

Economics of Non-renewable Resources: Conditions for Optimal Depletion

In economic terms, non-renewable resources are resources of economic value that cannot be readily replaced at the speed with which they are being consumed. They are available in fixed quantities. Examples of nonrenewable resources include crude oil, natural gas, coal, and uranium. These are all resources that are processed into products that can be used commercially

The economics of nonrenewable resources addresses some of the most problematic issues concerning the sustainability of the world economy. In 1931, Harold Hotelling introduced the Hotelling rule—the fundamental theoretical principle of non-renewable resource economics in respect of Conditions for Optimal Depletion or extraction of exhaustible resources or non-renewable resources. The theory is explained as below.

Hotelling tries to discover the conditions under which exhaustive resources can be extracted optimally over time, under perfect competition.

Hotelling's rule states that the most socially and economically profitable extraction path of a non-renewable resource is one along which the price of the resource, determined by the marginal net revenue from the sale of the resource, increases at the rate of interest. It describes the time path of natural resource extraction which maximizes the value of the resource stock.

Assumptions:

- Micro analysis of an exhaustible resource (e.g. coal).
- Perfect competition in the product market, the price (p) of coal is constant.
- Price is known to the mine owner.
- Constant returns to scale. Extraction costs do not rise but remain constant, even as the mineral gets exhausted.

- No change in technology or improvements in mining.
- So MC remains constant. $AC = MC$
- Perfect foresight regarding future costs, demand and prices, no uncertainty.
- Downward sloping demand curve for the mineral.
- Mine owner is aware of the stock reserves of the non-renewable resource.
- Constant extraction costs, as mineral gets depleted, extraction costs do not rise.

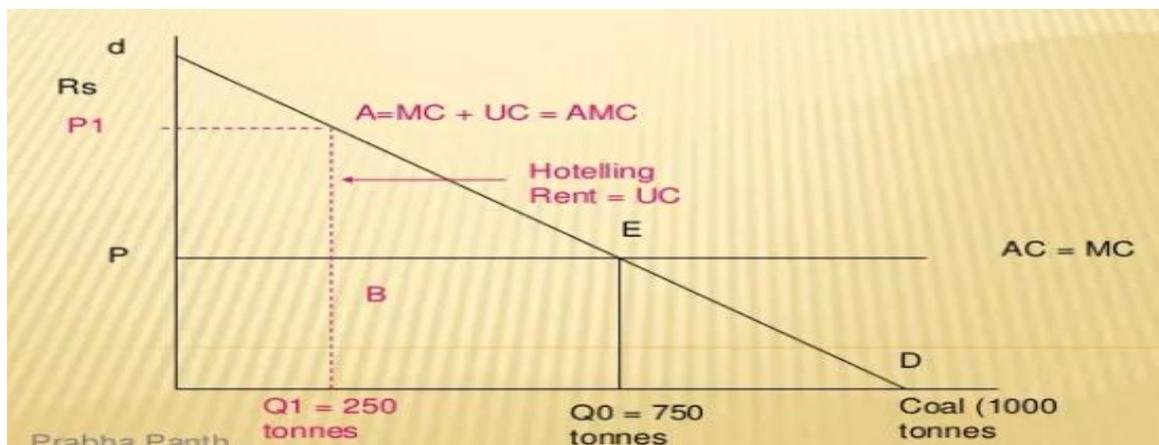
In hotelling rule, we have hotelling rent also known as user cost. It is the opportunity cost of postponing extraction of a non renewable resource. If the mineral is extracted now, the present profit will be earned but there will be depletion of mineral. If the mining is postponed then the profits can be gained in the future. User cost is thus the present value of the marginal profits

from selling the resource at a future time. This gives the future amount expected from a resource when the mining is done in future rather than doing it now.

In hotelling rule there are conditions for optimal depletion of the exhaustible resource. These conditions are:

1. In Perfect competitive market, equilibrium exists when the price is equal to marginal cost.
2. In the case of non renewable resource, the price equals Augmented user cost (AUC) and equals to marginal cost (MC) plus User cost. Symbolically: $P = AUC + U$
3. Postponing extraction of the resource for the future involves preference of time.
4. The future price should exceed present price of extraction to provide compensation for the loss of present earnings resulting from conservation

Diagrammatic illustration of the model:



When to postpone extraction:

- Extraction leads to exhaustion of the resource, if $MC = P$ rule is followed in perfect competition.
- Mine owner expects resource price may rise in future due to resource scarcity,
- The minimum amount of expected increase in price in future = $(P1 - P0) = (UC)$.
- In the diagram $P1 > P0$, the difference is UC , i.e. $P1 = P0 + UC$.
- If future $P1 > P0$, then the mine owner will be prepared to postpone resource extraction.

Time Preference or NPV:

- Postponing extraction, means postponing earning of profits,
- Waiting for the future earnings involves loss of interest on present earnings. ,
- Therefore the future expected profit has to be discounted by the rate of interest.
- Miner compares present earnings at the given price, with the discounted earnings overtime, to decide whether to extract now or in the future.

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Example

- Two time periods: T0 and T1.
- Total reserve of non-renewable resource is 100 tonnes.
- Present price (P0) of the resource is Rs.20.
- $MC = AC = Rs. 20$
- Rate of discount is 10%
- By what rate should future price P1 increase to postpone extraction?

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Conditions for Resource Conservation:

1) The expected future price P_1 , should be equal to Augmented Marginal Cost:

$$P_1 = AMC = (MC + UC)$$

2) Future price P_1 should exceed the present price P_0 by the rate of discount:

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

- If $P_0 (1+r) < P_1$ the mine owner will prefer to extract now.
- If $P_0 (1+r) \geq P_1$ he will prefer to postpone extraction.

Discounted Future Price:

In our example $p_1 = p_0 (1+r) = \text{Rs.}20 (1 + 0.1) = \text{Rs.}22$.

So future price has to increase by Rs.2

The mine owner equates present earnings with discounted future earnings:

$$P_0Q_0 = (P_1Q_1) / (1+r)$$

- 1st year earnings = $\text{Rs.}20 \times 30t = \text{Rs.}600$
- 2nd Time period earnings = $\text{Rs.}22 \times 30t = \text{Rs.}660$

- Discounting by the rate of interest of 10% = $\text{Rs.}660 / 1.1 = \text{Rs.}600$

- This satisfies the NPV rule that $P_0Q_0 = (P_1Q_1) / (1+r)$

Hotelling's Fundamental Equation or Rule:

"The optimum path of depletion of a non-renewable resource is decided by the expected rise in future price at least by the rate of discount or interest."

- Along the optimal path of depletion of a non-renewable resource:
- The marginal net price, which is identical to the resource or Hotelling rent, should increase at the rate of discount.
- If the initial price is too high, there will be too much conservation in early years and a part of the resource stock will be left in the ground.
- If, on the other hand, P_0 is too low, there is over-exploitation, and the resource stock will be depleted too early.

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Criticism:

- 1) If future prices are not properly predicted, leads to over or under exhaustion of the non-renewable resource.
- 2) The reserve position of the mine may not be known.
- 3) Changes in the rate of discount leads to fluctuations in the natural resources market.
- 4) In perfect competition, expectations do not rule. So an individual mine owner cannot change his production decisions. This is possible only in a monopoly.
- 5) MC of extraction may not remain constant.
- 6) No discussion of exhaustion of global minerals, and impact on development.