ECONOMICS OF NON-RENEWABLE RESOURCES
B.A 6th Sem (Major)

1. Introduction: Renewable Versus Non-renewable Resources

The New Webster's Dictionary defines "renewable" as "replaceable naturally or by human activity". Examples of renewable resources include trees and other plants, animal populations, groundwater, etc. In contrast, non-renewable resources are those that are not replaceable, or replaced so slowly by natural or artificial processes that for all practical purposes, once used they would not be available again within any reasonable time frame. Obvious examples are oil and mineral deposits.

Economists add another dimension to this distinction between renewable and nonrenewable resources. Since economics is concerned with the allocation of scarce resources, for an economist non-renewable resources not only have a fixed stock, they are also in limited supply relative to the demand for them.

Traditionally, the major economic issues in the study of non-renewable resources have involved predicting the future production and price trajectories, as well as the date of possible resource exhaustion. In addition, there has been an effort to understand the impact of alternative market structures, such as pure competition, monopoly, and a cartel-dominated oligopoly, on the predicted trajectories. More recently, the environmental costs associated with the extraction and consumption of non-renewable resources has also come into focus.

The Hotelling Model of Resource Depletion(very important)

The central question in non-renewable resource economics is: given consumer demand and the initial stock of the resource, how much should be harvested in each period, so as to maximize profits? A simple example brings out the underlying intuition. For now, assume away any extraction costs and focus on the price per unit, p, of the resource in the market. Assume also that the real (inflation adjusted), risk-free interest rate on investments in the economy is r per cent per year. Then, the owner of the resource can either extract the resource now or hold on to it to extract in the future. Any amount of the resource extracted today will not be available in the future, and any resource left untouched today may fetch a higher price in the market in the future. These are the two fundamental factors influencing the resource owner's extraction decision. If the owner extracts the resource today he can invest the proceeds and earn r per cent year. However, if he expects the price of the resource to rise faster than r per cent per year, then it would make sense to hold on to the resource, forgo the interest earned on the proceeds but earn a higher total income by selling the resource at a higher price per unit. The opposite argument would hold if the resource price was expected to rise slower than r per cent per year.

In a competitive market where there are a large number of sellers, and each seller can sell any quantity at the going market price, each resource owner would be faced with the same options and would follow the same logic. The theoretical result is that in this market the quantity extracted will be such that resource price will rise at exactly r per cent per year. If it were to rise slower, resource owners would begin to sell off current stocks and the current market price would fall. If the resource price were to increase at a rate faster than r per cent per year, all owners of the resource would hold on to their stock, decreasing the current supply in the market, thereby inducing the current market price to rise. The equilibrium price trajectory for a non-renewable resource would, therefore, be rising exponentially as shown in Figure 1, where P0 is the initial price and T indicates the time period of resource exhaustion.

An implication of the continuously rising price is that the quantity extracted would be continuously falling until such time as the resource is exhausted. As the price rises the demand for the resource is slowly choked off. Eventually the price would be so high that demand would be eliminated altogether. In the basic model, this is precisely when the resource stock would also be completely exhausted. To understand why, suppose that when the price is sufficiently high to choke off entirely all the demand, resource owners are left with some positive quantity of the resource. This remaining stock would be completely worthless to the owner since no one would want to buy it. Realizing this, the resource owners would begin to sell off the stock at lower prices before the demand is choked off by the high prices. However, this would mean that there would be an excess supply of the

resource in the market which would lower current prices. The production trajectory would be extended in time and again the price would continue to rise at r percent per year until all the stock is completely depleted. The equilibrium production (or extraction) trajectory for a non-renewable resource is also shown in
Figure 1.

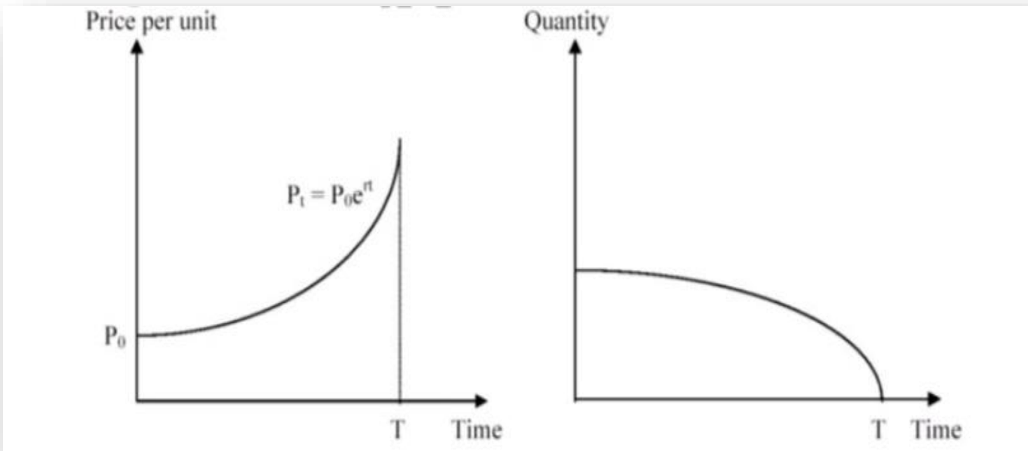

Figure1: Equilibrium Price and Quantity Trajectories for a Non-Renewable Resource

This basic result that the price of a non-renewable resource in a competitive market would rise at the interest rate and that the production trajectory would be monotonically declining till the resource is exhausted was established by Harold Hotelling.

Variations on the Basic Hotelling Model

1. Extraction Costs

Extraction costs per se do not change the fundamental logic of the above model. Suppose that the marginal extraction cost is slowly rising over time. This could be because a larger quantity of resources is being extracted in each period or due to more stringent environmental policies requiring more expensive extraction techniques, or both. Whatever the reason, so long as the marginal extraction cost is not determined directly by the *cumulative* amount of the resource extracted, the result would be that net price, i.e., price minus the marginal extraction cost, or scarcity rent, would rise exponentially at r per cent per year.

It is important to note that even though Hotelling's model of resource depletion implies that net price would be rising exponentially at the interest rate, this does not mean that the market price (i.e., the price paid by the consumer) will follow this trajectory. The consumer price is the marginal extraction cost plus the scarcity rent. If extraction costs are falling, say due to technological improvements as in the case of the oil industry during the last decades of the twentieth century, then it is entirely possible that the market price is constant or even declining in the near term. So long as the downward pressure due to the falling marginal extraction cost outweighs the rising scarcity rent, the consumer price will be decreasing. Eventually, however, as the resource gets depleted and the scarcity rent rises rapidly and outweighs the marginal cost, the market price will rise.

When the marginal extraction cost is rising over time, the equilibrium production trajectory is monotonically declining, as in the simple case with no extraction cost.

However, if the marginal extraction cost decreases with time, then it is also possible for the equilibrium quantity trajectory to increase in the near term. During this period, the downward pressure of the falling marginal cost more than offsets the rising user cost.

2. Reserve Dependent Costs

A more sophisticated theory of non-renewable resource depletion would link the marginal extraction cost directly to cumulative production or the remaining stock of the resource. These are referred to as "reserve dependent costs" in the literature. In this case, each unit of the resource extracted today is not only unavailable in the next period, but also increases future extraction costs by lowering the remaining reserves. The opportunity or user cost of extracting a finite stock of resources is now two fold: foregone interest income and higher extraction costs. In this case, the scarcity rent does not rise at the interest rate, but at the interest rate less the percentage increase in cost due to a marginal reduction in remaining reserves.

Note that the basic principle remains intact: at equilibrium, the marginal benefit from extraction must equal the marginal economic cost (defined as the sum of marginalextraction cost and the user cost).

Monopoly (important)

The fundamental results of the Hotelling model remain unchanged when the entire stock of the resource is owned by a single seller. In this case it is the marginal profit or the difference between the marginal revenue and marginal extraction cost that grows at r per cent per year. However, if in the presence of a static demand curve the price elasticity of demand decreases as the quantity extracted increases, the monopolist's production trajectory will be longer than that of the competitive resource owner when faced with identical costs, initial stock, and consumer demand. The monopolist takes advantage of the relatively lower price elasticity in the earlier periods to restrict output and charge a higher price than the perfectly competitive resource owner. The result is that the extraction path tends to get stretched out over time – that is, monopoly slows the depletion rate. This result has led to the adage, "a monopolist is a conservationist's best friend". The monopolistic and competitive price and quantity trajectories are
compared in Figure 2, where Tc and Tm indicate exhaustion under competition and monopoly, respectively.

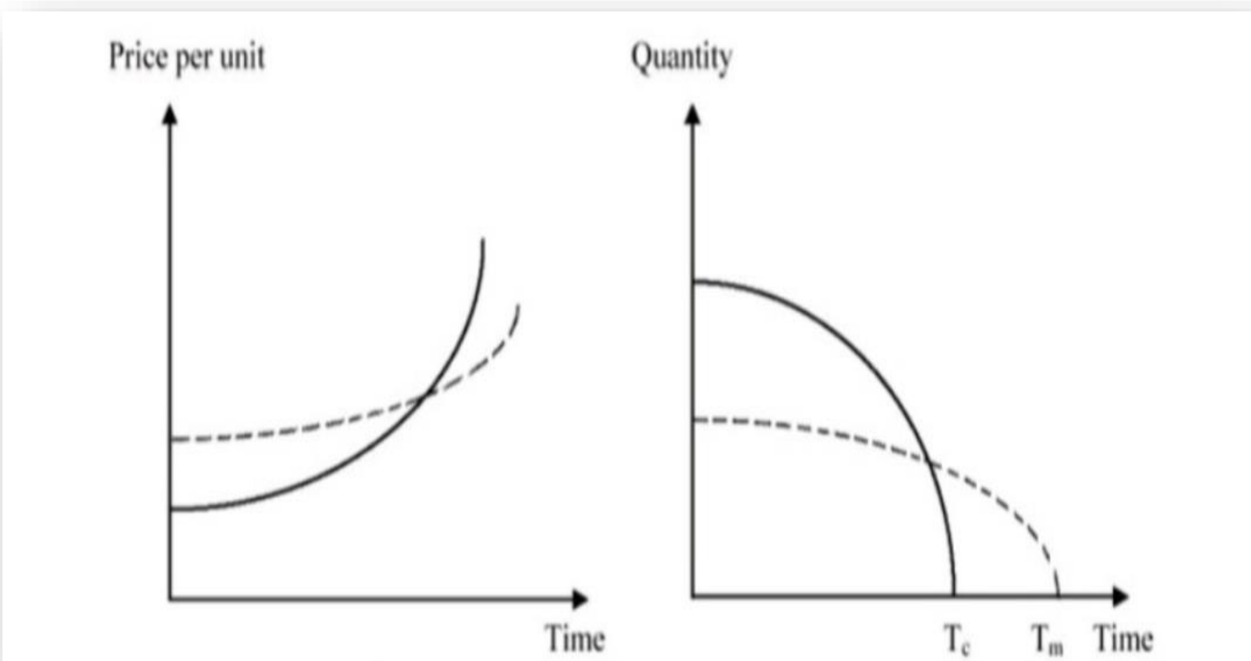

Figure 2: Monopoly vs. Competitive Equilibrium Price and Quantity Trajectories

Conclusions

The Hotelling model of resource depletion is the fundamental economic model used to analyze the issues relating to the use of non-renewable resources. Under this model, resource owners seek to maximize the present value of net benefits obtained from extracting the resource, given consumer demand for the resource and subject to the constraint that total extraction cannot exceed the initial resource stock. The optimal extraction decisions for each period in the production horizon are interdependent, since a unit of the resource extracted today is unavailable for extraction in the future. The key result obtained is that scarcity rent (the difference between marginal revenue and marginal cost, appropriately defined) increases at the rate of discount. The only exception to this “Hotelling rule” is the situation where the marginal extraction costs depend on cumulative extraction. In this case, the rent increases at a rate less than the discount rate. The difference is caused by the increase in marginal cost due to marginal reduction in remaining reserves. However, in all cases, the marginal benefit from extraction to the resource owner is exactly equal to the marginal economic cost at equilibrium.

The Hotelling rule holds regardless of whether the resource stock is owned by a monopoly or a perfectly competitive firm. The difference lies in the definition of scarcity rent. Under perfect competition, each of innumerable firms faces a perfectly elastic (horizontal) demand curve, and marginal revenue is identical to price. Here rent may be defined as the difference between price and marginal extraction cost. In the case of a monopoly, the firm faces a downward-sloping demand curve and price exceeds marginal revenue. Therefore, scarcity rent is the excess of marginal revenue above marginal cost.

******