital. On the other hand, if an economy were to end up at point B, it would be devoting all of its resources to the production of consumer goods and none of its resources to the formation of capital.

While all economies produce some of each kind of good, different economies emphasize different things. About 19% of gross output in the united states each year is new capital. In Japan, capital accounts for 32% of gross output while in Ethiopia the figure is only around 10%. Japan is closer to point A on its ppf, Ethiopia closer to B, and the United States is somewhere in between.

Points that are actually on the production possibility frontier can be thought of as point of both full employment and "production efficiency". Resources are not going unused, and there is not waste. Points that lie within the shaded area, but that are not on the frontier, represent either unemployment or production inefficiency. An economy producing at point D in figure (No. 1) an produce more capital goods and more consumption goods, for example, by moving to E. this is possible only (a) if resources were initially not fully employed or (b) if resources were not being used efficiently.

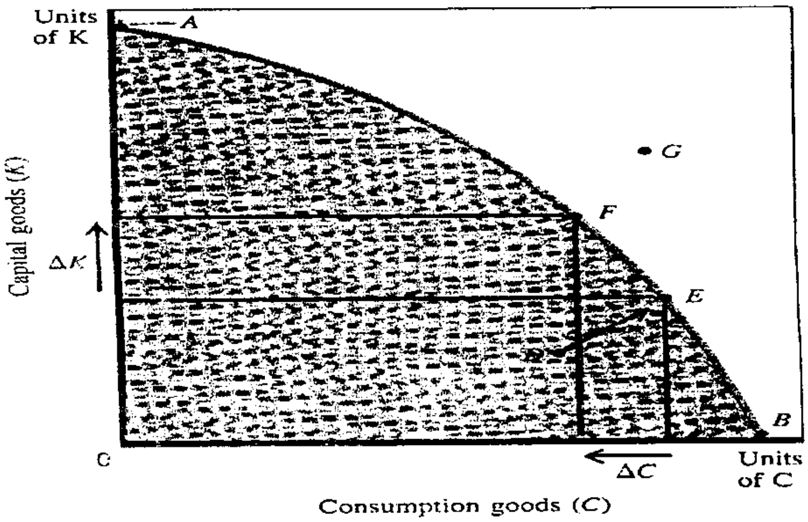


Figure No. 1
Production Possibility Frontier

Figure (No. 1)

The production possibility frontier illustrates a number of economic concepts. One of the most important is opportunity cost. The opportunity cost of producing more capital goods that fewer consumption goods can be produced. Moving from E to F, ΔK is the change in the number of capital goods; here it shows an increase. To produce more capital goods, resources must be transferred from the production of consumer goods. ΔC is the change in number of consumer goods; here it shows a decrease.

Unemployment:

During the great depression of the 1930s, the U.S. economy experienced prolonged unemployment. Millions of workers who were willing to work found themselves without jobs. In 1933, a full 25% of the civilian labor force was unemployed. This figure stayed above 14% until

1940, when the United states entry into world war II created millions of jobs. In 1975, and again in 1982, the economy experienced high levels of unemployment. In June of 1975, the unemployment rate went over 9% for the first time since the 1930s. in December of 1982, when the unemployment rate hit 10.8%, nearly 12 million were out looking for work.

In addition to the hardship that falls on the unemployed themselves, unemployment of labor means unemployment of capital. During the downturn of 1982, industrial plans were running at less than 69% of their total capacity. That meant that a considerable fraction of the nation's industrial capital was sitting idle and, in effect, being wasted. Clearly, when there is unemployment we are not producing all that we can.

Periods of unemployment correspond to points inside the production possibility frontier, point like D in Figure (No. 1) moving onto the frontier from a point like D means moving up and to the right, achieving full employment and increasing production of both capital goods and consumer goods.

Inefficiency

Recall that an efficient economy is one that produces the things that people want at the least cost. Although production inefficiency occurs when a country is producing inside its production possibility frontier, an economy is also inefficient when it is producing at the wrong point on the ppf – that when it is producing a combination of goods and services that does not match the wants of its people.

Certainly, a badly managed economy will not produce up to potential and will be inside the ppf. Suppose, for example, the land and climate in Ohio are best suited for corn production and that land and climate in Kansas are best suited for wheat production. If congress passes a law forcing farmers in Ohio to plant 50% of their acreage in wheat and farmers in Kansas to plant 50% in corn, neither corn nor wheat production will be up to potential. The economy will be at a point like A in figure (No.2)- inside the production possibility frontier. Allowing each state to specialize in producing the crop that it produces best increases the production of both corn and wheat and moves the economy to a point like B in figure (No.2).

In extreme cases a wrong output mix is obvious. Suppose, for example, that a society uses all of its resources to produce beef efficiently, but that everyone in the society is a vegetarian. The result is a total waste of resources (assuming that the society cannot trade beef for vegetables with another society).

A wrong mix of output can be less obvious, however. Beef production is a highly competitive industry in the United States. Hundreds of thousands of farmers sell Millions of cattle each year to hundreds of meat packing firms. Most grocery stores have plentiful stocks at reasonable prices because there are many suppliers competing for business.

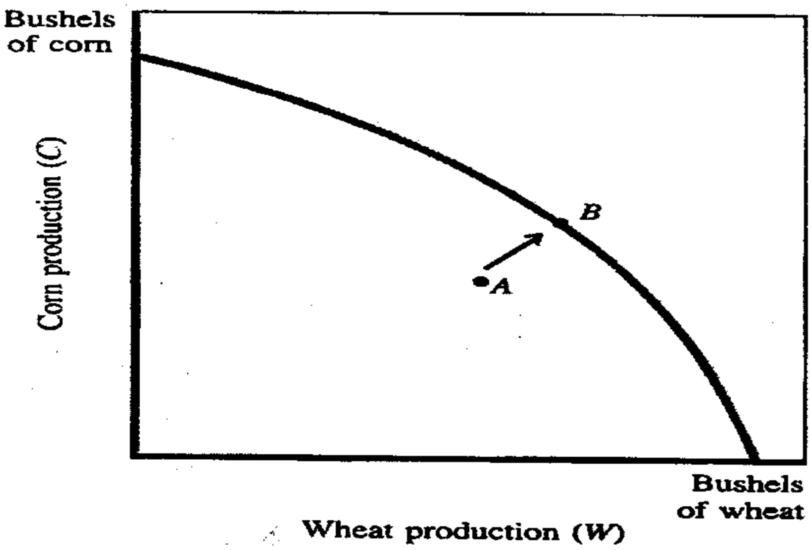


Figure (No. 2)

Inefficiency from Misallocation of Land in Farming

Society can end up inside its production possibility at a point like A by using its resources inefficiently. If, for example, Ohio's climate and soil were best suited for corn production and those of Kansas were suited for wheat production a law that forced Kansas farmers to produce corn and Ohio farmers to produce wheat would result in less of both. In such a case might be at point A rather than point B.

Suppose that the government were to grant a monopoly on beef production– that is, the sole right to produce beef– to a single company. Even if all resources remained fully an efficiently employed, the monopoly would push the economy to a less desirable point on the ppf– that is, a point at which beef is underproduced and other goods are overproduced, a point such as B instead of A in figure (No.3). in the absence of the monopoly, the society can move back to point A, which more closely matches the preferences of its people, (reason is that a monopolist tends to produce less than what is produced in a competitive industry.)

Negative Slope and Opportunity Cost:

As we've seen, points that lie on the production possibility frontier represent points of full employment and efficiency of production. But society can choose only one point on the curve. Because a society's choice are constrained by available resources and existing technology, when those resources are fully and efficiently employed it can produce more capital goods only by reducing production of consumption goods.

Recall that the slope of a curve between two points can be approximated by dividing the change between the points on the Y axis (ΔY) by the change between the points on the X axis (ΔX). Moving from point E to point F (No.1) involves increasing capital production by ΔK units and decreasing production of consumption goods by ΔC units. Capital production increases $(\Delta K\ is\ a\ positive\ number)$ and consumption goods production decreases (ΔC is a negative number). thus the value of the slope of a ppf, $\Delta K/\Delta C$, is a negative number.

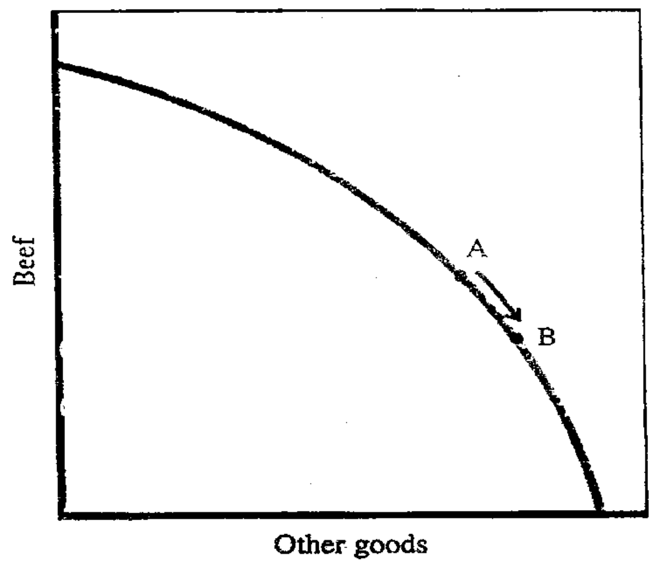


Figure (No. 3)

Inefficient Mix of Output Resulting from a Monopoly

Even if resources are combined efficiently in production, the result is inefficient if the economy is not producing the combination of goods and services that people want. This can occur if a monopoly an industry.

The value of the slope of a society's production possibility frontier is called its marginal rate of transformation (MRT). The MRT is the number of units of capital goods you can get by given up one unit of consumer goods. If in moving from E to D in figure (No.1) we gain 100 units of capital goods and give up 50 units of consumer goods, the marginal rate of transformation would be −2. how do we arrive at this figure? Remember

$$\text{MRt = slope of ppf} = \frac{\Delta Y}{\Delta X} = \frac{400-300}{500-550} = \frac{+100}{-50} = -2$$

We can transform consumer goods into capital goods at a rate of 2 to 1- two units of capital goods for every one unit of consumer goods.

A valuable feature of the production possibility frontier is that it forces you to think of opportunity cost. If we want more consumer goods, the cost is a sacrifice of capital goods.

The Shape of the Production Possibility Frontier an Increasing Opportunity Cost

We have suggested that the slope of the ppf indicates the trade-off that a society faces between two goods that it produces. We can learn something further about the shape of the frontier and the terms of this trade-off. Let us look at the trade-off between corn and wheat production in Kansas and Ohio. In a recent year Kansas and Ohio together produced 510 million bushels of corn and 380 million bushels of wheat. Table (No.1) presents these two numbers plus some hypothetical combination of corn and wheat production that might exist for Kansas and Ohio together. Figure (No.4) graphs the data from table (No.1).

Now suppose that the demand the demand for corn dramatically increases. If this happens, framers would probably shift some of their acreage from wheat production to corn production. Such a shift is represented by a move from point C up and to the left along the ppf toward points A and B in figure (No.4) as this happens it becomes more and more difficult to produce additional corn.

The best land for corn production was presumably in corn, and the best land for wheat production in wheat. As we try to produce more and more corn, the land is less and less well suited to that crop. And as we take more and more land out of wheat production, we will be taking increasingly better wheat producing land. All of this is to say that opportunity cost more corn, measured in terms of wheat, increases.

Table (No.1)

Production possibility Schedule for total wheat and corn production in Ohio and Kansas

Point on PPF	Total corn production (millions of Bushels per year)	Total Wheat production (millions of Bushels per year)
A	700	100
B	650	200
C	510	380
D	400	500
E	300	550

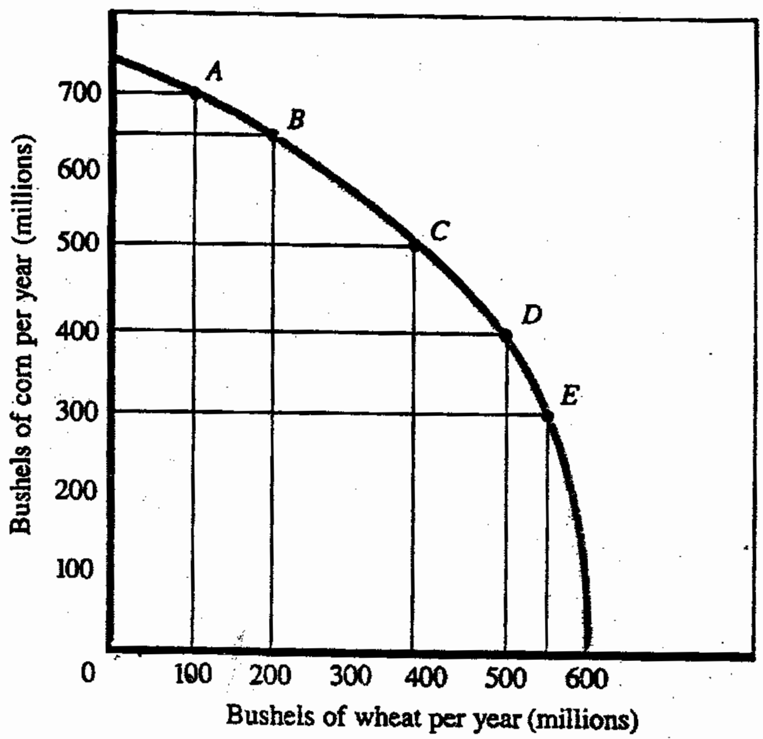


Figure (No. 4)

Corn and Wheat Production in Ohio and Kansas

The ppf illustrates that the opportunity cost of corn production increases as we shift resources from wheat production to corn production. Moving from E to D, we get an additional 100 million bushels of corn at a cost of 50 million bushels of wheat. Moving from B to A, we get only 50 million bushels of corn at a cost of 100 million bushels of wheat. The cost per bushel of corn– measured in lost of forgone wheat– has increased four times.

Moving from E to D, we can get 100 million bushels of corn (400–300) by sacrificing only 50 million bushels of wheat (550– 500) that is, we get two bushels of corn for every bushel of wheat. However, when we are already taxing the ability of the land to produce corn, it becomes more difficult to produce more corn, and the opportunity cost goes up.

Moving from B to A, we can get only 50 million bushels of corn (700−650) by sacrificing 100 million bushels of wheat (200 − 100). For every bushel of wheat, we now get only a half bushel of corn. On the other hand, if the demand for wheat were to increase substantially and we were to move down and to the right along the production possibility frontier, it would become increasingly difficult to produce wheat and the opportunity cost of wheat in terms of corn would rise.

It is important to remember that the ppf represents choices available within the constraints imposed by the current state of agricultural technology. In the long run technology may change, and when that happens we have growth.

Economic Growth:

Economic growth is characterized by an increase in the total output of an economy. It occurs when a society acquires new resources or when society learns to produce more with existing resources. New resources may mean a larger labor force or an increased capital stock. The production and use of new machinery and equipment (capital) increases the productivity of workers. Improved productivity also comes from technological and innovation, the discovery and application of new, efficient techniques of production figure (No.5) shows how growth shifts the ppf.

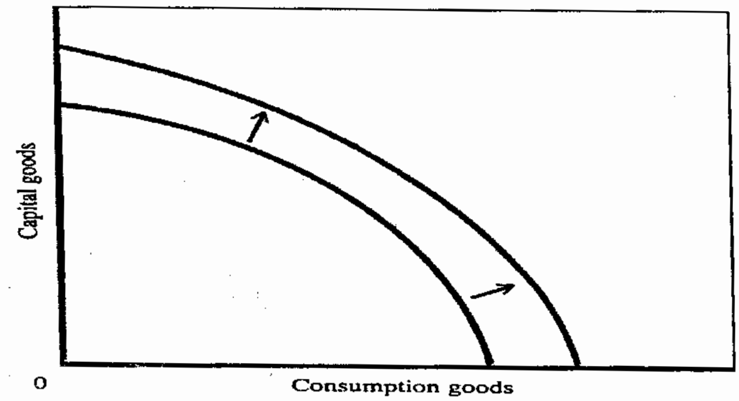


FIGURE (No. 5)

Shift of a production possibility frontier Due to economic growth

Economic growth occurs when a society acquires more resources or when a society learns to produce more with existing resources. Economic growth shifts a society's production possibility frontier up and to the right.

The last 30 years have seen dramatic increases in the productivity of U.S. agriculture. Based on data compiled by the Department of agriculture Table (No.1) shows that yield per acre in corn production has quadrupled since the late 1930s, while the labor required to produced it has dropped dramatically. Productivity in wheat production has also increased, at only a slightly less remarkable rate: output per acre has tripled, while labor requirements are down nearly 90 percent. There increase are the result of more efficient farming techniques, more and better capital (tractors, combines, and other equipment), and advances in scientific knowledge and technological change (hybrid seeds, fertilizers, and so forth). As you see in figure (No.6). increases such as these shift the ppf up and to the right.

Table (No.2)

	Corn		Wheat	
	Yield per Acre (Bushels)	Labor hours per 100 bushels	Yield per Acre (Bushels)	Labor hours per 100 bushels
1935-1939	26.1	108	13.2	67
1945-1949	36.1	53	16.9	34
1955-1959	48.7	20	22.3	17
1965-1969	78.5	7	27.5	11
1975-1979	95.3	4	31.3	9
1981-1985	107.2	3	36.9	7
1982-1986	109.3	3	37.1	7

Source U.S. department pf Agriculture, economic research service, agricultural statistics, 1989,table 566.

Sources of Growth and the Dilemma of the Poor Countries:

Economic growth arises from many sources, the two most important of which, over the years, have been the accumulation of capital and technological change. for poor countries capital is essential: they must build the communication networks and transportation systems necessary to develop industries that function efficiently. They also need capital goods in order to develop their agricultural sectors.

Recall that capital goods are produced only at a sacrifice of consumption goods. The same can be said for technological change. Technological change comes from research and development that uses resources, and thus it too must be paid for. The resources used to produce capital goods – to built a road, a tractor, or a manufacturing plant-and to develop new technologies could have been used to produce consumption goods.

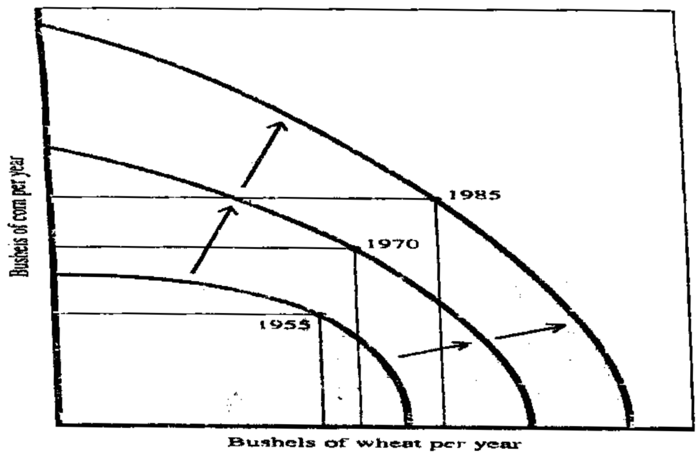


Figure (No. 6)

Increasing productivity shifts the ppf up to the right productivity increases enhanced the ability of the United States to produce both corn and wheat. As table (No.2) shows, productivity increases were more dramatic for corn than for wheat. The shifts in the ppf were thus not parallel.

Note the ppf also shifts if the amount of land or labor in corn and wheat production changes. Although we emphasize productivity increases here, the shifts between years were in part due to land and labor changes.

When a large part of a country's population is very poor, taking resources out of the production of consumption goods such as food and clothing is very difficult. in addition, in some countries those wealthy enough to invest in domestic industries may choose instead to invest abroad because of constant political turmoil at home. As a result, it often falls to the government to generate revenues for capital production and research out of tax collections.

All of these factors have contributed to the growing gap between rich and poor nations. Figure (No.7) graphs the result, using production possibility frontier. On the left, the rich country devotes a larger portion of its production to capital, while the poor country produces mostly consumption goods. On the right, you see the result: The ppf of the rich country shifts up and farther and faster.

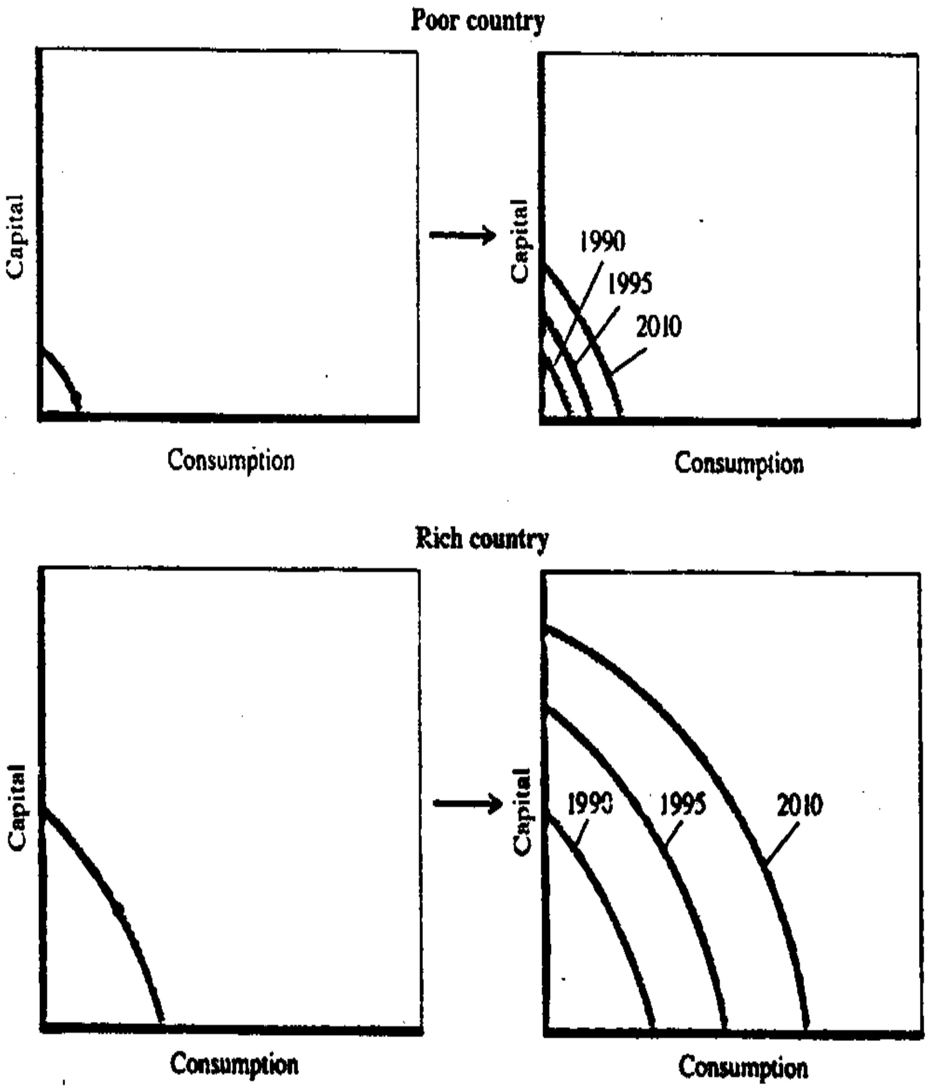


Figure (No.7)

Capital goods and growth in poor and Rich countries

Rich countries find it easier to devote resources to the production of capital than poor countries do. But the more resources that flow into capital production, the faster the rate of economic growth. Thus the gap between poor and rich countries has grown over time.

Questions

For each item, determine where the statement is basically true or false:

1) Human wants are unlimited, and resources are scarce.
2) Resources force individuals and societies to choose.
3) Central function of any economy is to transform resources into useful form in accordance with those choices.
4) The production is the transformation of resources into useful form in accordance with choices of society.
5) The term resources may be capital resources not nature resources.
6) Knowledge are an important part of a nation's resources.
7) Consumers are those who take resources and transform them into usable products, or outputs.
8) Resources have alternative uses.
9) Every economy does not face the basic economic problem.
10) Resources are scarce if demand is less than its availability.
11) Only producers face economic problems.
12) A PPC is drawn on the assumption that resources of the economy are increasing.

13) A point inside the production possibility curve shows underutilization of resources.

14) Unemployment of labour means that resources are not being fully employed.

15) Better technology will lead to an inward shift of the production possibility curve.

16) A production possibility curve can depict more than two goods in an economy.

17) An economy needs to choose the point at which it wishes to operate on the production possibility curve, as all points are equally efficient.

18) Private manufacturing firms and government purchase resources and produce products for the market.

19) National defense and fire protection are examples of outputs produced by the government.

20) Consumer goods are anything that is produced that will be used to produce other goods or services over time.

21) Capital need be tangible.

22) A wise investment in capital is one the yields future benefits that are less valuable than the present cost.

23) The increasing the productivity of labor can generate future benefits in excess of cost.

24) The production possibility frontier illustrates the principle of constrained choice and scarcity.

25) The PPF is a graph that shows some combinations of goods and services that can be produced if all of society's resources are used efficiently.

26) All points below and to the left of the PPF, represent combinations that cannot be reached.

27) Points that are actually on the PPF can be thought of as points of full employed and not production efficiency.

28) Points that are above and to the right of the PPF, resources are not going unused, and there is not waste.

29) All points below and to the left of the PPF, represent either unemployment or production inefficiency.

30) The opportunity cost of producing more capital goods is that fewer consumption goods can be produced.

31) To produce more capital goods, ⌂C shows an increase and ⌂K shows a decrease.

32) Unemployment of labor is not necessary means unemployment of capital.

33) When there is unemployment we are not producing all the we can.

34) An efficient economy is one that produces the things that people want at the least cost.

35) An economy is inefficient when it is producing inside its PPF.

36) An economy is inefficient when it is producing at the wrong point bon the PPF.

37) A badly managed economy will not produce up to potential and will be inside the PPF.

38) When those resources are fully and efficiently employed it can produce more consumption goods only by reducing production of capital goods.

39) Inefficient mix of output resulting from a monopoly.

40) The value of the slope of a society's production possibility frontier is called its marginal rate of transformation (MRT).

41) The MRT is the number of units of capital goods you can get by given up one unit of consumer goods.

42) If we want more consumer goods, the cost is a sacrifice of capital goods.

43) The slope of the PPF indicates the trade-off that a society faces between two goods that it produces.

44) In the long run technology may change, and when that happens we have growth and the PPF shift to the left.

45) Economic growth is characterized by an increase in the total output of an economy.

46) Economic growth occurs when a society acquires new resources or when society learns to produce more with existing resources.

47) Economic growth shifts a society's production possibility frontier up and to the right.

48) Economic growth arises from many sources, the accumulation of capital and technological change.

49) Capital goods satisfy society's wants at the present.

50) Investment in economics is the creation of capital or producing additional capital.

51) Unemployment means that large portions of the nation's capital and labor are idle and being wasted.

52) Unemployment occurs because of misallocation of resources.

53) Economic growth is shown graphically as a leftward or outward shift of the production possibilities curve.

54) The reason economic growth occurs is because of increases in our capital stock.

55) When the PPF is a straight line, the economy is experiencing constant cost.

56) Opportunity cost and cost are synonyms.

57) Society's production possibilities curve bows out because of decreasing opportunity cost.

58) Money is a resource.

59) The circular flow of income model consists of resources and money, which flow in the opposite direction.

60) There are only three general types of markets.

61) Scarcity implies choice, which in turn implies opportunity cost.

62) An opportunity cost is the highest preferred alternative taken.

63) Businesses supply goods and services to household.

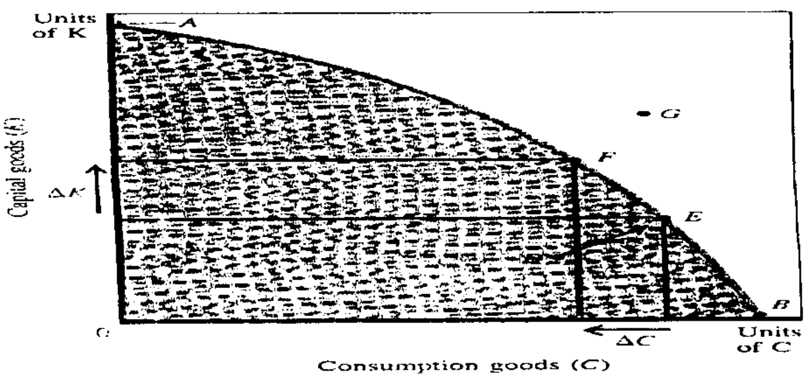
64) Households demand resources.

65) Investment goods are synonymous with capital products.

66) Specialization and trade based on comparative advantages increase our production possibilities.

67) Capital products include plant and equipment.

68) Opportunity costs are always measured by the value of the next best alternative.



From the above figure:

69) If an economy operates at point (A), it would be producing only capital goods and no consumer goods.

70) If an economy operates at point (B), it would be devoting all of its resources to the production of consumer goods and none of its resources to the formation of capital.

71) Point (F) will give the greatest rate of economic growth.

72) If the united states produce some of each kind of good, emphasize about 19% of gross output is new capital. And also in Ethiopia, capital accounts for 32% of gross output, while in japan is only around 10%. So, Japan is closer to point A on its PPF, Ethiopia closer to B, and the United States is somewhere in between.

Consider the following PP between products X & Y

Products	
X	Y
0	20
1	18
2	14
3	8
4	0

73) The opportunity cost of producing the 1st, 2nd, 3rd, 4th units of X are 2Y, 4Y, 8Y, 6Y respectively.

74) The opportunity cost is decreasing.

75) Resources are not perfectly adapted to all uses or to alternative resources.

In this case the PPF will be bowed in.

Completion:

The production possibilities curve is a model that shows we are faced with_______________ that_______________ have to be made, and that _______________ will be incurred with any decision. This is the value of the most highly preferred alternative not taken. Scarcity is shown in the model by the fact that a point_______________ (inside/outside) the curve is unobtainable in this period of time.

We begin with two basic choices. The first is whether to employ our resources fully and efficiently. If we choose to employ our resources fully and efficiently, this is shown as a point_______________ (inside/outside/on) the production possibilities curve. If we do not employ our resources fully and efficiently, this is shown as a point _______________ (inside/outside/on) the curve. Second, we have the choice of how to allocate our resources. If we devote a relatively high percentage of our scarce resources to the production of investment.

(capital) products, we will experience a _______________ (greater/smaller) rate of economic growth. Economic growth is shown graphically as a _______________ (rightward or outward/leftward or inward) shift of the production possibilities curve. The reason economic growth occurs is because of increases in our _______________ (capital/consumer) stock.

Consumption goods satisfy our wants____________ (directly/indirectly) and in the ____________ (present/future). Investment goods satisfy our wants____________ (directly/indirectly) and in the ____________ (present/future). It may be tempting to choose many want-satisfying products now, but they will come at the expense of a ____________ (lower/higher) rate of economic growth. So in making a choice between consumption goods and investment goods, an____________ Is involved.

The opportunity cost of more investment goods is ____________ (fewer/more) consumption goods, and vice versa, for as we produce more and more of one type of product we will have to give up proportionately____________ (greater/smaller) amounts other products. That is to say, the opportunity cost of producing more and more of one type of product____________ (decreases/increases).

This is because resources are____________ (perfectly/not perfectly) adaptable to alternative uses. Because of increasing opportunity costs, the production possibilities curve bows____________ (in/out) from the origin.

In reality, the actual choice between consumption goods and investment goods is determined by the market process, the political process (governments), and the interaction between the two.

The production possibilities curve can also be used to show the choice between public goods and private goods. But the essential concepts are the same as before. That is, there are ____________ (increasing/decreasing) opportunity costs associated with producing greater amounts of one type of product. The choice between public and private goods and the consequent effect on economic growth depends on the number of capital products produced. in other words, producing more or fewer public goods must be judged as contributing or not contributing to economic growth on the basis of whether it is_______________ (increasing/decreasing) our capital stock.

We know that increasing our nation's capital stock will cause economic growth and that economic growth_______________ (increases/decreases) our production possibilities. Specialization and trade based on comparative advantage also_______________ (increases/decreases) our production possibilities. For specialization and trade to be efficient, we need a _______________ (money/barter) economy. Anything that is generally acceptable as a medium of exchange is _______________ (money/a resource). Money must also act as a _______________ (store of purchasing power/resource). Money facilitates specialization and trade based on_______________ (comparative/absolute) advantage.

A diagram that shows the interdependence between consumers (households) and producers (businesses) is known as the _______________model. This model shows the_______________ (independent/interdependent) relations between_______________ (narrow/broad) segments of the economy. A simple circular flow of income model incorporates only the private sector. The private sector consists of_______________. and _______________ As the ultimate owners of resources, consumers________________ (demand/supply) resources to producers. Producers use these resources to produce ________________ therefore, the producers ________________ (supply/demand) goods and services to consumers. On the other hand____________________(consumers/producers)____________________ (supply/demand) resources from households in the form of money payments. The flow of money from businesses to households constitutes the income to households. With this income, the ________________ (households/businesses) ________________ (supply/demand) goods and services. However, because the control over resources is not equally distributed, a nation's income is not equally distributed. Therefore goods and services are not equally distributed.

For a market to exist, there must be a ________________ (demand/supply) for and a ________________ (demand/supply) of the item. From the simple circular flow model, we can see that, in the product market, households do the ________________ (demanding/supplying) while businesses do the ________________ (demanding/ supplying). In the resource market, households do the ________________ (demanding/ supplying) while businesses do the ________________ (demanding/supplying).

Problems and applications

1- Consider the following production possibilities between products X and Y.

Product X	Product Y
0	20
1	18
2	14
3	8
4	0

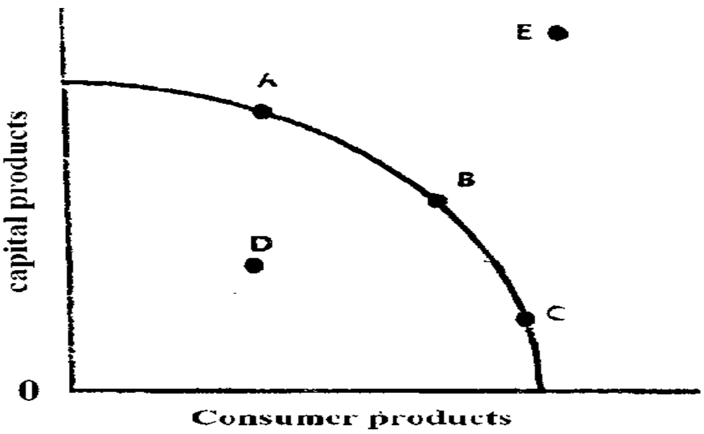
a. What is the opportunity cost of producing the first unit of X? The second unit of X? The third unit of X? The fourth unit of X?

b. Is the opportunity cost of producing successively larger amounts of X increasing, decreasing, or remaining the same?

c. What is the economic justification for increasing opportunity costs?

d. If this production possibilities curve was graphed, would it be a straight line or would it bow out or in with respect to the origin?

2. Answer the following questions based on the production possibilities curve.



a. Which of the points shown would give the greatest rate of economic growth?

b. What does point D represent?

c. What does point E represent?

d. what do points A, B and C represent?

3- Consider the production possibilities of Dana and Julio shown below.

	Dana		Julio
Good X:	0 1 2 3 4	**Good X:**	0 2 4 6 8
Good y:	8 6 4 2 0	**Good y:**	32 24 16 8 0

a. Is increasing opportunity cost applicable for either Dana or Julio?

b. For Dana, what is the opportunity cost of X in terms of Y for each of the production possibilities? Of Y in terms of X?

c. For Julio, what is the opportunity cost of X in terms of Y for each of the production possibilities? Of Y in terms of X?

d. Who has the comparative advantage in the production of X? Of Y?

e. Assume Dana and Julio each specialize in the production for which they have a comparative advantage (Dana produces all X and Julio produces all Y). However, both Dana and Julio would like to have some X and some Y. what would be fair terms of trade?

f. Would Dana and Julio both be better off by specializing in their comparative advantage and then trading?

4. Draw a simple circular flow of income model. Indicate by arrows who is doing the demanding and the supplying.

5- What would happen to our production possibilities if we could develop a very cheap synthetic fuel?

6- Use graphs to express a positive (direct) relationship and an inverse relationship between any independent and dependent variables. (Note: an independent variable goes on the horizontal, or X, axis and a dependent variable goes on the vertical, or Y, axis.)

True-false

For each item, determine whether the statement is basically true or false. If the statement is false, rewrite it so it is a true statement.

1- Scarcity implies choice, which in turn implies opportunity cost.

2- Businesses supply goods and services to households.

3- An opportunity cost is the highest preferred alternative taken.

4- Allocating a relatively greater amount of our scarce resources to the production of consumption goods will give us a greater amount of economic growth in the future.

5- Unemployment is shown as a point outside the production possibilities curve.

6- Households demand resources.

7- Economic growth is shown as a leftward (inward) shift of the production possibilities curve.

8- Increases in our capital stock contribute to economic growth.

9- The actual choice between consumption goods and investment goods we end up with is determined by the market process, the political process (government), and by the interaction between the two.

10- Because resources are perfectly adaptable to alternative uses, we have increasing opportunity cost.

11- Specialization and trade based on comparative advantage increase our production possibilities.

12- Money is a resource.

13- A market exists if there is demand for the item.

14- The circular flow of income model consists of resources and money, which flow in the opposite direction.

15. There are only three general types of markets.

16. In the product market, businesses (producers) do the demanding.

17. Investment goods are synonymous with capital products.

18- Opportunity cost and cost is synonyms.

19. Our nation's distribution of income is determined by control over resources.

Multiple choices

Choose the one best answer for each item.

1- Society's production possibilities curve bows out because

a. we are faced with scarcity.

b. a point inside the curve represents unemployment.

c. we attempt to maximize our output given our limited resources.

d. of increasing opportunity cost.

e. resources are perfectly adaptable to alternative uses.

2- The combination of consumption goods and investment goods that we end up with.

a. will have to be a point inside the production possibilities curve

b. will have to be a point on the production possibilities curve

c. is determined by market process.

d. is determined by the market process, the political process, and the interaction between the two

e. none of the above

3- With respect to the production possibilities curve, economic growth is shown by

a. a point outside the curve.

b. a movement along the curve toward more investment goods and fewer consumption goods.

c. increasing opportunity cost.

d. a leftward shift of the curve

e. a rightward shift of the curve.

4- A production possibilities curve

a. represents different combinations of goods that can be produced if we employ all our resources fully and efficiently.

b. bows out.

c. shows we are faced with scarcity.

d. shows we are faced with increasing opportunity cost

e. all of the above.

5- Which of the following may increase our production possibilities?

a. cost sharing

b. specialization of labor

c. economies of scale

d. the use of money to facilitate trade

e. all of the above

6. The three basic types of markets in a capitalist system are the

a. product, resource and money markets.

b. private, government, and international markets

c. labor, capital, and technology markets.

d. product, resource, and international markets.

e. government, product, and resource markets.

7. Capitalism is characterized by

a. the concept of private property

b. producers and consumers.

c. economic activity coordinated through the market system

d. a and b

e. a and c

8. Capital products

a. include plant and equipment.

b. contribute to economic growth

c. satisfy our wants indirectly.

d. are produced at the expense of consumer products when we employ all of our resources fully and efficiently

e. all of the above

9- Which of the following is true of opportunity cost?

a. it is stated in terms of dollars and cents.

b. it is incurred when moving from a point inside the production possibilities curve to a point on the curve.

c. it decreases as we move down along the production possibilities curve.

d. it is applicable to any choice that is made.

e. it is not applicable for government policymakers.

10. Which of the following will definitely increase our production possibilities?

a. more private goods and less public goods

b. diseconomies of scale

c. more consumer goods and less capital goods

d. specialization and trade based on comparative advantage

e. a greater reliance on the political process to allocate our resources.

11. **Which of the following would not be included in the product market?**

a. automobiles purchased by consumers

b. bulldozers purchased by businesses

c. home computers purchased by consumers

d. steak purchased for consumption

e. boots purchased by consumers

Discussion questions:

1. Is it possible to devote too many resources to investment goods?

2. We know that the range of fair terms of trade may be quite wide. What do you think determines the actual terms of trade between two nations who have a comparative advantage in different products?

3. Is it possible to specialize labor too much?

4. Constant opportunity cost means resources are perfectly adaptable to alternative uses. Constant opportunity cost characterizes some alternative production processes, such as gasoline and heating oil in oil refineries. Can you think of any others?

5. Why is it that many doctors and lawyers share the same office and equipment?

6. Why has the Soviet Union experienced a higher rate of economic growth than the United States since World War II?

7. Why do public utilities operate on such a large scale? Would we all be better off with our own generating plants in our backyards?

8. The cost of higher education is usually associated with tuition and fees, books, room and board, entertainment, and so on. Is there another cost that one must consider?

9. What effect may population growth have on our production possibilities and our standard of living?

Fill – in – the blank questions:

1- The most important word in economics is________________

2- The three economic questions every system must answer are ________________

3. Statements based on opinion or personal values are called________________ Statements.

4. Statements that can be verified or refuted by looking at the facts are called ________________ statements.

5- Economists often use equations, graphs, or word to abstact from the real world the most important elements in order to explain economic outcomes. These________________ allow economists to make reliable predictions.

6. When an economy is operating on its production possibilities frontier and as a result the highest level of material well-being is achieved, we say the economy is operating________________

7. A graphic device used to show the possible combinations of goods and services that an economy can produce is called the ________________

8- When the PPF is bowed out in shape, the economy is experiencing________________ costs.

9. When the PPF is a straight line, the economy is experiencing ________________ costs.

Multiple choice questions

1- The three basic economic questions are

a. what, where, and when

b. how, where, and when.

c. what, how, and for whom.

d. for whom, when, and how much.

2. A movement of an economy from a point inside its production possibilities frontier (PPF) to a point on the PPF indicates that

a. there has been economic growth.

b. previously unemployed resources are now being employed or are being used more efficiently.

c. the economy's resources have increased.

d. more women are participating in the labor force.

3. Which of the following is the best example of positive economics?

a. steelworkers ought to get higher wages.

b. oil companies are making profits that are too high.

c. higher energy prices tend to reduce energy consumption.

d. social security benefits should be only for the needy.

4. A point to the right of the current production possibilities frontier could be attained by

a. changing opportunity costs.

b. economic growth

c. eliminating inefficiency in management

d. changing political philosophies

5- Which of the following will cause an economy's PPF to shift outward?

a. a reduction in the unemployment rate

b. a change in the combination of commodities produced

c. an increase in technological know-how

d. a decline in the number of women in the labor force

The following information applies to questions 6-8. Assume the following maximum output in bushels per labor hour.

	Wheat (in bushels)	**corn (in bushels)**
Canada	**6**	**12**
United States	**8**	**15**

7- The United States has an absolute advantage in the production of

a. corn.

b. wheat.

c. both corn and wheat

d. neither corn nor wheat

8- In order for there to be no comparative advantage, the numbers of bushels would change as follows:

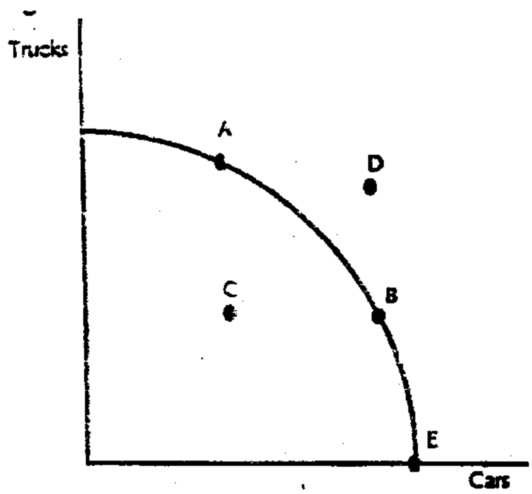
a. change Canada's twelve to fifteen

b. change United States' fifteen to sixteen.

c. change Canada's six to eight.

d. change United States eight to twelve.

Use the following figure to answer questions 9–12.



9. The opportunity cost of producing an additional car is

a. higher at point A than point B

b. higher at point B than point A

c. the same at point A than point B

d. impossible to tell from the graph

10. If the economy is operating at point A, which of the following is true?

a. the United States is inefficient at producing cars and trucks.

b. there is no scarcity of cars or trucks.

c. the economy experiences constant costs in the production of cars.

d. point A is preferable to point C.

11. **The PPF indicated in the figure is characterized by**

a. increasing costs

b. decreasing costs.

c. constant costs.

d. first increasing, then decreasing costs.

12. **Given the PPF indicated in the figure, which point (c) represent (c) an inefficient use of resources?**

a. C and E

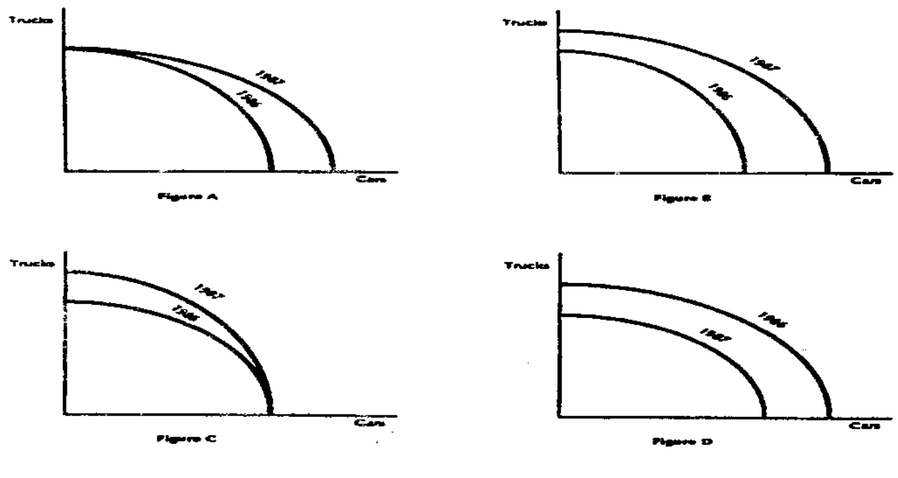
b. C and D

c. C

d. D

e. E

13. **Which one of the figures below represents an improvement in the technology for truck production from 1986 to 1987?**



a. A

b. B

c. C

d. D

True-false question

1- The study of normative economics is requisite to the study of positive economics.

2- Any time there is a market price for any particular good or service, it can be described as scarce

3- If the economy is operating within the production possibilities frontier, additional output can be secured by moving toward the frontier.

4- Opportunity costs are always measured by the value of the next best alternative.

5- The existence of comparative advantage between two producers who trade leads to a lower level of combined output

6- A decline in the rate of productivity growth implies that output per labor hour is declining.

7- The PPF is a straight line when there are no opportunity costs.

8- If Japan has an absolute advantage over the United States in the production of automobiles and computers, there are no gains to be made from specialization and trade between the two countries.

Chapter Two

Resource Allocation over Time

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Allocation of Nonrenewable Resources

Resources can be renewable or nonrenewable. Renewable resources, if properly managed, can last indefinitely. We might reasonable expect that a well-managed farm, forest, or fishery could remain productive for centuries. Nonrenewable resources, on the other hand, cannot last forever. Some may be in relatively short supply. Examples would be high-grade deposits of copper ore or crude oil supplies. This raises questions of how much of these nonrenewable resources we use today and how much we save for future use, or for future generations.

A common concern is that we are using up earth's resources too fast. Another point of view is that technological progress and adaptation will avoid resource shortages. What does economic theory have to say about this issue?

A simple version of nonrenewable resource analysis begins by assuming that we have a known, limited quantity of a resource of a resource that we can use during two different time periods. The supply of high-grade copper, for example, is relatively fixed in amount. How should we allocate this limited resource between current and future time periods?

If we consider all possible future periods, the problem becomes more complex (though not theoretically insoluble, as we will see). A simple initial model of nonrenewable resource allocation deals with only two time periods. Our economic analysis will weigh the economic value of copper in the present as compared with copper in the future. Owners of copper deposits will decide whether to exploit them immediately, or to hold them for a future period, based on an estimate of probable future prices. We can formulate the problem as a simple extension of standard supply and demand theory.[1]

Equilibrium in The Current Time Period

First, let us consider only the current time period. Figure (1a) shows a hypothetical supply and demand for copper. From this we can derive the marginal net benefit curve for copper, which shows the difference between value to the consumer and cost of supply for each unit of copper. (for example, if we can extract a unit of copper for $50 and its value to the purchaser is $150, its marginal net benefit is $100.)

Graphically, marginal net benefit is the vertical difference between the supply curve and the demand curve. Marginal net benefit is generally largest for the first units extracted, then declines to zero at equilibrium (where the supply and demand curves meet). If we were to produce more than the equilibrium quantity, marginal net benefit would become negative as supply costs rise above the value to the purchaser.

The marginal net benefit concept is a handy way of compressing into one curve information about both supply and demand in one period. The marginal net benefit of copper in the present period is shown by curve MNB in figure (1b).

Algebraically, if the demand and supply schedules are given by

$$P_d = 150 - 0.25Q_1$$

and

$$P_s = 50 - 0.25Q_1$$

Marginal net benefit is given by

$$\text{MNB} = P_d - P_s = 100 - 0.5Q_1$$

At the supply and demand equilibrium of $Q_1 = 200$, marginal net benefit is zero, indicating that producing and consuming more than 200 units of copper will provide no additional net benefit. The area under the marginal net benefit curve shows total net benefit (just as the area under a demand curve shows total benefit and the area under a supply curve shows total cost).

When marginal net benefit is just equal to zero, total net benefit is maximized (as shown by the area under the marginal net benefit curve in Figure (1b). this corresponds to the ordinary supply and demand equilibrium for the first period, at quantity of 200 and a price of 100. We will call this the static equilibrium− the market equilibrium that will prevail if only present costs and benefits are considered.

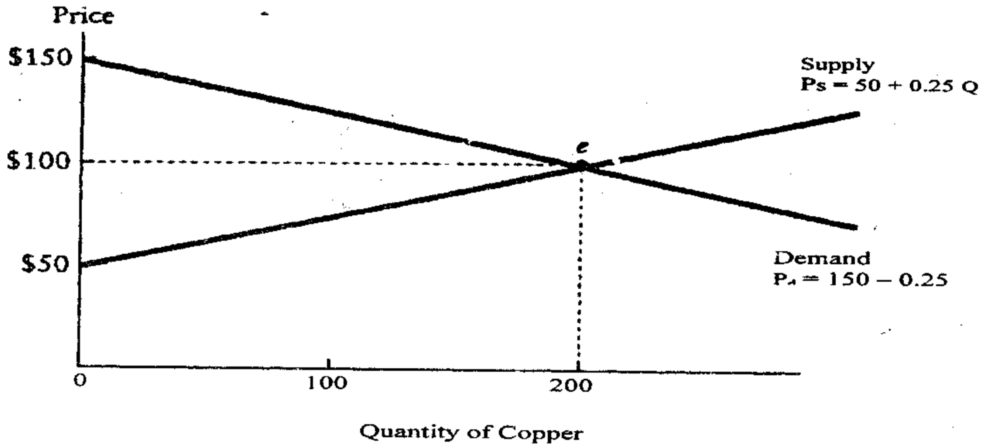
Balancing Present and Future Periods

Now let's consider the marginal net benefit of copper in the second time period. We cannot know this value for sure, of course, because no one can foretell the future, but we do know that a fixed quantity of copper must be divided between the two periods. Let's make a simplifying assumption that the marginal net benefit of copper in period 2 will be exactly the same as in period 1. (this assumption is not necessary for the analysis, but it will make our first example simpler.)

A graphical trick will allow us to compare the two periods. We use the horizontal axis to measure the total available quantity of copper- say, 250units- and put the marginal net benefit curve for the first period, MNB1 on this graph in usual way. Then we put the marginal net benefit curve for the second period, MNB2, as on the graph in mirror-image fashion, going from right to left. thus we have two horizontal scales, with the quantity used in period 1 shown left to right, and the quantity used in period 2 shown right to left (Figure 2).

One more step will complete our analysis. Because we want to compare two different time periods, we must translate future values into their equivalent in present values. The economic concept of present value relies on use of a discount rate to convert future to present monetary values. Suppose, for example, I promise to give you $1,000–ten years from now. What is the value of this promise today?

(a) Supply and Demand for Copper



(b) Marginal net benefit for Copper

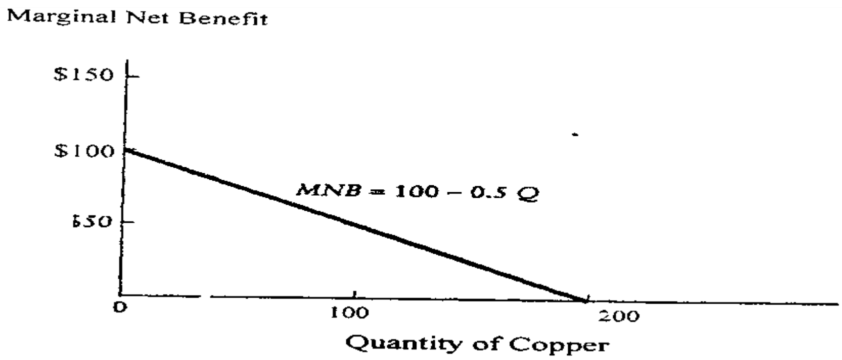


FIGURE 41 *Supply, Demand, and Marginal Net Benefit for Copper*

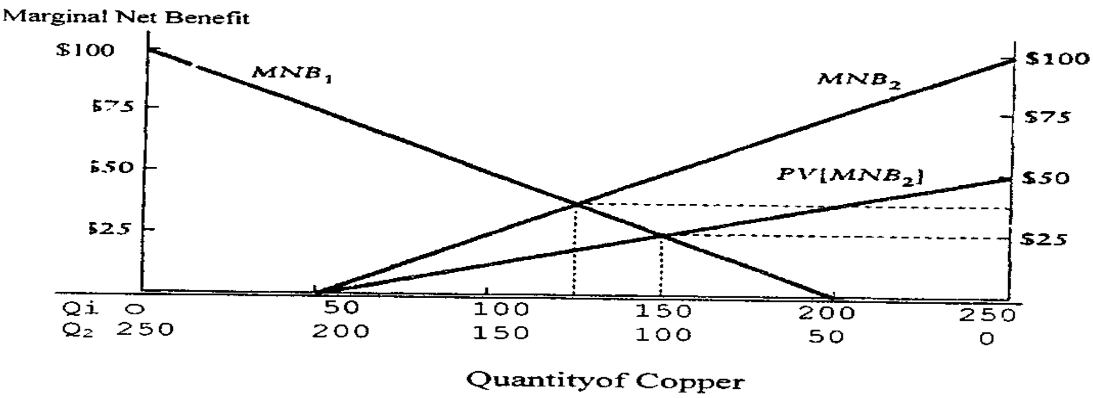


Figure 2 Allocation of Copper over Two Time Periods

Assuming I am trustworthy and you will definitely receive the money, the answer depends on the discount rate, reflected in financial terms as a rate of interest on deposits. Let us assume a 7.25 percent interest rate. Five hundred dollars put in the bank today at compound interest would be worth almost exactly \$1,000 in ten years. We can say that the present value of \$1,000 to be received ten years from now is equal to \$500 in cash today. In other words, you would be equally well off with \$500 today or \$1,000 ten years from now.

Using this present value method, we can convert the marginal net benefit of copper in period 2 into period 1 values. We do this using the formula:

$$\text{PV } [MNB_2] = MNB_2\ /(1\ +\ r)^n$$

Where r is the annual discount rate and n is the number of years between periods. If r = 0.0725 or 7.25%, and n =10, we can closely approximate PV [$MNB2$] as

$$MNB2/(1.0725)10 = MNB2/2$$

This present value of marginal net benefit schedule for period 2 is shown in Figure2 as a line exactly half the height of the undiscounted MNB_2

Dynamic Equilibrium for Two Period

The reason for special graphical format now becomes apparent. Consider the point where the two curve MNB_1 and PV [$MNB2$] cross. At this point the present value of the marginal net benefit of one unit of copper is the same in both time periods. This is the optimum economic allocation between periods since at this point no additional net benefit can be obtained by shifting consumption from one period to another. As you can see from the graph, this optimal allocation is 150 units in period 1 and 100 units in period 2. Algebraically, we obtain this solution by solving two equations:

$$\boldsymbol{MNB_1} = \textbf{PV } [\boldsymbol{MNB_2}]$$

And

$$\boldsymbol{Q_1 + Q_2 = 250}$$

The second equation is the supply constraint, which tells us that the quantities used in the two period must sum to exactly 250, the total quantity available. We can solve the equations as follows:

$$\boldsymbol{MNB_1 = 100 - 0.5Q_1 = MNB2 = (100 - 0.5Q2)/2}$$

$$\boldsymbol{100 - 0.5Q_1 = 50 - 0.25Q_2}$$

Because $\boldsymbol{Q_1 + Q_2 = 250}$, $\boldsymbol{Q_1 = 250 - Q_2}$ substituting this in we have:

$$\mathbf{100 - 0.5\ (250 - Q_2) = 50 - 0.25Q_2}$$

$$\mathbf{0.75Q_2 = 75}$$

$$\mathbf{Q_1 = 150;\ Q_2 = 100}$$

We can check the assertion that this solution is economically optimal by using the kind of welfare analysis, (see Figure 3). By choosing the equilibrium point where $Q_1 = 150$ and $Q_2 = 100$, we have achieved maximum total net benefit, shown by the shaded area A +B in Figure 3a. (Area A is the net benefit in the first period, area B the net benefit in the second period).compare this result with welfare effects of any other allocation, for example, the allocation $Q_1 = 200$, $Q_2 = 50$. As shown in Figure 3b, total welfare for two periods is less with this new allocation (by the area B_2). B_1 shifting fifty units from period 2 use to period 1 use, we have gained a first−period benefit equal to A_2, but lost a second−period benefit equal to $A_2 + B_2$ for a net loss of B_2. Total welfare is now $A_1 + A_2 + B_1$ less than the area A + B in figure 3A. Similarly, any other allocation we try will prove inferior to the optimal solution of $Q_1 = 150$, $Q_2 = 100$. (try, for example, $Q_1 = 100$, $Q_2 = 150$. Show the effect of this allocation on total net benefit)

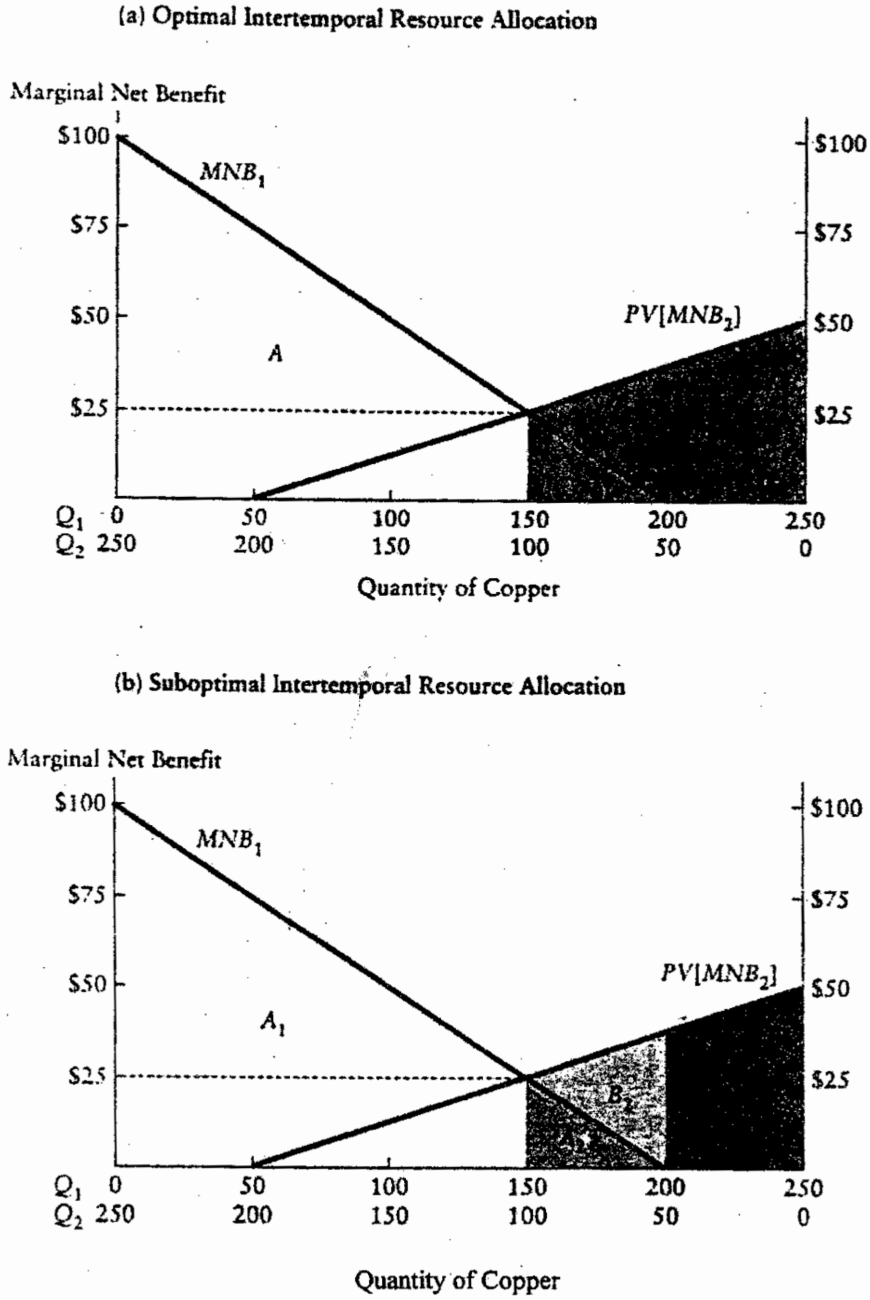


FIGURE (3) *Different Intertemporal Resource Allocations*

User Costs and Resource Depletion

Let's translate what we have learned from this algebraic and graphical analysis into more common-sense terms. We Know that we can increase our, benefit today by using more copper (in this example up to 200 units, which is the most we would use today if we took no account of future needs). If we chose to use only fifty units today, two hundred would be left for the next period – enough to fulfill the maximum demand in that period. At any use level greater than 50 units, we start to cut into the amount of copper available for future use.

Another way of putting this would be to say that we start imposing costs on-future consumers of copper by using up copper today. On our graph, those user costs show up as the steadily rising curve PV[MNB2]. The more we use today, the higher these costs become. User costs are in fact a different kind of third-party cost or externality- externalities in time.

We can justify using up copper today so long as the benefits from doing so outweigh user costs imposed on future citizens. But once the user costs become higher than the benefits from consumption today-in our example, at any level of present consumption above 150 units- we reduce total economic welfare by our excessive present consumption. Going back to our algebraic and graphical analysis, we define an exact value for the user cost at the period 1 consumption level we have defined as is optimal. The vertical distance to the intersection point of MNB_1 and PV[MNB_2]shows the user cost at equilibrium. We can calculate this easily by evaluating either MNB_1 or PV[MNB_2] at the intersection point where Q_1= 150 and Q_2= 100.

User cost = $\boldsymbol{MNB_1 = 100 - 0.5(150) = 25}$

Or

PV[$\boldsymbol{MNB_2}$]= $\boldsymbol{50 - 0.25(100) = 25}$

The user cost at equilibrium is thus $25.

What does this mean? Suppose we go back to the original supply and demand schedules for period 1 (redrawn in Figure 4a). if we don't consider period 2 at all, the market equilibrium in period 1 will be 200 units of copper at a price of $100. Now suppose we add to the ordinary supply costs the user cost derived from Figure 2 – just as we added an environmental external cost to the ordinary supply costs in the previous section. The result is shown in Figure 4a as the social cost schedule S'.

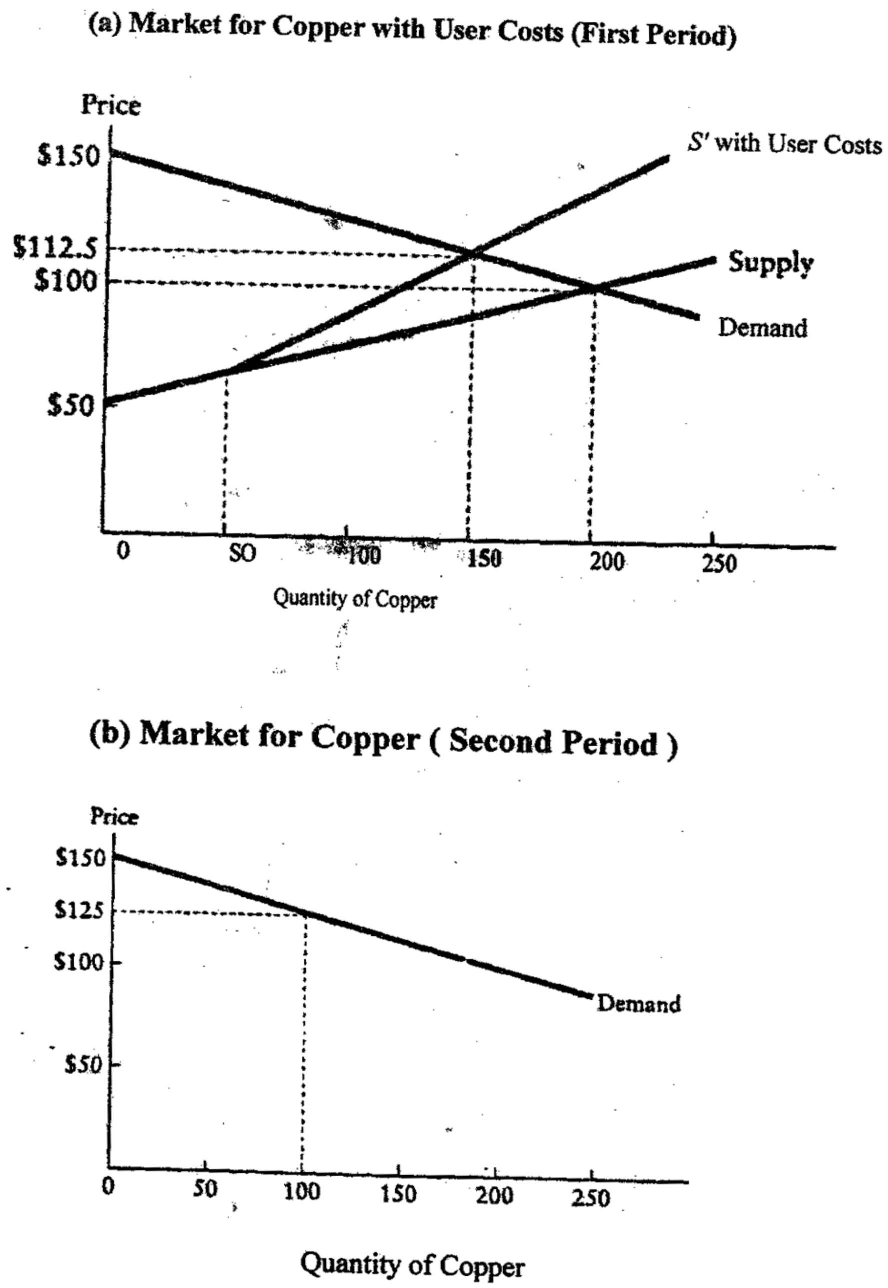


FIGURE (4) *Market for Copper in Two Periods*

A new equilibrium appears at 150 units of copper consumption, with a price of $112.50. the user cost at this new equilibrium is $25 – the vertical distance between the old supply curve S and the new social cost curve S'. with a first-period consumption of 150 units, 100 units will remain for consumption in the second period, at a second-period price of \$125 (assuming demand conditions are unchanged). This is shown in Figure 4b.

If user costs are internalized in this fashion, the new market equilibrium, known as dynamic equilibrium, reflects both the needs of the present and of the future. The higher price will send a signal to producers and consumers of the resource to produce and use less today, thereby conserving more for the future. But how will user costs be reflected in the market?

One possibility is a resource depletion tax imposed on copper ore production and sales. Like a pollution tax, this tax will raise the effective supply schedule to the real social cost S'. Other policy mechanism could include direct government control of resource exploitation, setting aside resource deposits or maintaining stockpiles.

In some cases, however, government intervention may not be necessary for user costs to be internalized into the market. This would be true especially if the time period until expected resource exhaustion is relatively short. In this case, private owners of the resource will anticipate the second-period situation and act accordingly.

If resource shortages are foreseen, profit-seeking resource owners will hold some copper stocks off the market or leave copper ores in the ground and wait for the higher prices likely to prevail in a shortage. This supply limitation will have exactly the same effect (a leftward and upward shift of the supply curve to S') as the imposition of a resource depletion tax. In this case no tax is necessary- the market process will automatically adjust for anticipated future limits on copper resources.

Hotelling's Rule and Time Discounting

What if we want to consider the real world, which presents not two periods but an infinite number of future periods? How much copper should we be prepared to set aside for 50 years from now? One hundred years extending our two –period analysis to a more general theory offers perspective on these issues. Such question tests the limits of our economic model and also address the interrelationship between social values and the more specific market values we deal with in economic theory.

We can calculate the new first- and second period prices using the original equations for the supply and demand schedules, with $25 added to the first period supply schedule to reflect the user cost. For the first period this gives us

$$P_d = 150 - 0.25Q_1 \; and \; P_s = 75 + 0.25Q_1$$

Setting these equal and solving, the first–period equilibrium is

$$Q_1 = 150. P_1 = 112.5$$

Because we know only 100 units remain for the second period, we can use the demand curve for the second period 9which we assumed to be the same) to solve for the second period price:

$$P_2 = 150 - 0.25(100) = 150 - 25 = 125$$

Our simple two period example makes clear that the discount rate is a critical variable. At different discount rates, the optimal allocation of copper between the two period will vary significantly. Let's start at one extreme – a discount rate of zero. In the example, the equilibrium allocation of copper would be 125 units consumed in each period. at a discount rate of zero, future net benefits receive exactly the same value as if they were current net benefits. The available copper is therefore divided evenly between the period.

At any discount rate above zero, we favor present consumption over future consumption to some degree. At a very high discount rate – say 50 percent per annum– the first period allocation of copper is 198 units, close to the 200 units that are consumed in the static equilibrium case, and user costs fall nearly to zero. In general, at high discount rates we weight present benefits much more heavily than future benefits (see Figure 4-5 and Table 4-1).

We can extend this logic from one period to many period, and even to an infinite. The principle involved is known as Hotelling's rule. This rule states that in equilibrium the resource net price (defined as the price minus extraction costs) must rise at a rate equal the rate of interest. Consider an example from the perspective of a copper ore deposit owner. the owner's profit per unit extracted is equal to the net price. In deciding whether or not to produce and sell the copper, the owner will weigh the net price available today against a possible higher future net price. She will compare the two using a discount rate equal to the commercial rate of interest. If the present net price, plus interest, exceeds the probable future net price, she will profit more by extracting the resource today and investing the proceeds, rather than waiting. If the expected future net price is higher than the net price today plus interest, she will wait and sell at the future date.

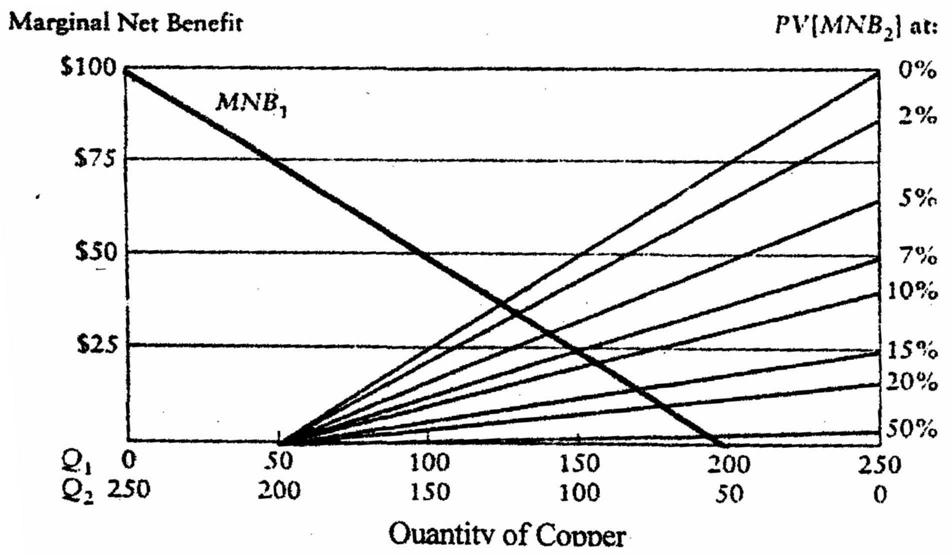


FIGURE (5) *Intertemporal Resource Allocation*

Table 4-1 different discount rates for intertemporal resource allocation

Discount rate (%)	$(1+r)^w$	$Q.$	Q_2
0	1.0	125	125
2	1.2	132	118
5	1.6	143	107
7.5	2.0	150	100
10	2.6	158	92
15	4.0	170	80
20	6.2	179	71
50	57.7	198	52

If all resource owners follow this logic, the quantity of copper supplied today will increase until today's copper price falls low enough to encourage resource owners to conserve, hoping for a better future price. At this point Hotelling's rule will hold: the expectations of future price increases will exactly follow an exponential curve $P_1(1+r)^n$, where P_1 is today's price, r is the discount rate, and n is the number of years from the present (see Figure6).

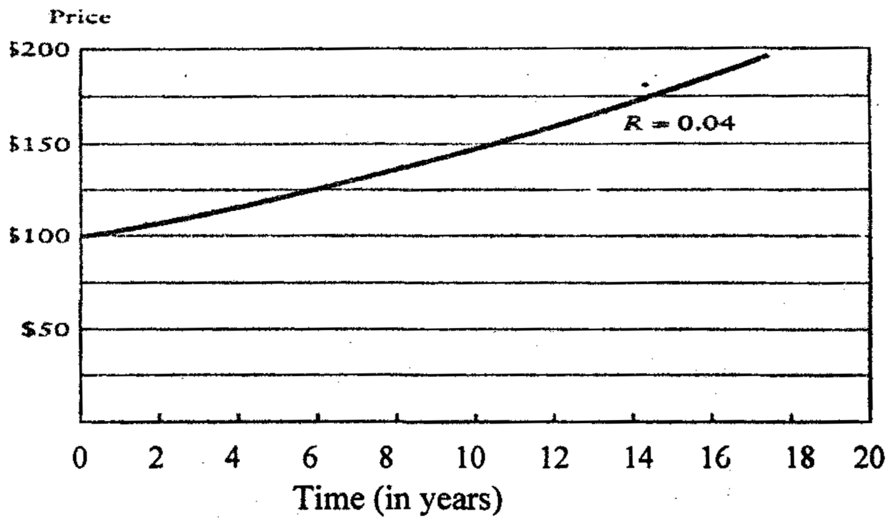


FIGURE 6 *Hotelling's Rule on Equilibrium Resource Price*

If this sounds confusing, consider this simpler, common-sense formulation: high discount rates create an incentive to use resources quickly; low discount rates create greater incentive to conserve. More generally, we can say that economic theory implies the existence of an optimal depletion rate. Under market conditions, a nonrenewable resource will be used up at certain “optimal” rate, and this rate will be faster at higher discount rates.

Interestingly, according to this theory it is optimal to deplete certain resources to complete exhaustion over a period of time – the higher the discount rate, the shorter the time. Like the theory of optimal pollution, this sounds wrong to many people. What about the ethical imperative to leave something for future generations?

The answer in economic terms is that a discount rate based on standard commercial rates of interest will give a low weight to the well-being of future generations. This leads some people to question whether we can justifiably apply present value analysis, based on a discount rate, over long periods of time.

Problem

We can modify the interperiod allocation model to deal with the issue of intergen–erational allocation of resources. Suppose a generation is thirty–five years and we are concerned with two generations only. Demand and supply functions for oil in the present generation are given by

$$\textbf{Demand } Q_d = 200 - 5P \textbf{ or } P = 40 - 0.2\,Q_d$$

$$\textbf{Supply } Q_s = 5P \textbf{ or } P = 0.2\,Q_s$$

1– Draw a demand and supply graph showing the equilibrium price and quantity consumed in this generation in the absence of any consideration of the future. Now draw a graph showing the marginal net benefits from consumption in this period at all levels of consumption up to the equilibrium level. Express the net benefit (benefit minus cost) algebraically.

2– Suppose the net benefit function is expected to be the same for the next generation, but a discount rate (interest rate) of 4 percent per annum for 35 years works out to $(1.04)^{35}$, approximately equal to 4. Total oil supply for both generations is limited to 100 units. Calculate the efficient allocation of resources between the two generations and show this graphically. (Set marginal benefits equal for the two periods, remembering to include the discount rate.)

3- What is marginal user cost for this efficient allocation? If you include this user cost in your original supply and demand graph, what is the new equilibrium? If the demand curve is the same in the second generation, what will be the price and quantity consumed in that period?

4- How would the answer diffe* if we used a zero discount rate? What can you conclude from this example about the general problem of allocation over long time periods?

Questions

Chapter two

Resources allocation overtime

For each item, determine where the statement is basically true or false:

1) Renewable resources, if properly managed, can last indefinitely.

2) A well-managed farm, fishery and forest could remain productive for centuries.

3) Non-renewable resources can last forever.

4) Non-renewable resources, some may be relatively short supply.

5) High grade deposits of copper or crude oil supplies are examples of Renewable resources.

6) Marginal net benefit is the vertical difference between the supply and demand curves.

7) Marginal net benefit is generally largest for the first units extracted, then declines to zero at equilibrium.

8) Marginal net benefit is generally lowest for the first units extracted, then rise and reach highest where the supply and demand meet.

9) If we were to produce more than the equilibrium quantity, MNB would become positive as supply costs rise above the value to the purchaser.

10) The area under the total net benefit shows marginal net benefits.

11) The area under the demand curve shows total benefits and the area under the supply curve shows total cost.

12) The area under the demand curve shows marginal benefits and the area under the supply curve shows marginal cost.

13) When the marginal net benefit is just equal to zero, total net benefit is minimized.

14) When the marginal net benefit is just equal to zero, total net benefit is maximized.

15) The economic concept of present value relies on use of a discount rate to convert future to present monetary values.

16) To convert the marginal net benefit in period 2 into period 1 value, we using this formula PV[MNB2] = MNB2/(1+r)n.

17) The more we use today, the higher these costs become.

18) The user cost is the vertical distance between the old supply curve and the new social cost curve.

19) Dynamic equilibrium reflects both the needs of the present and of the future.

20) The lower price will send a signal to producers and consumers of the resource to produce and use less today, thereby conserving more for the future.

21) High discount rates create an incentive to use resources quickly.

22) Low discount rates create lower incentive to conserve.

23) Under market condition, the existence of an optimal depletion rate, a renewable resource will be used up at a certain optimal rate, and this rate will be faster at higher discount rates.

24) If the extraction cost is $50 and the value to purchaser is $150, the MNB equal 100.

25) If the MNB equal 200 and the extraction cost is 75, the value of purchaser is 125.

26) Static efficiency, the economic criteria to choose a many alternatives that happen at the same time.

27) Dynamic efficiency is a generalization form of the static efficiency concept in which the present value is used to compare the net benefits received in one period with other periods.

28) Static equilibrium represents the market equilibrium that prevails if only present benefits and costs are considered.

29) Dynamic equilibrium is the market equilibrium that occurs if future benefits and costs are considered and the future values must be discounted to their present values.

30) Total willing to pay represent the area under the demand curve to the left from the origin to the allocation point of interest.

31) The optimal economic allocation between periods is the point of intersection between [MNB1] curve and PV[MNB2] curve.

Chapter Three

Exhaustible Resources the

Theory of Optimal Depletion

Chapter Three

Exhaustible Resources the Theory of Optimal Depletion[2]

Key Result in the Theory of Optimal Depletion an Informal Introduction:

There are essentially two conditions that must holds along an optimal depletion path there turn out to be the optimal control conditions, but they can be understood much less formally as well.

How is an exhaustible resource different from an ordinary good or resource? Simply in that it is limited in quantity and is not producible. But this means that extraction and consumption of a unit today involves an opportunity cost: the value that might have been obtained at some future date. The opportunity cost must be taken into account in determining how to allocate the resource over time. In particular, instead of the usual efficiency condition price = marginal (production) cost, we have price = marginal (production) cost + opportunity cost. This is the first condition of optimal depletion; as shown in figure (No. 1), it implies that less of the resource will be extracted today than if it were producible, given the demand P = P(y), where P is price and y is

[2] **Anthony C. Fisher, "Resource and Environmental economics "Cambridge university press London, 1981, chapter 2, PP.10 – 51.**

quantity, only y* units will be extracted by a planner or resource manager seeking to allocate extraction efficiently over time, leaving a positive difference (AB in Figure no1) between the price and the marginal cost of production or extraction.

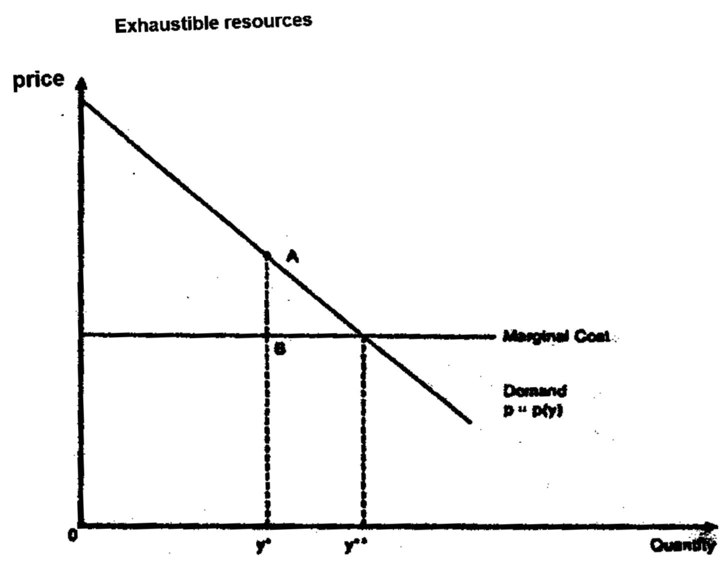


Figure (No. 1)

Relationship between marginal cost and price for an exhaustible resources.

The second condition of optimal depletion describes the behavior of the opportunity cost over time. But before getting into this, we should introduce a bit of terminology. The difference between price and marginal extraction cost is known by a number of different names in the resource economics literature: user cost (from the opportunity cost to the user of taking a unit today), royalty, rent, net price, and marginal profit. We shall generally use the term royalty, although one should be familiar with the others.

Now what can be said about the behavior of the royalty over time? Consider a unit of the resource, say a barrel of oil. What is the net social benefit from extracting the barrel today? Clearly it is the royalty, the difference between the price (or what consumers are willing to pay) and the cost of extraction. But that same barrel might also be expected to yield a royalty if extracted and consumed next year. At which of the two times should it be extracted to yield the greater net benefit?

To help answer this question, let us work through a simple numerical example. Suppose that there are just 10 barrels of oil in the ground in total, that the (constant) marginal cost of extraction is \$2 per barrel, that the demand in period t (t = 0, 1) is given by the equation $P_t = 10 - Y_t$ where P is price and Y is extractive output, and that the rate of discount is r = 0.10. Now we can ask our question: what allocation of output over the two periods will yield the greatest net benefit from the oil? For simplicity, we assume just two periods, but the results we obtain can readily be extended. This is an approach that will be used frequently. For many purposes, a simple two-period example or model will do. Where it becomes important to determine the behavior of some variable such as output or price over many periods, an appropriate model will be formulated.

Net (social) benefit in a single period is customarily measured as the difference between what consumers are willing to pay for a good and what it costs to produce. In figure (N0.1) this is the area between P (y) and MC from y = 0 to Y = y*. Note again that the area, or benefit, is bounded by y*, not y**, the output for which price = marginal cost. The net benefit can also be represented analytically, according to the geometric interpretation of the integral of a curve as the area under the curve. In this case the total willingness to pay is the integral of the demand curve, and the total cost is the integral of the marginal cost curve. The net benefit, or the difference between willingness to pay and cost, can then be written as

$$\int_0^{y_0}(10 - y^1)dy^1 - \int_0^{y_0} 2dy^1$$

Or

$$\int_0^{y_0}\lfloor(10 - y^1) - 2\rfloor dy^1$$

In the first period and

$$\int_0^{y_0}\lfloor(10 - y^1) - 2\rfloor dy^1$$

In the second period, where Y_0 and Y_1 represent actual first and second−period outputs and y^1 is a variable of integration.

Our objective is now to choose a level of output in each period in such a way as to maximize the sum, over both periods, of these benefits, taking care to multiply the second period's benefit by the discount fact $1/(1 + r)$ to obtain a present value. In symbols, the problem is

$$\mathbf{max}_{y_0+y_1} \boldsymbol{imize} \int_0^{y_0} \lfloor(\mathbf{10} - \boldsymbol{y^1}) - \mathbf{2}\rfloor \boldsymbol{dy^1} \, .$$

$$+ \int_0^{y_0} \frac{[(\mathbf{10} - \boldsymbol{y^1}) - \mathbf{2}]\boldsymbol{dy^1}}{\mathbf{1+0.10}}$$

Subject to

$$\boldsymbol{y_0} + \boldsymbol{y_1} = \mathbf{10}$$

This is a constrained maximization problem, which we can readily solve by setting up the Lagrangian expression

$$\boldsymbol{L} = \int_0^{y_0} \lfloor(\mathbf{10} - \boldsymbol{y^1}) - \mathbf{2}\rfloor \boldsymbol{dy^1} \, .$$

$$+ \int_0^{y_1} \frac{[(\mathbf{10} - \boldsymbol{y^1}) - \mathbf{2}]\boldsymbol{dy^1}}{\mathbf{1.1} + \boldsymbol{\lambda}\,(\mathbf{10} - \boldsymbol{y_0} - \boldsymbol{y_1})}$$

Where λ is a Lagrange multiplier, differentiating with respect to y_0, y_1 and λ , and setting the results equal to zero. We obtain

$$(10 - y_0) - 2 - \lambda = 0 \qquad \frac{(10 - y_0) - 2}{1.1} - \lambda = 0$$

$$\mathbf{10 - y_0 - y_1 = 0}$$

Solving for y_0 , Y_1 and λ , we find y_0 = 5.14 (approximately), y_1 = 4.86, and λ = 2.86. substituting the values for y_0 and Y_1 back into the demand equation, we find P_0 = $4.86 and P_1 = $5.14.

Now let us interpret these results. The royalty in period 0, the difference between price and marginal cost, is $2.86. The royalty in period 1 is $3.14, but notice that when discounted it comes to just $2.86 ($3.14/1.1). In other words, the present value of the royalty is the same for both periods; equivalently, the (undiscounted) royalty has grown by 10%, the rate of discount. This is, in fact, a fairly general result, even though we have obtained it in a simple numerical example. As we shall see, for the special case in which costs do not rise with cumulative extraction, the second condition of optimal depletion is that the present value of the royalty must be the same in all periods or, equivalently, the in discounted royalty must rise at the rate of interest.

There is an illuminating interpretation of the Lagrange multiplier, λ here. Recall the multiplier is a shadow price: the change in the (optimal) value of the objective function corresponding to a small change III the constraint. In this case we are talking about the increase in benefits that would result from having one more barrel of oil in the ground, or the decrease that would result from having one less. But this is just the opportunity cost of producing the barrel now, the royalty. Notice that because of the first order conditions in our example this is indeed equal to the difference between price and marginal cost in the current period, or the present value of the difference in the next period.

All of this makes economic sense. Consider oil in the ground as a capital asset. How much of this asset must be held if the pattern or investment in the economy is to be efficient? Efficiency requires that there be no gain to be had in shifting from one asset to another, which in turn implies that the returns must be the same for all. Ordinarily the return includes a capital gain, plus a dividend, minus depreciation. However, for an exhaustible resource there is no dividend and also no depreciation. The return in this case must come entirely in the form of a capital gain or a rise in the value of the asset. But the value is just the difference between price and marginal cost, or the royalty. Thus extraction is apportioned among periods in such a way that the royalty rises at the (common) rate of interest.

The discussion to this point has been in terms of efficiency in allocating an exhaustible resource over time, but it should be intuitively clear that (as we shall prove later in this chapter) the same conditions must hold in a competitive equilibrium. As long as there are gain to be had in shifting a unit of extraction, or the pattern of investment in resources in the ground, there can be no equilibrium.

Now let us make explicit some additional simple points about the behavior of resource price and output over time. we have established that the royalty rises at the rate of interest. In symbols, this can be stated as

$$(P_1 - MC) = (P_0 - MC)(1 + r)$$

Then the equation for the time path of price is

$$P_1 = MC + (P_0 - MC)(1 + r)$$

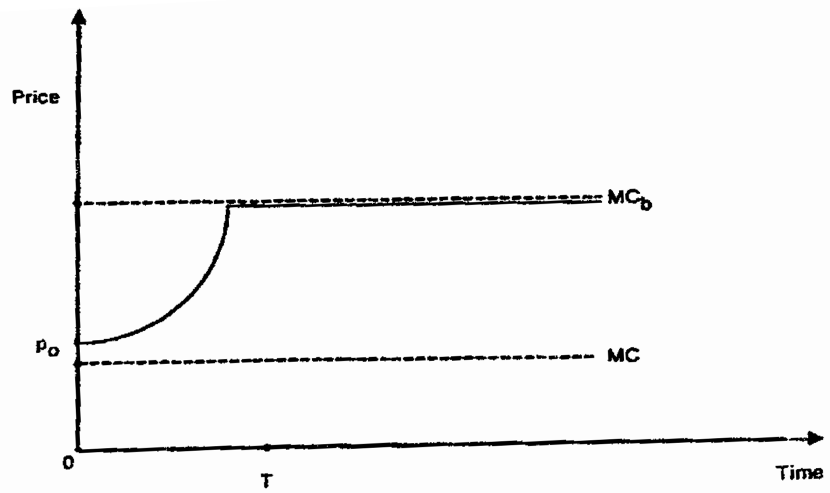


Figure (No. 2) Time path or price and its relationship to resource and backstop costs.

Extending this to many periods, we have

$$P_1 = \text{MC} + (P_0 - \text{MC})\,(1 + r)^t \qquad (1)$$

Price draws away from marginal extraction cost, rising at rate that approaches the rate of interest as the royalty component of price comes to dominate the extraction cost component. This is shown in figure (No.2).

Does price indefinitely? Clearly in our numerical example it cannot rise $10 per barrel, because at that price the quantity demanded falls to zero. More generally, we may suppose that there will be a limit set by the price, or cost, of a substitute. For oil, the substitute, or backstop, as it is sometimes called, could be coal, and ultimately perhaps nuclear fusion or some form of solar energy. The backstop is just a resource or a technology that can provide the same services as the oil (thermal units of energy), but at higher cost, and without risking exhaustion in any meaningful time frame. Of course, it may be that it will be impossible to substitute for some relatively minor uses of oil, in which case price could continue to rise, although even here a limit would be set by tile value of the product or service using the oil.

Let us suppose that a backstop exists, say solar energy, that can provide energy at a (marginal) cost equivalent to MC_b dollars per barrel of oil. Note that this is also the price, because with an unlimited resource stock there is no royalty. What we shall show is that the cost of the backstop not only sets an upper limit on the price of oil but also determines the initial price by determining the initial royalty to be added to the marginal cost of extraction.

At time T, the switch data from oil to the backstop, the price is given, from equation (1), by

$$\boldsymbol{P_T} = \mathbf{MC} + (\boldsymbol{P_0} - \mathbf{MC})\,(\mathbf{1} + \boldsymbol{r})^{\mathrm{T}}$$

But we also have $P_T = MC_b$, so that

$$(\boldsymbol{P_0} - \boldsymbol{MC}) = \frac{(\boldsymbol{MC_b} - \boldsymbol{MC})}{(\mathbf{1} + \boldsymbol{r})^{\boldsymbol{T}}}$$

In other words, the royalty at t = 0 ((P_0 − MC) is the difference between the cost of the backstop and the cost of oil, discounted back from the switch date. Substituting this expression for P_0 − MC into equation (1), we obtain an equation in terms of the cost of the backstop (and the cost of oil) for the price of oil at any time t < T:

$$P_t - MC \quad + \frac{(MC_b - MC)}{(1+r)^{T+1}} \tag{2}$$

This is shown in figure (No. 2), where the royalty rises at rate r to MC_b − MC and the price rises to MC_b at time T.

The model in the next section is essentially a much more general treatment of the same idea, namely that costs rise with cumulative extraction. There, instead of a single jump to a backstop, we shall consider the more realistic situation in which there are in effect many backstops, different qualities of the resource being extracted, each denoted by a different cost.

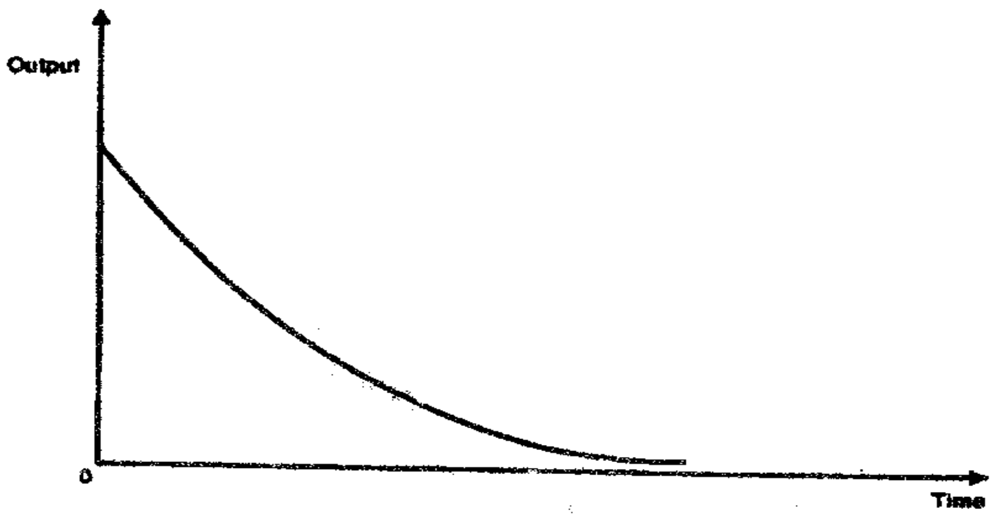


Figure (No. 3) Time path of output.

But first, what can we say about the behavior of output in the simple model in this section? Clearly, if demand is stable (and downwards sloping), as assumed in our example, and price is rising then output must be falling, as shown in figure (No.3). However, this is not a general result, because demand could well be rising over time as a consequence of rising, income or improvements in the technology of using the resource. Output must, of course, ultimately fall as the resource approaches exhaustion.

At this point the reader familiar with the behavior of extractive-resource prices over time may wish to object. But if this is true, the price path in figure (No.3) must also represent a special case of some sort. There are indeed two important qualifications: that the amount of the resource available and the cost of extracting it be known. Clearly, discoveries if new deposits, as well as cost-reducing innovations, can affect the price of a resource. Subject to the conflicting pulls of depletion and discovery, price is observed to fluctuate, often about a downward trend. This is not inconsistent with the simple theory we have been developing. The theory describes an equilibrium path, one that will tend to be followed in the absence of shocks provided by unanticipated discoveries. The theory can also be extended to describe an equilibrium with resource stocks augmented by (costly) exploration.

The easy identification of an efficient pattern of exhaustible–resource allocation with a competitive equilibrium also deserves some qualification at this point. There are at least two resource of difficulty. First, as with their goods or resources externalities. Or, more generally, market failures can make an equilibrium inefficient. Two kinds of externalities seem particularly important in the case of extractive resources. Spillovers associated with exploitation of a common pool (of oil or fish, to take frequently cited examples) by several different producers, and environmental disruption.

A second source of diverge between markets determined and efficient rates of depletion is the divergence between private and social rates of discount. We have already seen the crucial role played by the discount rate in determining resource price and output paths. If, as some economists and others have suggested, the appropriate social discount rate is below the rate used by private resource owners, there may be a tendency for resources to be used up too quickly I. a market economy.

There is perhaps one final point that should be made before we launch on a discussion of optimal depletion in the next the section. By optimal depletion we mean efficient depletion, and by this we mean, as explained in connection with our numerical example, the pattern of depletion that maximizes the present value of net benefits from the resource. Now, when we make a decision on the basis of present value, we are, as in the example, discounting the benefits that accrue to future periods, or generations. Thus far we have spoken of net benefits from resource use, without specifying to whom the benefits (or the costs) accrue. Yet clearly all individuals do not share equally in the fruits of depletion. Some gain a little, others gain a lot, and still others may be hurt, Moreover, the gain or loss of a dollar of income may mean more to some than to others.

The concept of efficiency we shall be using (maximization of net benefits) does not address these distributional concerns in our monopolist depends on the nature of demand (the relationship between price and marginal revenue), especially its behavior over time. This is easily illustrated with the aid of some simple numerical examples.

We have already determined, in section 1, the solution to a problem involving 10 barrels of oil to optimally depletion over two periods, given demand, costs, and a discount rate. This is also, of course, the competitive solution. Now how does the monopoly solution compare? The key is that marginal revenue less marginal cost must rise at the rate of interest (remember, in this example $\partial c / \partial X_t = 0$).That is, instead of equation (1), we have

$$\boldsymbol{MR_t} - \mathbf{MC} = (\boldsymbol{MR_0} - \mathbf{MC})\ (\mathbf{1} + \mathbf{r})$$

And substituting for MR_t, MR_0, MC, and r

$$\mathbf{10 - 2y_t - 2 = (10 - 2y_0 - 2)\ (1 + 0.10)}$$

This equation can be solved for y_0 and y_t (because $y_0 + y_1 = 10$, we have two equations in two unknowns) to yield $y_0 = 4.95$ and $y_t = 5.05$. These values compare with the competitive $y_0 = 5.14$ and $y_t = 4.86$, indicating that the monopolist depletes the resource more slowly.

This is not a perfectly general result. However, it does follow as long as elasticity is decreasing, over quantities. The linear demand curve in our problem clearly falls in this class. But examples can be constructed that show the monopolist accelerating depletion, given a demand curve that exhibits increasing elasticity over some range of output.

The same result, the monopolist accelerating depletion, can also occur as a consequence of changes in demand over time. For example, suppose demand becomes less elastic, shifting from $P_0 = 10 - y_0$ to $P_t = 20 - 2y_t$. Then, proceeding as before, the competitive depletion path is $y_0 = 3.48$, $y_t = 6.52$, and the monopoly path is $y_0 = 4.97$, $y_t = 5.03$. This makes sense. The monopolist can restrict second-period output to take advantage of the less elastic demand.

There is a qualification here, however. If depletion is accelerated, as in the example, price may rise at a rate greater than the rate of interest, as in fact it does in the example. But it is not clear that such an equilibrium can be sustained in the face of the opportunity it creates for profitable arbitrage. Further, the necessary condition for accelerated depletion, elasticity falling over time, does not seem very likely. Instead, we might expect that demand will become increasingly elastic as substitutes become increasingly available. It is easily verified that increasing elasticity leads to slower depletion by a monopolist. The intuition in this case is that the monopolist restricts first-period output to take advantage of the (relatively) inelastic demand.

My impression, then, is that there is a tendency for monopoly to retard depletion in a model where a resource stock of uniform quality is exhausted in finite time, as in the examples just analyzed, and in much of literature on this question. To this, I would only add the conjecture that the tendency would be strengthened in a model where costs rise with cumulative depletion. Where costs do not rise and the resource is entirely depleted, competitive and monopoly depletion paths must cross. If the monopolist produces less (than the competitive industry) in the early periods, he must ultimately produce more. But my conjecture is that this need not happen where the resource is not exhausted, where very high cost units remain in the ground indefinitely. In such a case, cumulative production need not be the same under both regimes; in particular, it may be lower for the monopolist, who simply produces less in each period.

Intermediate Market Structures: The Resource Cartel

Thus far we have been contrasting the polar cases of perfect competition and pure monopoly. What of intermediate market structures, in particular one or another form of oligopoly? There are, of course, many different models of oligopoly behavior that are now being applied to exhaustible-resource industries. We shall not attempt a review of the literature here, other than to note an approach that has proved interesting in connection with the analysis of cartel, specifically OPEC, behavior.

In this approach, the cartel, even acting as a unit, is not the only seller in the market. Some production comes from a competitive fringe, small producers who take the price set by the cartel in each period. The cartel, in turn, takes account of fringe supply in setting price. With the additional (and crucial) assumption that fringe supply adjusts with a lag, a price path can be determined to maximize the present value of cartel profits.

This has been done for the OPEC cartel in a numerical simulation of the world oil market by Pindyck (1978a). The results, shown in table (No. 2), are quite different from those discussed thus far for a competitive industry or a monopoly, in that price change is not monotonic. The price initially jumps dramatically, to take advantage of the lag in fringe adjustment. It then falls, gradually (and modestly) over a period of about five years, and only after this time begins a slow and steady rise.

How well has the simulation tracked OPEC pricing decisions? OPEC did, in fact, jump the price of oil to around the predicted level, over $10 per barrel, but in 1974, not 1975. More significantly, price did fall, in real terms, over the next four to five years a especially if one takes into account the fall in the value of the dollar, in which oil prices are denominated, relative to other currencies. Moreover, early 1979 looked like the final turning point, with a modest price increase scheduled by OPEC. UP to this point, the agreement between theory and simulation, on the one hand, and events, on the other, is striking.

Table (No.2) Optimal OPEC price path

Year	$Price^{a}$
1975	14.08
1970	11.75
1977	10.70
1978	10.28
1979	10.19
1980	10.26
1985	11.28
1990	12.51
1995	13.80
2000	15.18
2005	16.72
2010	20.52

a1975 dollars, 10% discount rate.

By the middle of 1979, however, price had again jumped sharply. Why did the model suddenly fail? A general answer is that calling three key turning points, over a period of up to five years, is probably already more than one ought reasonably to expect of a model of such a complex process. In the more distant future, uncertainties multiply, institutions change, and so on. In the case at hand it seems fairly clear that the rapid price rise can be explained, at least in part, by the virtual halt in oil exports from Iran, which until 1979 was OPEC's second largest producer, after Saudi Arabia. The model, and for that matter economic theory, can perhaps be faulted for failing to predict the Islamic Revolution in Iran. A Fairer conclusion, in my judgment, is that the model did reasonable well for a time, then ran into trouble because of events normally considered outside the realm of economics.

Note, by way, the tendency of a dominant producer initially to restrict output and raise price, just like a monopolist. To be sure, this represents another special case, but one that embodies a greater degree of realism than the simple two-period monopolies analyzed earlier.

Relationships between a dominant producer and the competitive fringe are of interest whether or not the producer also happens to be, like OPEC, a cartel. But there is a classic question concerning cartel behavior that has recently received an illuminating answer in another application to OPEC pricing and production decisions, an extension by Hnyilicza and Pindyck (1976) of Pindyck's model of a unified cartel.

The question is how the implied output restrictions (implied by the cartel's price increase) are to be allocated among the members. Cartels are generally believed to be unstable because of the difficulties they face in trying to resolve this question. Each member, especially each small member, has a powerful incentive to cheat, to sell more than his assigned share by slightly shaving price. It is clear that if all members (or even a substantial fraction) try to do this, the cartel will collapse. There has, in fact, been some scattered price shaving by OPEC members over the past several years. But the cartel has raised prices vary substantially and has held together rather well, by and large. Why has it been so successful?

One reason, clearly, is the enormous incentive. Pindyck's simulation suggests a joint gain from cartelization in the neighborhood of $1 trillion, present value! Where this much money is at stake, ways may be found to overcome the counter incentive to cheat. Another reason is probably the Iranian cutback. This was fortuitous, but it has certainly helped solve the question, for the past two years at least.

What the study by Hnyilicza and Pindyck (1976) shown is that the dynamics in the exhaustible-resource case suggest a more general solution: rotate the cutbacks among the members. Specifically, for OPEC, members were classified in the study as either savers, with (relatively) low immediate cash needs and a low discount rate, or spenders, with high cash needs and a high discount rate. In a numerical simulation of pricing and saver and spender output decisions, discounted profits were increased for both groups (over the amounts they would receive under historically given output shares) by having the savers absorb the initial cutbacks.

There is some evidence that this solution has been adopted by OPEC. The model simulation called for no production from the savers, initially. Clearly this is not realistic. As these authors recognized, the temptation to cheat would be strong, because savers would risk the breaking up of the cartel before they would even begin to deplete their reserves. Further, the model appears not to take account of the costs of adjusting away from historical production levels. That is, the spenders might not be able to expand production as rapidly as they would need to in order to take up the slack caused by a complete shutdown by the savers. Nor, presumably, would the savers, for their part, welcome the idea of a complete, if temporary, shutdown, with very substantial investments in capacity for producing, transporting, and refining oil already in place. Yet the model does point in the right direction. Much, if not all, of the excess capacity in OPEC is in Saudi Arabia, the principal saver country. Despite ambitious domestic investment plans, the Saudi have, in effect, absorbed the cutbacks needed to sustain OPEC.

We began this section by observing that some degree of monopoly has characterized markets for different resources at different times. Let us close by considering why this is so. Specifically, what are the conditions required for a successful cartel? What can we learn from the experience of OPEC?

Two things stand out, I think, first, the cartel must control a substantial share of the supply of the resource. OPEC, with about two-thirds of the world's oil reserves and a similar fraction of (noncommunist) world oil production, clearly qualifies. By contrast, the less well known international council of copper-exporting countries (CIPEC) accounts for only about one-third of (noncommunist) world copper production, and as shown in Pindyck's original study, they can expect very modest gain from cartelization.

The comparison of OPEC and CIPEC well illustrates a second condition for a successful cartel: inelastic supply response from the competitive fringe. This is satisfied in the case of OPEC by the lag in fringe supply. In the short to medium run, non OPEC petroleum supplies are not easily expanded, despite large price increases. Unfortunately for CIPEC, this is not true for copper. Secondary copper, produced from scrap, appears to be quite responsive to price in the short run.

Both conditions (a large share of the market and inelastic fringe supply) seem likely to be associated with substantial gains to cartelization. And if, as in the case of OPEC, the joint gains are large enough, it seems that ways might be found to hold the cartel together. A fair conclusion, on the basis of this casual surgery of the evidence, is that whether or not a resource cartel will be successful depends importantly on the relationship between cartel and fringe supply, and also perhaps on the cartel's ability to solve the problem of allocating cutbacks among its members. Oil may not be the only exhaustible resource subject to cartelization and a rapid increase in price, but as the experience of the copper producers suggests, the success of OPEC does not necessarily portend similar developments in other resource markets.

4- Uncertainty and Depletion:

Just as we have considered whether monopoly speeds up or slows down depletion, we can raise the same question about the effect of uncertainly. There are two easy answers, both probably wrong or, at least, incomplete. One is that in an Arrow-Debreu economy, in which markets exist for every commodity at every date in every state of the world, uncertainty will not affect the rate of depletion. The reason is that the resource owner not only knows current and future prices but also can insure himself against adverse events, such as unexpectedly running out.

The difficulty is, of course, that such a complete set of contingent commodity markets does not exist in any real economy. there are insurance markets and especially in the resource sector, futures markets in which dated commodities are traded. But these markets are limited. It is not possible, for example, go buy or sell at a given price a barrel of oil in the year 2000 in the event that there is a revolution in Saudi Arabia. So the difficulty is that resource owners must, from expectations about future prices and then act on these expectations in making decisions about how much of the resource to use at any time. Further, they probably have to bear at least; 11J some of the risk involved in such decisions. The question we shall be asking in the remainder of this section is this: how are depletion decisions affected by uncertainty in an economy characterized by incomplete futures and risk markets?

We have said that there is another easy answer to the question about the effect of uncertainty. It is that uncertainty is typically reflected, at least in economic models, in a higher discount rate. And our own models tell us that the higher the discount rate the higher the rate of price increase, and therefore the rate of depletion. This is certainly one possible result, but I believe that a complete answer to the question about the effect of uncertainty is more complicated. Uncertainty can arise in many different ways, involving resource demand or supply or both. The effect on the rate of depletion is not always captured simply by an increase in the discount rate. Further, the effect of a change in the discount rate is not clear-cut, once we take into account the possibility of expanding the resource stock through exploration and development of new deposits.

A formal analysis of the effects of the many different Kinds of uncertainty is beyond the scope of this study. The model of Section (2) could be extended to deal with one or two, perhaps, but this would involve the more advanced mathematical methods of stochastic control. Instead, our strategy will be to identify some key uncertainties in resource markets and then see what intuition and a little analysis, where intuition may not suffice, backed by references to the literature, suggest about the effects of each. Note that we are trying to answer a positive question about the behavior of resource owners. There is also a question whether or not that behavior continues to be consistent with allocative efficiency. This turns out to be more difficult in that it involves first determining what we mean by efficiency in these circumstances.

Effects on Depletion of Different Kinds of Uncertainly

The conventional answer to the question about the effect of uncertainty (namely, that it is reflected in an increase in the discount rate, which in turn accelerates depletion) can be appropriate when the uncertainty is about demand for the resource. This sort of uncertainty might be assumed to be positively related to the distance in time from the depletion decision. The resource owner is likely to be less certain about demand 10 years from today than about demand 1 year from today. If he is risk-averse, depletion will be shifted toward the present, just as it would be if the discount rate were raised.

But demand uncertainty can be time-related in a different way that can lead to just the opposite conclusion. Suppose the variation in returns from extraction is related only to the amount extracted in a given period. Price is random, but the random component is identically distributed in each period. We noted earlier that, ignoring uncertainty, and assuming that price is rising, unless demand is shifting out over time, output will be falling figure (No. 3). Then the variation in returns, which is proportional to output, must also be falling. The risk-averse resource owner will therefore shift extraction toward the future.

Still another kind of uncertainty related to demand for the resource can be shown (here a little analysis will he required) to lead the conventional result, a tilt toward the present. Suppose the resource is subject to the threat of expropriation. Or suppose there is a risk that the market might be lost because of the appearance of a lower-cost substitute (a cheaper backstop) at some future date. The uncertain event is then on that, when it occurs, will destroy the value of the resource to the owner. What is uncertain is the date. Let us assume that the owner wishes to maximize the expected present value of the resource. In other words, he is risk–neutral. The result we shall obtain clearly follows if he is risk–averse, but it does not depend on this.

Let the probability of disaster through expropriation or obsolescence at the end of period t be π_t, $0 \leq \pi_t \leq 1$, $\sum_t \pi_t = 1$, and let the value obtained during the period be v_t, t = 0 or 1. The expected present value is

$$\boldsymbol{\pi_0 v_0 + \pi_0 \left[v_0 \frac{v_1}{(1+r)}\right]}$$

Where r is the discount rate. This can be rewritten as

$$\boldsymbol{(\pi_0 + \pi_1)v_0 + \pi_1 \frac{v_1}{(1+r)}}$$

Because π_0 + π_1 = 1, and $\pi_t \leq 1$, taking account of the probability of disaster by maximizing expected value is simply equivalent to adding a new discount rate or effectively increasing the old one. this in turn, means that price must rise more rapidly, and depletion is accelerated.

Table (No.3)

Effects on depletion of different kinds of uncertainty

Kind of uncertainty	Effects on depletion
Uncertain demand for the resource, with degree of uncertainty related to distance in time from the depletion decision	Shifts depletion toward the present
Uncertain demand for the resource, with variation in expected returns related to quantity of output	Shifts depletion toward the future
Uncertainty regarding date of event that will destroy the value of the resource to the owner (e.g., expropriation, discovery of a. cheaper substitute)	Shifts depletion toward the present
Uncertain size of resource stock	Shifts depletion toward the future

Now, what about uncertainty on the supply side? This may be largely uncertainty about the outcome of exploratory activity, which we shall treat in Section (5). But suppose exploration is not made explicit, and the resource owner's problem is simply one of optimally depletion a stock of unknown size. What he is worried about, in this case, is running out unexpectedly. Our intuition tells us, correctly, that if the owner is risk-averse he will wish to slow depletion to husband the resource against the (unknown) day when it will run out.

The different kinds of uncertainty we have considered and their hypothesized effects on depletion are summarized in table (No.3). These informal results suggest that uncertainty does not necessarily speed up depletion and therefore is not always appropriately reflected in a higher discount rate.

Discounting and Depletion:

There is, in addition, difficulty with the proposition that a higher discount rate, for whatever reason, will lead to more rapid depletion. Thus far we have ignored the effect of the discount rate on activities other than depletion of a known deposit. But a high discount rate is likely to restrict investment generally, and the exploration and development of new deposits of a resource specifically. Exhaustible resources have been likened to hardtack consumed by sailors stranded on a barren island. Alternatively, they might have viewed as capital capable of accumulation through investment. The truth probably contains elements of both views, but to the extent that resources are like capital goods, we might conjecture that a rise in the discount rate would lead to more rapid depletion for an initial period, followed by a reduced rate as a consequence of restricted investment in exploration and development during the initial period. This pattern seems particularly likely when the resource is subject to expropriation. Depiction from known, producing mines or wells would be accelerated, but little effort would go into finding and developing new ones.

Instability in Resource Markets:

We may not be able to say whether uncertainty, in general, leads to a slowing down or a speeding up of depletion it depends on the nature of the uncertainty. But there is a presumption that it is likely to lead at least to instability in resource markets, with the consequence that depletion, whether too fast or too slow, may be inefficient.

As we noted earlier, in the absence of a complete set of futures markets, resource owners must form expectations about future prices and then act on these expectations in making decisions about how much of the resource to extract at any time. It is easy to think of ways in which this can lead to instability. (What is at stake here is the existence, not just the stability, of an equilibrium.)

Suppose that for some reason the current price of the resource rises. One plausible way for expectations regarding future prices to be formed is from the behavior of current prices, perhaps from a distributed lag of current and past prices. Suppose a rise in the current price leads to a rise in the expected future price. But this, in turn, will lead to a further rise in the current price as resource owners decide to cut back on production and hold more of the resource in the ground to take advantage of the higher price expected in the future.

Does the second–round rise in the current price imply a further rise in the future price? There does appear to be a possibility that the cycle of changes is explosive, that an equilibrium price path does not exist. Clearly the possibility depends on what we might call the elasticity of expectations, the percentage change in expected future price divided by the percentage change in the current price. In particular, the existence of an equilibrium will depend on the behavior of the elasticity of expectations at the corners (I.e., where the expected future price is either very high or very low).

It is easy to see how the elasticity must behave in order to assure an equilibrium. We can illustrate we simple two-period example. We make the following assumptions: the current price of a competitively owned resource, oil, is $10 per barrel; next year's expected price is $11; there are no costs of production; the discount rate is 10%; the elasticity of expectations is 2. Now, as a consequence of a shift in demand, the current price jumps 10%, to $11. Then next year's expected price must increase by 20%, to $13.20. But this, in turn, means that the price of oil is expected to rise by more than the rate of discount (a 10% rise, from a base of $11, would imply an expected future price or just $12.10). Oil in the ground becomes an attractive investment, so that owners of oil resources cut back on current production- until the current price rises to $12, restoring equilibrium in the capital market (a 10% rise, from this point, would mean that oil would sell for the expected $13.20 after one year).

So the change in current price has induced a change in expected future price, which in turn has induced a further change in current price. But this is not the end of the story. The $12 current price is not an equilibrium, because the rise from $11 induces a further change in next year's expected price (from $13.20 to $15.58), which, again, leads to cutbacks in current production to bring about a capital-market equilibrium in which the current price of oil is $14.16 per barrel. By exactly the same reasoning, this increase leads to still a further increase in the expected future price, and so, in an explosive cycle.

Now suppose that all the conditions of this example hold, except that the elasticity of expectations is just 1. In this case, the original 10% increase, from $10 to $11, triggers a 10% increase in the expected future price, to $12.10. But this is exactly the price implied by an oil price increase at a rate equal to the rate of discount (also 10%, in our example). No change in production plans is called for, and so there is no pressure on current price.

Equally simple calculations will verify that any elasticity of expectations greater than 1 will lead to the explosive cycle, whereas an elasticity of 1 or less will be consistent with equilibrium of the price path. In fact, an equilibrium will result provided that the elasticity eventually falls to 1. This is not an unreasonable requirement. Resource owners, Assisted perhaps by information compiled by government agencies, might be assumed to hold expectations of future prices rooted in their knowledge of developments in the technology for producing the resource and the likely demand for it. Although there will still be uncertainty, bounds on future price might be set, at least

This informal analysis is supported by some results from the much more abstract theory of temporary general equilibrium, in particular by one of the condition for the existence of a temporary general equilibrium. Suppose that future prices (for all commodities) are not known, and agents must from expectations and act on them in making decisions about current consumption and production, exactly as we have assumed for exhaustible resource. Current or spot markets can clear, but because individual expectations about the future need not coincide, markets will happen, and must clear again, and so on. One condition for the existence of a sequence of spot-market equilibria (temporary equilibria) is that each individual's expected future price lies within a closed bounded interval. But this is essentially what we are talking about in the resource case. Knowledge of demand and cost developments is likely to set bounds on expected future price.

Uncertainty and Inefficiency:

Given that an equilibrium exists, will it be efficient? The theory of temporary general equilibrium can shed some light on this question, too. The key result is that the sequence of temporary equilibria need not be Pareto-optimal. Fairly restrictive conditions on consumer preferences must be met to assure optimality. Of course, if an equilibrium does not exist, the question of optimality can hardly be raised.

The question calls also be attacked more directly by specifying as in our analysis of depletion under certainty, objectives for planner and private resource owner and determining whether or not the resulting price and output paths coincide. The choice of objective is crucial, but not obvious in either case. In particular, what do assume about attitudes toward risk and about markets for sharing or spreading risk?

There has long been a notion that social decisions might appropriately be made on the basis of a neutral attitude toward risk, even though individual members of society are risk averse. This is one reason that some economists believe that the true social discount rate is below the rates observed in private capital markets. The private rates include a premium for the risk born by the individual investor, and this ought to be disregarded in a public investment decision. Recently this notion has been formulated precisely with respect to the choice of objective for a planner. There are conditions under which maximization simply of aggregate expected consumer surplus will be efficient, but these conditions are fairly restrictive. What is required is essentially that all of the stochastic variation in price originate on the supply side. If demand is also subject to random shifts, as a consequence of fluctuations either in income or in any of the factors affecting consumer preferences, expected consumer surplus will not be an appropriate measure of welfare.

For the private resource owner, the situation is somewhat different Maximization of an expected value (e.g., expected profits) will generally not be appropriate. Because a complete set of markets for shifting risk does not exist, the resource owner will presumably display some degree of risk aversion. Recent analyses of firm behavior under uncertainty have suggested that even in an economy with a stock market, which permits risk sharing and spreading simple expected-value maximization by the firm's manager is not in the interest of risk-averse shareholders.

A comparison of firm and plan objectives suggests at least, the possibility of some differences in attitudes toward risk and ways of dealing with it. Where differences exist, presumably competitive depletion will veer away from the planner's optimum. Still, we need to be cautions in drawing conclusions here. The planner cannot in all cases (perhaps not even in most cases of interest) appropriately ignore the risk preference of individuals where he cannot, both socially optimal depletion and competitive depletion may be affected in much the same way by uncertainty.

A more fruitful way of proceeding may be to search for types of risk that would be perceived differently by planner and firm. One obvious example is the risk of expropriation we have suggested; this would lead a private resource owner to speed up depletion. But such behavior would not be socially optimal, at least not from a global point of view. Note, however, that if the resource owner could insure himself against the risk of expropriation, the depletion decision would not be distorted.

Finally, in weighing the merits of market and government in managing an exhaustible resource, we should take note of the skeptical view of governmental behavior generally voiced by economists of the

Chicago and Virginia schools. We have already abandoned the assumption of a complete set of competitive markets, leading to all the difficulties discussed earlier. But if we now similarly abandon the notion of a perfect planner, it is not clear, in my judgment, that the government will do any better. A part from the question of the planner's motivation to behave in the way assumed in our models, to allocate the resource efficiently, there is the question of his ability to do so. Even if the problem is simply to maximize the expected value of consumer surplus, the planner will need to form expectations of future demands. It is not obvious that he will be more successful in this than private resource owners will be in forecasting future prices.

Questions

Chapter three

Exhaustible resources:

The theory of optimal depletion

For each item, determine where the statement is basically true or false:

1) Exhaustible resource is limited in quantity and is not producible.
2) The extraction and consumption of a unit today for an exhaustible resource not involves an opportunity cost.
3) The opportunity cost must be taken into account in determining how to allocate the resource over time.
4) The efficiency condition of optimal depletion is price = marginal cost.
5) The difference between price and marginal extraction cost is known by user cost, rent, marginal benefit, net price and royalty.
6) Royalty is the net social benefit from extracting the resource.
7) The difference between what consumers are willing to pay and the cost of extraction is known "royalty".
8) The present value of the royalty mustn't be the same in all periods.
9) The undiscounted royalty must rise at the rate of interest.
10) Efficiency requires that there be gain to be had in shifting from one asset to another.
11) Efficiency implies that the returns must be the same for all.
12) Ordinarily the return includes a capital gain, plus a dividend, minus depreciation.
13) For an exhaustible resource there is no dividend but there is depreciation.

14) The return in an exhaustible resource must come entirely in the form of a capital gain or a rise in the value of the asset.

15) The extraction is apportioned among periods in such a way that the royalty rises at the rate of interest.

16) The backstop is a resource or a technology that can provide a different services, but at higher cost, and without risking exhaustion in any meaningful time frame.

17) Discoveries if new deposits, as well as cost reducing innovations, can affect the price of a resource.

18) Resources externalities or market failures can make an equilibrium efficient.

19) The appropriate social discount rate is above the rate used by private resource owners, there may be a tendency for resources to be used quickly.

20) The optimal depletion means efficient depletion.

21) The concept of efficiency minimizing the net benefits.

22) If depletion is accelerated, price may rise at a rate greater than the rate of interest.

23) The increasing elasticity leads to slower depletion by a competitor.

24) The monopolist restricts first-period output to take advantages of the relatively elastic demand.

25) The costs don't rise and the resource is entirely depleted, competitive and monopoly depletion paths must cross.

26) If the monopolist produces less than the competitive industry in the early periods, he must ultimately produce more.

27) Cumulative production may be higher for the monopolist, who simply produces less in each period.

28) Uncertainty will affect the rate of depletion.

29) The resource owner knows current and future prices and also can insure himself against adverse events.

30) The higher the discount rate the lower the rate of price decrease, and therefore the rate of depletion.

31) The effect of uncertainty is reflected in an increase in the discount rate, which in turn accelerates depletion.

32) A low discount rate is likely to restrict investment generally, and the exploration and development of new deposits of a resource specifically.

33) Uncertainty leads to instability in resource markets.

34) The elasticity of expectation is the percentage change in expected future price divided by the percentage change in the current price.

35) Uncertain size of resource stock shifts depletion towards the future.

36) Uncertain demand for the resource, with degree of uncertainty related to distance in time from the depletion decision shifts the depletion toward the future.

37) Uncertain demand for the resource, with variation in expected returns related to quantity of output shifts depletion towards the present.

38) User cost represents the opportunity cost of using the resources today instead of using it in the future and reflected as an increase in both the current and future prices.

39) User costs = $30, it means that the price of the next period will decrease by $30 because of using up more of resource today.

Chapter Four

Pollution: analysis and policy

Chapter Four

Pollution: Analysis and Policy

The Economics of Pollution Control

One of the services provided by natural systems is a sink function– the capacity to absorb wastes and pollution. Although essential to human life and economic systems, this function has often been abused by excessive pollution. This raises two questions for environmental policy. First, how much pollution is acceptable– given that any society must emit some waste products? Second, how can we best control or reduce pollution to this acceptable level?

How Much pollution is too Much?

If we take an economic approach to answering this question, we need to compare marginal costs and benefits associated with a pollution-generating activity. This leads to the concept of an optimal pollution level–the amount of pollution that exactly balances marginal social benefits and marginal social costs. At any way of looking at this is to consider the marginal cost of pollution control versus the marginal cost of pollution damage (Figure (1). In this approach, pollution reduction is worthwhile so long as control costs are less than the benefits gained in terms of reduced damage.

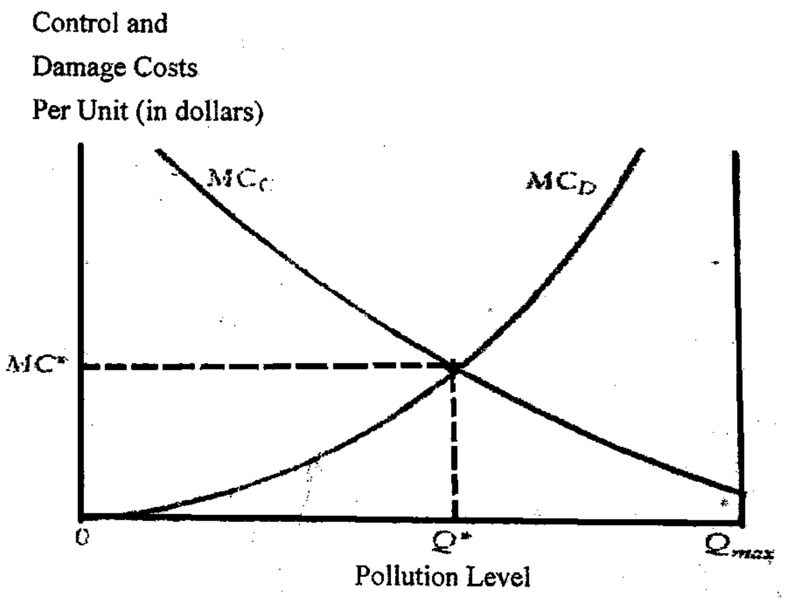


FIGURE (1) *Marginal Costs of Pollution Damage and Control*

Picking a Pollution Control Policy

We discussed pollution taxes or charges levied per unit emitted. Other options include regulation, in which the government sets specific limits on emissions, or transferable pollution permits, which allow firms to emit only the level of pollution for which they have permits. Transferability implies that firms can buy and sell these permits, with low−emitting firms able to sell extra permits, and high−emitting firms able to purchase additional permits.

In this chapter, we will approach the questions of the level and method of pollution control primarily in terms of economic analysis. At the same time, we will bear in mind the limitations of a purely economic perspective. In dealing with the impacts of pollution, we may not be able to measure all relevant costs and benefits in economic terms. This is especially true when multiple pollutants affect the environment, when cumulative ecosystem damage and degradation is at issue, or when subtle effects of persistent pollutants are poorly understood.

In such cases, economic analysis may not capture the full scope of ecosystem effects. Economic analysis, however, is essential to understand how pollution control policies affect firms and individuals, and the role that economic incentives play in altering behavior with regard to the production and consumption of pollution generating products.

Marginal Costs and Benefits of Pollution Control

Let us look first at the question of pollution levels. Figure (1) shows a general analysis applicable to many pollution control issues. The horizontal axis shows the quantity of pollution emitted in a particular industry, with pollution levels increasing from left to right. The maximum level, Q, shows the expected amount of pollution with no pollution control. As pollution control policies are implemented, the amount of pollution will drop below Q_{max} , moving from right to left on the horizontal axis. MC_D , the marginal cost of damage, shows the marginal costs associated with pollution emissions. These tend to rise in a nonlinear, upward-curving pattern, indicating that incremental emissions are proportionately more damaging once the environment is already polluted. This is consistent with both common sense and scientific evidence- a small amount of automobile exhaust on a clear day may be a mere annoyance, but the same amount added to a smog-choked intersection at rush-hour could trigger significant breathing and health problems.

MC_c the marginal cost of control, rises as pollution levels fall (moving from right to left on the graph). This also makes sense in terms of practical experience. It is generally easier to clean up the first few units of pollution than to reduce pollution to low levels. As we approach zero emissions the control costs are likely to soar, and for many pollutants a zero level would require shutting down production entirely.

Economic theory indicates that the optimum level of control is Q^*- where the marginal damage cost exactly equals the marginal control cost $\{MC^*\}$. At Q^*, the cost of cleaning up one more unit of pollution is greater than the benefit it brings in reduced damages. On the other hand, cleaning up one less unit will increase damages by more than it reduces control costs. Therefore Q^* is the most efficient level of cleanup. This balancing of marginal control cost with marginal damage cost is known as that.

Equimarginal Principle

It is easy enough to find Q^*on our graph, but how can we identify it in real life? This is not so easy, because we are unlikely to know the shape and location of the MC curves with any precision. As we saw, valuation of environmental damages is an imprecise science and involves many judgment calls. Control costs may be easier to estimate based on industry experience, but these too are often uncertain.

Industries often estimate control costs at higher levels than actually occur when control policies go into effect. For example, the automobile industry has often argued that controlling tailpipe emissions would boost vehicle costs by a large margin. In practice, the implementation of significantly tighter vehicle emission standards has had little impact on costs.

Similarly, the electric power industry predicted high costs for sulfur oxide (SO_x) reduction, but the real costs (as shown by the price of SO_x emissions permits, discussed below) were considerably lower. On the other hand, control costs can run much higher than estimated, as has often proved the case for cleaning up toxic waste facilities.

Despite these uncertainties, the equimarginal principle is central to the economic analysis of pollution control policies. Even if we cannot define the precise goal, we know that it will be better to use efficient policies– those that give the greatest result for the lowest cost–rather than inefficient policies that bring relatively higher costs and reduced benefits. Economic analysis can help us formulate efficient policies and analyze the advantages and disadvantages of different approaches. In the following sections, we will consider some of the possible options for pollution control from this point of view.

Pollution Control Policies: Standards, Taxes, Permits

One option for pollution control is direct regulation of pollution-creating activities. Government departments such as the U.S. environmental protection Agency can set emissions standards for particular industries or products, subject to legislative guidelines. Many people experience such standards at an annual automobile inspection. Cars must meet certain standards for tailpipe emissions: a car that fails must correct the problem before receiving an inspection sticker.

What are the advantages and disadvantages of standards from the economic perspective? The clear advantage is that standards can specify a definite result. This is particularly important in the case of substances that pose a clear hazard to public health. By imposing a uniform rule on all producers, we can be sure that no factory or product will produce hazardous levels of pollutants.

Systems that require all economic actors to meet the same standard, however, may have the problem of inflexibility. Fixed standards work well when pollution-generating activities are similar. For example, different models of automobiles are sufficiently alike to impose the same emissions rules on all. But consider an industry with many plants of different sizes and ages. Will it make sense to have the same rule for every plant? A particular standard might be too difficult for the older plants to meet, forcing owners to shut them down. On the other hand, the same standard might be too lax for more modern plants, allowing them to emit pollution that could have been eliminated at low cost.

In the case of an industry with many different plants, a market−based pollution control system may make sense. One such system is a tax, or per unit charge, for emissions. As we saw, a pollution tax reflects the principle of internalizing externalities. If producers must bear the costs associated with pollution by paying a per unit charge, they will find it in their interests to reduce pollution so long as the marginal control costs are less than the tax

Once again Q_{max} is the level of pollution emitted with no controls. If, as shown in figure (2), a uniform charge or pollution tax equal to $T_1$is imposed, pollution will fall to Q_1 producers will find it preferable to reduce pollution to this level, at a total cost of E (the area under the marginal control cost curve between Q_1 and Q_{max}) rather than paying a fee equal to E + F on these units. They will also have to pay a total charge equal to B +D on the quantity Q_1 of pollution they continue to emit. Thus their total cost arising from pollution control plus charges will be B +D +E. this is less than B + D + E +F , which they would have to pay if they undertook no pollution reduction.

If the per–unit charge is set higher, at T_2, producers will reduce pollution to Q_2. This will involve control costs of C + D + E, and pollution charges of A + B. the extra units of pollution reduction involve higher marginal costs, but so long as these costs are less than T_2 producers will find it worthwhile to undertake the extra expense and thus avoid paying the fee on the units of pollution between Q_1 and Q_2.

Which of these pollution tax levels is correct? To find out, we must measure the real costs of pollution damage. Notice that the marginal cost of damage curve shown in figure (1) has been omitted in figure (2). This is consistent with real life policy making, in which we rarely have a precise measure of damages in economic terms. This raises the possibility that the pollution charge will be set too high, or too low.

Notice, however, that for any given tax level producers' response will be economically efficient. In the case where different producers have different control costs, they can decide independently as to which level of pollution control makes sense for them. Those who have high control costs will reduce less, but pay a higher total charge for pollution emitted. Those who can cut pollution at low cost will reduce more, thereby reducing the charges they must pay.

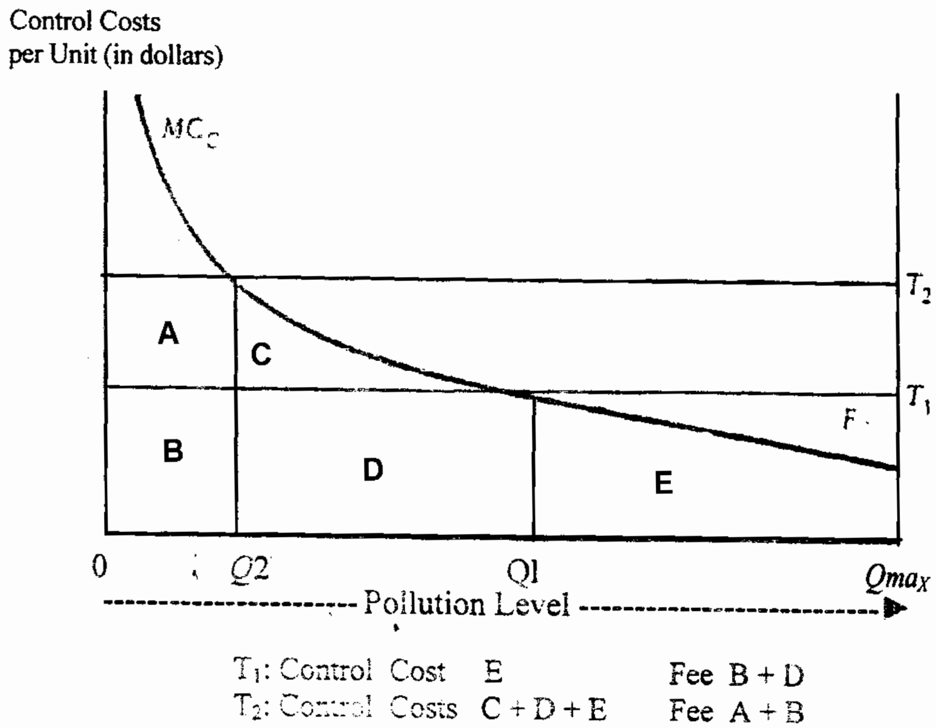


FIGURE (2) *A Per-Unit Charge for Pollution Emissions*

This cost-minimizing logic ensures that cleanup expenses are directed to wherever they can achieve the most. Here we have a different application of the equimarginal principle- marginal control costs are being equalized among all producers. If the tax level reflects the true damage costs, it will also be true that marginal control costs for all producers are equal to marginal benefits from damage reduction.

Transferable Pollution Permits

Economic efficiency in pollution control is clearly an advantage. One disadvantage of pollution charges, however, is that it is generally impossible to predict the total amount of pollution reduction a given charge will produce. It depends on the shape of the MC_C curve shown in figure (2), which as we have noted is usually not known to policymakers.

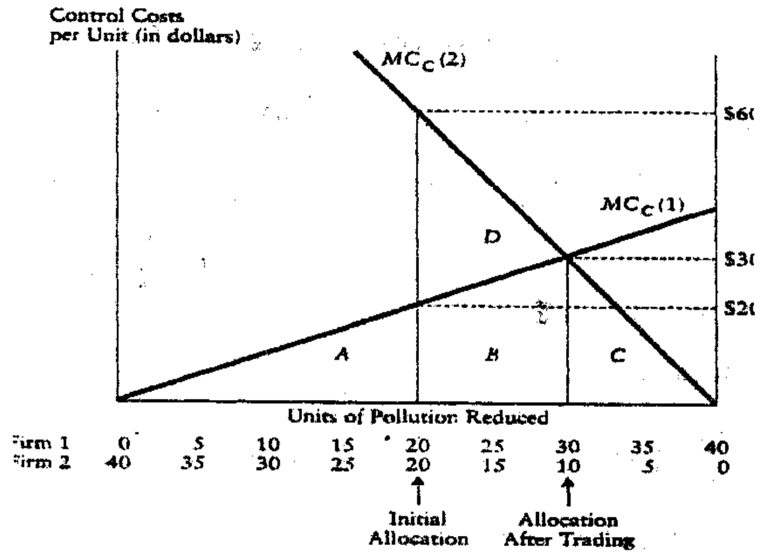
Suppose that the policy goal is a more precise and definite reduction in pollution levels within a region. For example, in 1990 the U.S. environmental protection agency set a goal of 50 percent reduction in sulfur and nitrogen oxide (SO_x and NO_x) emissions that cause acid rain. What is the best way to achieve such a specific target, while also achieving economic efficiency?

One approach, used in the U.S. clean air act amendments of 1990, is to set up a system of transferable pollution permits. The total number of permits issued equals the desired target level of pollution. These permits can then be allocated to existing firms or sold at auction. Once allocated, they are fully transferable, or tradable, among firms or other interested parties. Firms can choose for themselves whether to reduce pollution or to purchase permits for the pollution they emit-but the total volume of pollution emitted by all firms cannot exceed a maximum amount set by the total number of permits.

Within this system, however, private groups interested in reducing pollution can purchase permits and permanently retire them, thus reducing total emission below the original target level. The permits also may be issued for a specific time period, after which fewer permits will be issued, resulting in lower overall pollution levels. Figure (3) illustrates a simplified version of a transferable permit system

In this simplified example we assume only two firms, each emitting 50 units of pollution. The policy goal is a total reduction of 40 units of pollution. The sum of reductions by the two firms must therefore equal 40. However, the marginal control costs for the two firms differ.

Figure (3) shows the different ways in which a total reduction of 40 units can be distributed between the two firms.



Before Trading

	Permits Issued	Units Reduced	Control Cost
Firm 1	30	20	$2,000
Firm 2	30	20	$6,000
	60	40	$8,000

After Trading

	Units Reduced	Control Costs	Value of Traded Permits	Net Costs
Firm 1	30	$4,500	$3,000 Income	$1,500
Firm 2	10	$1,500	$3,000 Payment	$4,500
	40	$6,000	$50	$6,000

FIGURE (3) *A Transferable Pollution Permit System*

The marginal cost of control MC_C curves for the two firms are plotted in different direction on the same axis, with pollution reduction by firm 1 going from left to right and for firm 2 from right to left. This is merely a graphical trick to make it easy to identify the point at which the equimarginal principle is satisfied (that is, the point at which the marginal control costs for the two firms are equal).

The two firms together are emitting 100 units of pollution. To achieve the $40-$unit reduction goal, a total of 60 permits must be issued. Suppose that the initial allocation of permits is 30 to each firm. If permits cannot be traded, each firm must cut back its emission from 50 to 30 – a net reduction of 20. This is shown in the middle of the graph. At this point, the marginal control cost is $\$200$ for firm 1 and $\$600$ for firm 2. This is the same result that would occur if a uniform regulation limited each firm to a maximum of 30 emissions units.

This result achieves the policy goal in terms of emissions reductions, but it is economically inefficient. Each firm's total control cost can seen on the graph as the area under the MC_C curve. Firm 1's total cost for pollution control is area A (= $\$2{,}000$), and the total cost for firm 2 is areas B + C + D (= $\$6{,}000$). The combined cost to achieve 40

units of pollution reduction is A + B + C + D = ($8,000). However, the firms can improve their own positions, and overall economic efficiency, by trading permits.

It will be advantageous for firm 1, which has lower control costs, to reduce pollution by 10 additional units (for a total of 30 reduced), thus using only 10 permits and selling the extra 10 permits to firm 2. Firm 2 will find it worthwhile to purchase 10 permits, allowing it to reduce pollution by only 10 units. The equilibrium price for the permits will be $300, which represents the value of marginal control costs for both firms at the point where firm 1 is reducing by 30 units and firm 2 by 10 units.

At this new equilibrium total control cost for firm 1 is area A + B (=$4,500), and total cost for firm 2 is area C (=$1,500). The combined cost is $6,000. The same pollution reduction goal has been achieved at a lower cost. Area D (= $3,000) represents the net savings from this more efficient solution. Figure (3) shows the costs with and without trading. Notice that- trading reduces the total costs for each firm, as well as the combined costs.

In a sense, a transferable permit system combines the advantages of direct regulation and an emissions charge system. It allows policymarkers to set a definite limit on total pollution levels, while using the market process to seek an efficient method of achieving the goal. It is economically advantageous for the firms involved, as our example shows, allowing a given amount of pollution reduction for the minimum economic cost. In addition, other interested parties can strengthen pollution control by purchasing and retiring permits, and pollution controls can be tightened over time by reducing the overall number of permits issued.

The trading equilibrium shown in figure (3) is consistent with the equimarginal principle, because at the trading equilibrium the marginal control costs for all firms are equal. (our example used only two firms for simplicity, but the principle can easily apply to an industry with many firms.) this uniform marginal control cost will also be the equilibrium price of a pollution permit. Firms will benefit by purchasing permits whenever the permit price is below marginal control costs or selling permits whenever the permit price exceeds these costs.

It does not necessarily follow, however, that a transferable permit system is always the ideal pollution control policy. Transferable permits have been used successfully for sulfur dioxide reduction under the clean air act amendments of 1990, and have been widely discussed as a tool for reduction of global carbon dioxide emissions, but numerous factors must be considered in deciding whether pollution taxes, permits, or direct regulation are the best policy tools for a particular goal. In the next section, we review some of these issues and look at some examples of pollution control in practice.

Policy Choice: Pollution Taxes Versus Tradable Permits.

Clearly, market based policies can play a significant role in pollution control. Both pollution taxes and tradable permits can promote efficiency, although as we have seen they are not always the most appropriate policies. When market-based policies are indicated, a further question arises: which market-based policy is best? Also, if we choose taxes, at what level should they be set? And if we choose permits, how many should be issued and to whom?

The choice of taxes versus permits relates closely to the shapes of the marginal cost of control and marginal cost of damage curves shown in figure (1). In analyzing the way in which these policies work, we focused on issues related to the marginal cost of control curve. But in the choice of policies, we must also consider the marginal cost of damage and the interrelationships between the two curves. A couple of examples will show why this is important.

Suppose that for a particular pollutant the marginal costs of damage are steep, or inelastic: that is to say they rise quickly as the level of pollution increases. On the other hand, the per unit costs of control for this pollutant tend to be fairly stable, with marginal cost rising only slowly as pollution reduction increases. This is shown in figure (5). In this case, a pollution tax is risky, because a small error in setting the tax level can lead to a large increase in pollution damage. In figure (5), the appropriate tax level to balance marginal damage and control costs would be to with resulting pollution level Q_0. But setting the tax slightly lower, at T_1 would cause firms to cut back on pollution control to Q_1, with marginal damage costs rising to P*. the large shaded triangle shows the net social loss from this extra pollution damage.

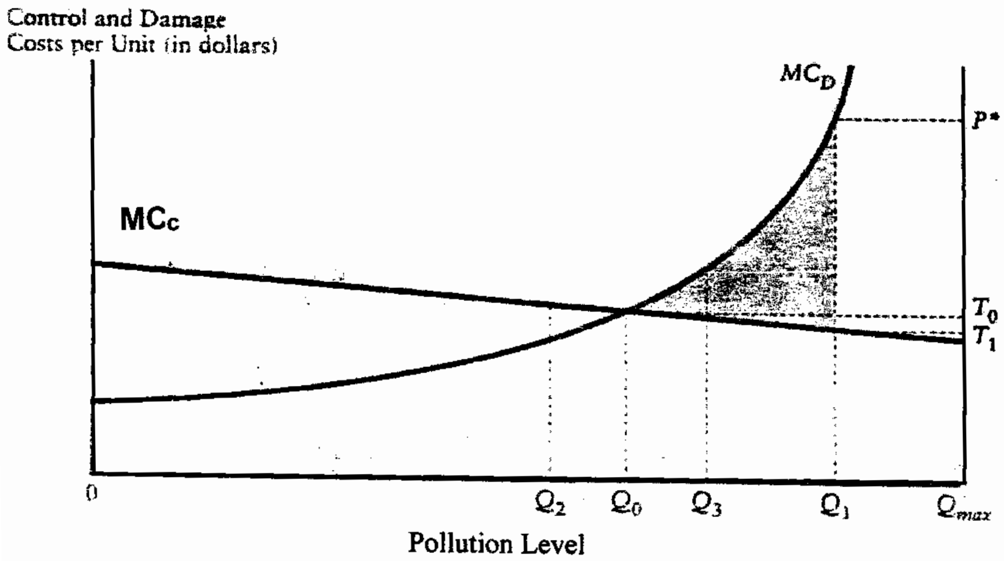


FIGURE (5) *Pollution Control with Steep Marginal Damage Costs*

This pattern of damage costs might be associated with a pollutant such as methyl mercury, which can cause serious nerve damage above a very low tolerance threshold. In this case, a quantity-based control system would be a much more effective policy.

Transferable permits or direct regulation could limit emissions to Q_0. A small error in either direction in setting the quantity control level (Q_2 or Q_3) would cause a much smaller net social loss (the small triangular areas between the marginal cost and damage curves from Q_0 to Q_2 or from Q_0 to Q_3).

A contrasting case occurs when the marginal cost of damage curve is relatively flat, but the marginal cost of control curve is steep, as shown in figure 6. Here control costs rise rapidly above a certain level, while damage costs are fairly stable.

In this case quantity controls pose the more serious risk of error. The ideal quantity control would be at Q_0 but an excessively strict control at Q_1 would cause a rapid rise in marginal control costs, to P*, with net social loss shown by the large shaded triangle. On the other hand, a tax policy could deviate from the appropriate level of T_0 without having much negative effect either in excessive cost or excessive damage. The impact of a tax policy with a tax level set too high (T_1) or too low (T_2) causes only a small deviation from the Q_0 control level, with net social losses equal to the small triangles between MC_c and MC_D between Q_0 and Q_2 or Q_0 and Q_3.

Industry spokespersons often argue that excessively rigid government regulations force high control costs for limited benefits. As we have seen, these arguments sometimes amount to crying wolf. Where industrywide control costs may genuinely be high, however, a tax or pollution charge will allow firms to make their own decisions.

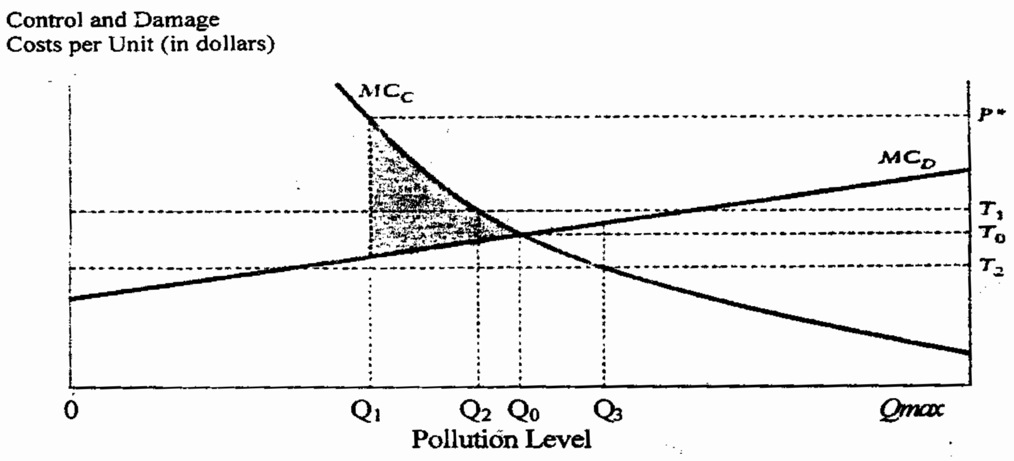


FIGURE (6) ***Pollution Control with Steep Marginal Control Costs***

About pollution control. They will not be forced to undertake exorbitant expenditures, but at the same time the tax will require them to account for the internalized social costs of pollution. For example, a tax on fertilizer or pesticides could encourage farmers to seek more environmentally friendly production techniques while allowing the use of chemical inputs where cost-effective.

Structuring Pollution Control Policies

A further issue in the use of market-based pollution control concerns how we allocate permits in a tradable permit in a tradable permit system. One approach is to issue permits to existing firms requiring new firms entering the industry to purchase permits on the open market. This obviously favors existing firms, who receive something of value (the permits) at no charge. However, it may be the most politically acceptable policy, because it will minimize industry opposition.

An alternative approach is a permit auction, in which permits are sold to the highest bidder. This has the advantage of bringing in government revenues that could be used to lower taxes elsewhere in the economy tradable permits sold at auction are economically similar to pollution taxes; the market–determined permit price is equivalent in effect to a per unit pollution charge.

A related issue is grandfathering of existing plants. This refers to a system in which strict pollution control regulations are applied to new plants, but existing plants are allowed to comply with less demanding standards (or no standards at all).

This is intended to avoid excessively high marginal control costs, but is clearly biased toward existing plants, and is open to abuse they had already reached. In the third period, emissions drop steadily to an eventual zero level.

Note the relationship between emissions and accumulations. As emissions rise at a steady rate, shown by the straight line in the first part of the upper graph, accumulations rise at an exponentially increasing rate. Accumulations continue to rise steadily

Problem

Two power plants are currently emitting 80 units of pollution each (for a total of 160 units). Control costs for Pant 1 are given by MC_c (1) = 2Q and for plant 2 by MC_c. (2) = 3Q, where Q represents the number of units of pollution reduction. Analyze the effects of the following policies in terms of control costs for each firm, total control costs, government revenues, and total pollution reduction:

a) A regulation requiring each plant to reduce its pollution by 50 units.

b) A pollution tax of $ 120 per unit of pollution emitted.

c) A transferable permit system in which 60 pollution permits are issued, 30 to each plant (use a diagram similar to figure (3), showing 100 units of pollution reduction).

Chapter four

Pollution: analysis and policy

For each item, determine where the statement is basically true or false:

1) The optimal pollution level is the amount of pollution that marginal social benefits are higher than the marginal social costs.
2) Pollution reduction is worthwhile so long as control costs are less than the benefits gained in terms of reduced damage.
3) The government sets specific limits on emissions, or transferable pollution permits.
4) Transferable pollution permits allow firms to emit only the level of pollution for which they have permits.
5) Transferability implies that firms cannot buy or sell the permits.
6) Transferability implies that low–emitting firms able to purchase additional permits, and high–emitting firms able to sell extra permits.
7) When multiple pollutants affect the environment, we may be able to measure all relevant costs and benefits in economic terms.
8) The marginal cost of damage that associated with pollution emissions, tend to rise in a nonlinear, upward–curving pattern.
9) The marginal cost of control rises as pollution levels rise.
10) It is easier to clean up the first few units of pollution than to reduce pollution to low levels.
11) For many pollutants a zero level would require shutting down production entirely.
12) Economic theory indicates that the optimum level of control is where the marginal damage cost exactly equals the marginal control cost.

13) The cost of cleaning up one more unit of pollution is lower than the benefit it brings in reduced damages.

14) Cleaning up one less unit will increase damages by more than it reduces control costs.

15) Valuation of environmental damages is an imprecise science and involves many judgment calls.

16) Fixed standards work well when pollution-generating activities are similar.

17) If producers must bear the costs associated with pollution by paying a per unit charge, they will find it in their interests to reduce pollution so long as the marginal control costs are higher than the tax.

18) Those who can cut pollution at low cost will reduce more, thereby reducing the charges they must pay.

19) The advantage of pollution charges, is that it is impossible to predict the total amount of pollution reduction a given charge will produce.

20) If the tax level reflects the true damage costs, it will also be true that marginal control costs for all producers are equal to marginal benefits from damage reduction.

21) The pollution control may strengthen by purchasing and retiring permits.

22) Pollution control can be tightened over time by increasing the overall number of permits issued.

23) Firms will benefit by purchasing permits whenever the permit price is below marginal control costs or selling permits whenever the permit price exceeds these costs.

24) Both pollution taxes and tradable permits can promote efficiency.

25) A pollution tax is risky, because a small error in setting the tax level can lead to a large increase in pollution damage.

26) A contrasting case occurs when the marginal cost of damage curve is relatively flat, but the marginal cost of control curve is steep.