Reading Materials for 6th Semester

Paper: 6.3

Unit: 2

# Topic : Conditions for Optimal Depletion of an Exhaustible Resource

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Exhaustible resources are those resources which are non renewable in nature. These resources were formed in millions of years and will get exhausted sooner or later. Examples of some exhaustible resources are coal, petroleum, natural gas, minerals etc.

Exhaustible resources will be depleted so long as the extraction rate is positive. The supply or extraction behavior of an exhaustible resource differs from that of an ordinary resource. An exhaustible resource is limited in quantity and is not producible like an ordinary resource. Ordinary good or resource, produced in the economy using available methods of production, can be replicated. But exhaustible resources can not be replicated. These are created by geological processes with geological time spans. There are two conditions for optimal depletion of an exhaustible resource, which are discussed below :

## First Order Condition for Optimal Depletion :

A price taking firm supplying ordinary goods will adjust production in all periods so that its marginal cost ( mc) of production in each period equals price (p) in that period. If the mc is less than p, the supplier can raise current profits by increasing production. However, when the firm is the supplier or extractor of an exhaustible resource, such behavior might require extraction of more stocks than is available to the firm.

Thus , in case of exhaustible resource , it require some modifications of the standard theory. Since an exhaustible resource is limited in quantity and is not producible, extraction and sale of a unit today involves an *opportunity cost.* This opportunity cost is usually called *user cost* (uc). The presence of user cost is central to the economics of exhaustible resources. User cost does not exist for conventional reproducible goods since the consumption of an amount now does not reduce the quantity that can be consumed in the future. However, a barrel of oil extracted today is a barrel unavailable for extraction in the future. In deciding whether to extract and sell an additional barrel today, the extractor must consider not only the cost of pumping the barrel, but also the cost of foregoing the highest return that could have been earned if the oil had instead been pumped and sold in the future.

Hence , it is necessary to have a more inclusive definition of marginal cost and it is called *augmented marginal cost. The augmented marginal cost* (amc) is, thus, defined as the marginal cost of extraction (mc) plus the user cost (uc).

When mc is defined in this way, it is optimal for a competitive resource owner firm to extract the resource in each period to the point where its amc equals the market price (p). Instead of the usual efficiency condition, price (p) = marginal extraction cost ( mc ), we have :

$P = mc + uc$ ........ ( 1 )

This is the first condition of optimal depletion of exhaustible resource.

As shown in the following figure, it implies that less of the resource will be extracted today than if it were a producible ordinary good or resource.

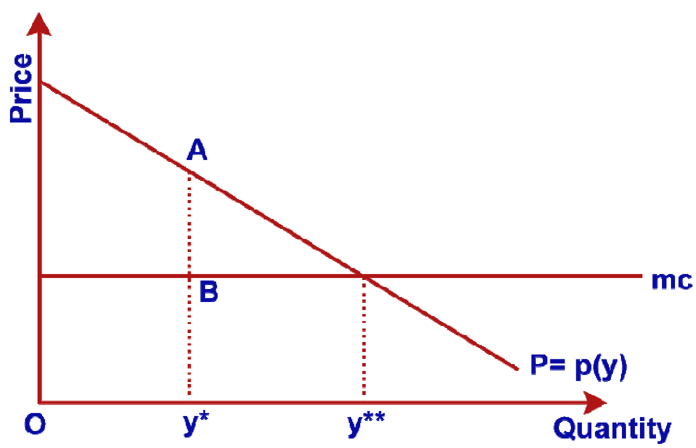


Figure A : Optimum Extraction of an Exhaustible Resource

Given the inverse demand function p = p (y), where p is the price and y is the quantity extracted , only y* units ( rather than y** where p = mc ) will be extracted by a price taking firm seeking to allocate extraction efficiently over time. This leads a positive difference AB ( the opportunity cost/ user cost) between p and mc.

**Second Order Condition for Optimal Depletion :**

Let us, for simplicity, assume just two periods: the resource owner either extracts and sells the resource today, in period O , or retains it in the ground until the next period 1.

Let the price he can obtain for a unit of the resource today be p o and the price he expects to prevail for a unit in the next period be p 1 . The cost per unit of extracting the resource and delivering it to the buyers is C, which is not expected to vary between periods O and 1 , that is C = mc remains constant.

If he sells the unit in period O he will receive net revenue of $P_0 - C$ but forgo revenue of $p_1 - C$ in the following period. The value in period O of the net revenue foregone is its present value $(p_1 - C)/(1 + r)$ where r is the discount rate.

Hence his return from selling a unit today will be :

$$(p_o - C) - (p_1 - C)/(1 + r)$$

Here, $(p_1 - C)/(1 + r)$ is the opportunity cost of his decision to sell a unit today. It is the user cost of his decision. It arises because he is faced with the alternative of selling it in the following period. If

$$(p_o - C) > (p_1 - C)/(1 + r)$$

He will be better off selling his resources in the current period. If, on the other hand,

$$(p_o - C) < (p_1 - C)/(1 + r)$$

He will be better off by leaving it in the ground. His optimum amount of current extraction is given where

$$P_o - C = (p_1 - C)/(1 + r) \qquad (2.1)$$

This implies that

$$p_o = C + (p_1 - C)/(1 + r) \qquad (2.1a)$$

Equation 2.1a states our earlier result that the current price of the resource when it is extracted optimally, should be equal to the mc plus the user cost (uc).

Transposing equation 2.1 , we have

$$(p_1 - C)/(p_o - C) = 1 + r \qquad (2.2)$$

Which implies that

$$(p_1 - C) = (p_o - C)(1 + r) \qquad (2.2a)$$

This equation ( 2.2 or 2.2a ) is the second condition for optimal depletion of exhaustible resource. It is usually described as the fundamental equation of exhaustible resource extraction.

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