

**117**

**THEORY OF EXHAUSTIBLE RESOURCES  
A SELECT SURVEY OF DETERMINISTIC  
MODELS**

**KESHAVA H.**

**OCTOBER 1992**

# **THEORY OF EXHAUSTIBLE RESOURCES**

**A SELECT SURVEY OF DETERMINISTIC MODELS**

**A DISSERTATION  
SUBMITTED TO THE  
UNIVERSITY OF POONA  
IN PARTIAL FULFILMENT  
OF THE REQUIREMENTS  
FOR THE DEGREE OF  
MASTER OF PHILOSOPHY  
(IN ECONOMICS)**

**BY**

**KESHAVA H.**

**GOKHALE INSTITUTE OF POLITICS AND ECONOMICS, PUNE**

**OCTOBER 1992**

## ACKNOWLEDGEMENT

My deepest gratitude is to Prof. B.S.R. Rao, my guide, for all the encouragement and guidance he gave me in the course of this work but for which this dissertation would not have appeared in its present form.

I owe a debt of gratitude to Prof. N. Rath who inspired and encouraged me in the beginning to work on this topic.

Besides, I must acknowledge with gratitude the help and support of my teachers, friends and many others, which they extended to me at all times. The continuous support of my parents and other members of the family certainly needs a special mention.

Last but certainly not the least, I must express my sincere thanks to Mrs. & Mr. Anand Kale, Mr. Vasant Khare and Mr. Nirmal Khare of Las-Com Services, Pune, who did a stupendous job of transforming a clumsy manuscript into its neatly typed form.

Of course, responsibility for all errors that remain in this work is solely mine.

Gokhale Institute of Politics  
and Economics,  
Pune 411 004.

Keshava H.

## CONTENTS

ACKNOWLEDGEMENT		ii
INTRODUCTION		1
CHAPTER	TITLE	PAGE
I	COMPETITIVE EXHAUSTIBLE RESOURCE MARKETS	6
II	EMPERICAL TESTS OF HOTELLING'S MODEL OF EXHAUSTIBLE RESOURCE EXTRACTION UNDER COMPETITIVE CONDITIONS	24
III	MONOPOLY IN EXHAUSTIBLE RESOURCE MARKETS	52
IV	PARTIALLY CARTELISED EXHAUSTIBLE RESOURCE MARKETS	70
V	SUMMARY AND CONCLUSION	112
	BIBLIOGRAPHY	119

## INTRODUCTION

Natural resources could refer to all the living and nonliving endowment of earth. These include agricultural land, forests, fisheries, mineral resources, water, nonmineral energy sources of solar, tidal, wind and geothermal systems, fresh air, scenic beauty of a woodland and a host of such natural endowments.

These natural resources are broadly classified into two groups :

- (i) exhaustible resources and
- (ii) renewable resources.

Exhaustible resources are those natural resources the stock of which declines with extraction. For example, oil, coal, natural gas etc. The total stock of these resources are given and cannot be increased. Improvement in technology can, of course, increase the usable stock. Again, discoveries of new deposits will increase the known stock. But the total (known plus unknown) stock cannot be augmented. In other words, these resources do not have a natural or biological regeneration process by which their stock size grows in a time-span relevant to human beings. Resources such as fossil fuels enjoy growth rates that operate only over geological time.

On the other hand, renewable resources are capable of being regenerated by some natural processes. This natural process may take the form of biological regeneration as in case of fish etc. or it may be a natural replenishment such as river water etc. Renewable resources include all resources having such a growth function, e.g., fish,

aquifers, forests, soil fertility.

An important point to be noted is that even renewable resources are exhaustible, if they are harvested at a rate much greater than their natural rate of regeneration. In such a case, their stock size will continuously decline. Thus renewability depends on appropriate non-destructive methods of management as with farm lands, fisheries etc., since some changes in natural resource systems are irreversible.

Natural resources have very important role to play in the functioning of an economic system. This role comes from the various uses which these resources have. Some resources have use in direct consumption, e.g., fish, water, fresh air etc. Some resources are used as inputs in intermediate processing, e.g., iron ore, copper ore etc., in smelting. Some resources have consumptive uses in intermediate processes such as fuels consumed in manufacturing and transport, while some other resources have in situ uses, e.g., free running rivers, wilderness etc.

This role of natural resources in the functioning of an economy was well recognised by economists. The classical economists were concerned about the impact of shortages of natural resources on human material well-being. We know about Malthus' doomsday forecast of increasing population pressure pressing on a fixed supply of agricultural land and resultant starvation as the ultimate population check. Ricardo, on the other hand pointed to the diminishing quality of all the natural resources as the cause of differential land rents and the ultimate check on the economic and population growth. Stanley Jevons in 1865

foresaw stagnation to Britain's industrial progress as he was convinced that coal, which was the major input in the then industrial activity was getting exhausted. On the other hand, J.S. Mill provided a more optimistic analysis of the natural resource situation holding out distinct hope that knowledge and technology could keep the Malthusian margin a good remove.

All these economists expressed concern over the effects of impending natural resource shortages, but surprisingly they did not go into the question of an appropriate rate of utilization of these resources. None had looked at the market mechanisms which determine the rate of depletion of these resources. Markets have historically played an important role in determining the exploration activity and rates of use. Besides, the analysis done by all the classical economists was aggregative. No effort was directed at looking at the impacts of exhaustible and the renewable resources separately.

It was only at the peak of the first conservation movement (1895-1927) that Lewis Cecil Gray attempted such an inquiry. The conservationists believed that the natural resources were being exploited too rapidly and their excessive cheapness had led to wasteful consumption. Hence they proposed that the production of these resources should be prohibited in certain regions or measures should be taken to hamper the production in general. In his two classic articles in 1913<sup>1</sup> and 1914<sup>2</sup>, Gray investigated the question of the rate of extraction that a competitive profit maximizing mine owner will pursue. For him, it was necessary to know this profitable rate of extraction of a profit

maximizing competitive mine owner in order to inquire what are the conditions, which in case of the individual determine the profitability of a conservation policy. Once these conditions are known, one could see whether the market mechanism will lead to conservation or over exploitation of the resources.

Then came the seminal work of Harold Hotelling in 1931<sup>3</sup>. He was not so much concerned with the behaviour of an individual firm in a competitive mining industry, but was interested in the intertemporal price behaviour and the pace of extraction both by a competitive industry and a private monopoly, and whether market mechanism can ensure a socially optimal extraction of the resources. The contributions of Gray and Hotelling created the subject of the 'Economics of Exhaustible Resources'.

In this dissertation, we briefly review some select models of exhaustible resource depletion under various market structures. The chapter scheme is as follows.

In the first chapter, we discuss the problem of resource extraction by a profit maximizing competitive exhaustible resource firm as well as the time paths of price and output in a competitive exhaustible resource market.

In chapter two, we review some of the empirical studies which have attempted at testing the empirical validity of the 'Hotelling Rule' under competitive conditions.

Chapter three deals with monopoly in exhaustible resource markets. The role of elasticity demand in determining the monopoly outcomes is demonstrated.



In Chapter four, we discuss the intermediate market structure, viz, oligopoly in exhaustible resource markets. It is assumed that there exist a resource cartel and a competitive fringe. Price and output behaviour under both a Nash-Cournot and a Stackelberg dominant firm model is discussed. Besides, a few simulation models of the major world resource markets are discussed.

We conclude this select and brief review in chapter five where we mainly focuss on the main issues in exhaustible resource depletion.

#### NOTES AND REFERENCES

1. Gray, L.C. (1913), "The Economic Possibilities of Conservation." Quarterly Journal of Economics 27, pp.497-519
2. \_\_\_\_\_ (1914), "Rent Under the Assumption of Exhaustibility." Quarterly Journal of Economics 28, pp.466-89
3. Hotelling, H. (1931), "The Economics of Exhaustible Resources." Journal of Political Economy 39, pp.137-75