Agric.-Econ. aspects

Part 2

PROCEEDINGS

Agricultural Economics Seminar

Compiled by

HOWARD F. ROBINSON, *Professor of Agricultural Economics*
FREDERIC A. WILLIAMS, *Professor of Agricultural Economics*

Department of Agricultural Economics
North Carolina Agricultural and Technical State University
Greensboro

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THEORY AND STATISTICS IN NATURAL RESOURCE ECONOMICS*

by

Walter G. Miller

Natural Resource Economics Division
U. S. Economics Research Service**

I. FOCUS OF DISCUSSION

As this seminar is just one of a series on "The Use of Economic Theory and Related Statistical Tools in Analyzing Economic Problems", I would like to assume that we already have among us a general understanding of the terms "theory" and "statistics" as used in the title of today's topic. I would like to start on the premise that there are useful concepts and techniques in both theory and statistics that can be applied in the analysis and solution of the real-world problems in natural resource economics. Our central objective is to look at some of these concepts and relate them to this branch of economics.

Let us direct our attention on the following set of questions: What is the scope and content of natural resource economics? Of the economic theories and concepts that have evolved, which of these are relevant for studies in this field? And how are the theories and statistics related?

In pursuing our search for answers to these questions we will not, of course, be able to do a complete job because of the time limitations and the complexity of the questions themselves. Each question could take several seminars of its own; we must therefore be satisfied with only an introductory treatment.

I would like to proceed with our discussion organized in 3 main parts. In the first part, I would like to review the scope and content of natural resource economics as a branch of economics. In the second part, I shall go through a study, which I am working on at the moment, to illustrate the role of theory as vividly as possible. In the third and last part, I shall indicate the theories and concepts that I have personally found useful as a researcher.

Let us now consider the scope and content of resource economics.

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II. SCOPE AND CONTENT OF NATURAL ECONOMICS

Natural resource economics can be defined as a branch of applied economics. It serves as an umbrella for a wide range of studies pertaining to the "primary" natural resources of land, water, and minerals, as well as studies pertaining to such "secondary" natural resources as forest, range, wildlife and energy. These secondary resources are obviously related to the primary resources through biological and physical processes and often must be taken into account in analyzing problems of land or water use. The main point here is that within the field of resource economics we will find specialists in studies of land, water, energy, forest, fisheries and other related subjects.

Emergence of Natural Resource Economics

As a branch of applied economics, natural resource economics has become popular only within the past 10 or 15 years. Prior to this time most of the studies now in this field were conducted under the name of land or water economics. Land economics may however be regarded as the main antecedent to natural resource economics. At one time, and perhaps even today, there are some economists who probably would like to define land to include all natural resources -- soil, water, air, minerals and all other elements of the natural environment as well. But as things have evolved, problems that were once regarded as being in land economics are now more often put under the resource-economics umbrella.

Substitution of the term natural resource economics for land economics has however made no obvious difference in the substance of the studies covered. It still tends to create some confusion however, when one considers that many kinds of resources are used in the production of goods and services. It would be quite reasonable to suggest that practically all economic problems of production should be in natural resource economics, because these resources are always involved. The classification of problems in natural resources is essentially based upon focus and emphasis, even though the classification may be sometimes arbitrary.

One justification for natural resource economics as a branch of applied economics is that the task of dealing properly with the use and management of all resources and their implications in a complex economic system is simply too great for any individual. Division of labor along resource line is probably as good as any other division because resources have peculiar characteristics of their own. In the first place, natural resources can be distinguished from human resources as well as "cultural" or capital resources. Among the natural resources themselves there are also criteria of classification. Such characteristics of natural resources as their exhaustibility are of economic and social significance. In the rest of this discussion, we shall simply use the term resource economics, for short, to mean natural resource economics.

Risks of resource depletion or deterioration depend upon the resource characteristics. Accordingly, natural resources have been classified as "stock" (or nonrenewable) and as "flow" (or renewable) resources. Stock resources are those whose quantities will not increase significantly over time, and are subject to exhaustion. These would include such resources as coal, oil, gas, stones, clay, soil of a given type and plant nutrients. As an example, it takes about 100 years for the formation of one inch of top soil, but this "increase" will be insignificant if it is more than offset by a loss elsewhere of, say, one or two inches per acre per year because of erosion. Flow resources are those whose quantities become available over time -- day by day, and year after year. There are no given "stocks" which can be exhausted in any one interval of time. These would include solar radiation, winds, rainfall, and scenic resources. Both the stock and flow types of resources are vital but the differences suggest the need for special treatment in economic analysis. For the stock resources, much of the attention has been centered on the problem of possible depletion. For the flow resouces, the concern has been with deterioration in quality.

The threats of resource depletion of deterioration may be said to be the chief reasons for the emergence of interest in resource economics. Thus we had a conservation movement beginning at the turn of this century. This movement has been reflected in programs such as those to avoid the exhaustion of the forest resources, and to minimize soil erosion. There has been also much concern about the possibility of depleting oil and gas resources. In addition, large public investments have been made to conserve and develop water in various parts of the country.

Continuing interest in resource economics stems mainly from the specter of increasing scarcity of certain resources in relation to the mounting population needs, and to the increasing competition for these resources as a result of shifts in demand. If it were not for dramatic advance in technology, the pressures would possibly create resource shortages and greater social and economic problems. Advances in technology will not necessarily resolve all current and emerging problems however. We are continually faced for example with the need to reallocate land to meet geographic shifts in population and the expanding demand for land for some uses.

Central Problems in Natural Resources Economics

What are the real problems in resource economics? Problems in resource economics are identified in the same way as other problems for studies in the social sciences. Generally these can be identified in one or more of the following ways: (1) an expression of confusion, doubts, or uncertainty about a given situation either by individuals, groups, or government, (2) a gap between what is actually achieved and a specific goal, and (3) a deviation from an ideal or optimal situation as defined by theory. 1/ In less formal language, economic problems

1/ The latter is more nearly a way of defining problems rather than identifying real problems. It may find its greatest usefulness in visualizing emerging problems.

arise because of insufficient information about given situations or relationships and give rise to questions such as what is happening, or might happen? What should be done? Or, how should something be done to achieve some stated objective? Thus we are more often concerned with "means" rather than "ends".

Because our economic system is essentially one in which the resources are allocated in production, distribution and exchange by the interactions of the decisions of individual economic units -- private and public -- in an interrelated network of markets, it is not always easy to identify problems that are clearly resource oriented. For example a problem of regional under-development may depend upon the natural resources at hand but also upon other considerations; and might be said to be rather a problem in general economic development. Then, too, highway development may involve problems of land use and acquisition but may be regarded as a problem in transportation rather than land utilization. Several other examples on this point could be cited. Thus it might be helpful to consider a problem in natural resource economics to be one in which the ownership, management, allocation and development of a natural resource is critical from the viewpoint of production, income or general welfare.

From the production viewpoint, a resource economist for example, may be concerned with such questions as the allocation of land among its competing uses, or the allocation of water among the alternatives. One of the most pressing problems today in many parts of the country stems from the increasing pressure on good farmland for nonagricultural purposes. This has been reflected in grave concern by people in such states as California and New Jersey where steps are being taken to halt the trends of urban encroachment. That land of a given quality is a stock resource, subject to depletion, seems to be the common basis for concern.

Another example of a current problem related to natural resource and production stems from the use of coal, oil and gas resources. As stock resources they are also subject to depletion. Thus there is the need for constant surveillance over their allocation and development. In this context allocation is significant in two ways. First, these resources must be allocated among their alternative uses to achieve the highest level of efficiency possible in their utilization at any given time. Second, the rates of use must be so adjusted or regulated so that the available stocks will not be depleted under foreseen technological developments. We can refer to the latter instance as allocation of use over time to maximize the production and income from these resources.

From the income viewpoint, a resource economist may be concerned with rent or income to land, and how this is distributed among people. He may also be interested in the income-effects of investments to develop the resources of a region. Ownership and other institutions related to resources may serve as a means of determining "who gets what" from resource utilization, development, or government programs affecting these activities. Here the interests of resource economists will coincide with the interests of specialists in human resources.

From the general-welfare viewpoint, a resource economist--in addition to the questions relating to production and income indicated above--may have special interest in the development and use of resources with more far reaching and widely spread implications. This would include questions relating to air or water pollution control or in recreational or aesthetic natural resources with widely diffused social effects in terms of either benefits or costs.

Resource economists now tend to claim a distinction from other applied economists on the basis that in dealing with natural resource development emphasis must be placed on the well-being of groups rather than individuals and attempt must be made to take explicitly into account "benefits" and "costs" to whomsoever they may accrue. He must recognize, what has long been referred to in welfare economic theory as external economies or diseconomies and is currently more often referred to as "externalities". For example, the investments incurred to reduce erosion or flood-damages in one location, may have effects in another location where the land is owned by someone else. In such situations, decisions to invest may be negatively affected; but may be resolved within a framework of maximizing general welfare.

Current Studies in Natural Resource Economics

Specific studies in natural resource economics pertain--directly or indirectly--to problems involving ownership, management, allocation and development of resources in relation to either production, income or general welfare. These are essentially studies that contribute to an understanding and solution of the broader and more general problems in resource economics.

In the Division that I work there are currently some 50 such contributory studies, covering a wide range of specific subjects. In addition, there are another 50 studies of resource potentials in specific river basins and watersheds. Thus, studies are being conducted on a subject-matter as well as regional basis, if we define a river basin as a region.

For administrative purposes, the studies on a subject-matter basis are divided among 4 branches namely: (1) Land Resources Branch, (2) Water Resources Branch (3) Environmental Economics Branch and (4) Resource Institutions Branch. All these branches are, however, concerned with land and water resources with particular reference to agriculture. Other uses of land and water are necessarily considered, however, to the extent that they are competitive to agriculture. The use of farmland for urban purposes or water for irrigation vs. other purposes should serve as examples.

The organization of "branches" along the current lines can be justified presumably on the basis of specialization and emphasis; even though the natural resources involved are mainly land and water. Work in "environmental economics" stresses the "quality" aspects as opposed

to the depletion aspects of resources. They are more concerned with problems such as resource-based recreation, and water pollution. The work in "resource institutions" covers land tenure, water rights, land-use regulations and programs and other institutions as variables relating to both land and water, and as such, are more directly concerned with ownership and management than with allocation and development per se.

The inherent characteristics of natural resources and the institutional framework within which they are used call for studies of an interdisciplinary or multidisciplinary nature. Thus some knowledge of soil science, or agronomy, for example, is necessary, in dealing with the relationships between land resources and production. Hydrology also become relevant. At the same time, some studies have to be pursued within a legal-economic framework because of the institutional environment. Accordingly, few if any, studies in resource economics are "pure" in the sense that they are conducted independently of contributions from other physical, biological, or social sciences.

Thus the staff of the Natural Resource Economics Division includes people trained as lawyers, geographers, urban planners as well as economists.

The immediate objectives of each contributory study varies according to the information sought, or vice versa. In every case however, a study is divided into two main phases -- a conceptual, or theoretical, phase and an empirical phase.

In the conceptual phase, theory as needed is brought to bear. But because the "economic purity" of the study will vary according to the immediate objectives, the need for economic theory will depend upon these objectives. For example, studies in land classification and inventory will need little or no formal economic theory, while studies to determine whether land is used efficiently will have great need for theory in its conceptual phase.

In the empirical phase of the study, the need for statistics will also vary according to the type of information needed and the objectives. Studies such as those covering a number of observations either to explain what is happening or to predict what might occur, will almost always have need for some type of statistics. Even some types of individual "case studies" may have need for statistics if we begin to count and evaluate attributes. Other conceptual analyses may find that such methods as budgeting or programming for "simulating" real relations may be applicable. Still, in some simulation models some of the basic ingredients may depend upon statistical data such as yields of specific crops either from records, surveys or controlled experiments.

III. APPLICATION OF ECONOMIC THEORY: AN EXAMPLE

As economic theory is normally dry and apparently sterile, I shall try to illustrate its role in practice. I shall do this by reviewing a concrete case involving a study on which I am now working and in which theory is being applied.

Before reviewing this study however, I believe it would be in order to restate the fundamental purposes of theory in economic research. Theoretical analysis does at least 3 things: First, it helps in identifying the relevant variables and the units of measurement that should be considered in the empirical phase of the analysis. Second, it helps in specifying the type of relationships, for example, whether the production from a resource is subject to diminishing returns or not. Third, it helps in selecting appropriate statistical techniques, for example, whether regressing analysis or some other techniques should be used. I would like for us to concentrate on these three uses of theory in research, in the study I am about to review. This study has been chosen because it has all the attributes to demonstrate these uses. Let us look into this study step-by-step.

Essence of the Problem.

The study stems from a problem in the production of electricity, and has been initiated because of doubts and uncertainty about what is going on and what the alternatives are. Although the study is directly concerned with the production of electricity, it is of interest to resource economists because it involves the utilization of our vital energy resources, the fossil fuels -- coal, oil and gas -- that are "stock" resources; and it carries with it implications for rural or regional development.

In 1966, about 413 million tons of "coal equivalents" were used up in steam electric generating plants; and this consumption is rising rapidly with expanding demand for electricity. Translated into dollars, this tonnage amounted to about 70 percent of the "variable cost" or producing electricity by steam (as compated to hydro-electric) plants. Preliminary estimates would suggest that considerable savings in fuel is possible. The saving in fuel could be allocated to other purposes, or saved (allocated over time) for use in future years and may reduce the depletion rate.

One of our first jobs was to formulate a research model and we had to rely on theory to do that.

The Theoretical Considerations:

Preliminary evidence leads to the suspicion that if the average size of generating plants were to increase, greater efficienty in the use of these natural resources might be achieved. Between 1956 and 1966 the average size of generating plants just about doubled, while

the variable costs per unit of power generated decreased considerably during the same period. Assuming that fuel consumption per unit of output also declines as size increases, then greater efficiency in the use of fuel, and other resources, is expected if plant size is increased. Our immediate objective therefore is to determine whether cost per unit of output does in fact decline with expansion in plant size; and if it does, how significant the decline is.

Since we were specifically concerned about costs, formal theory suggested that we should consider certain economic concepts of costs. After this consideration, we were convinced that we should develop a "model" involving long-run costs. As you might recall, long-run costs are those in which all the factors of production are treated as variable; there are no fixed costs. The long-run average total unit cost is defined as an "envelope curve" touching the short-run average total unit costs as shown in Figure 1. This envelope curve is also referred to as a "planning function". It shows how the average total cost per unit of output will decrease, remain constant, or increase as the size of a plant is increased. Thus the basic concept we decide on was the "planning function".

Symbolically, we can define this cost as:

$$C_t = (C_i + C_o + C_m + C_f)$$

in which,

C_t = average total cost per kilowatt hour (kwh) per year

C_i = investment cost per kwh in annual equivalent

C_o = operating cost per kwh per year

C_m = maintenance cost per kwh per year

C_f = fuel cost per kwh per year

As a mathematical (or statistical) function the costs could be expressed as:

$$C_t = f(S) \qquad (2)$$

in which f(S) simply means "a function of S", with S referring to size of plant. Our central hypotheses to be tested are (1) that this function is declining as size is increasing, and (2) that the function will take the shape as shown in Figure 1. The forms of the function to be fitted are essentially:

$$C_t = aS^b P^c, \text{ or} \qquad (3)$$

$$C_t = a - b_1 S + b_2 S^2 + P^c \qquad (4)$$

in which "P" refers to an index of output of plant capacity.

FIGURE 1

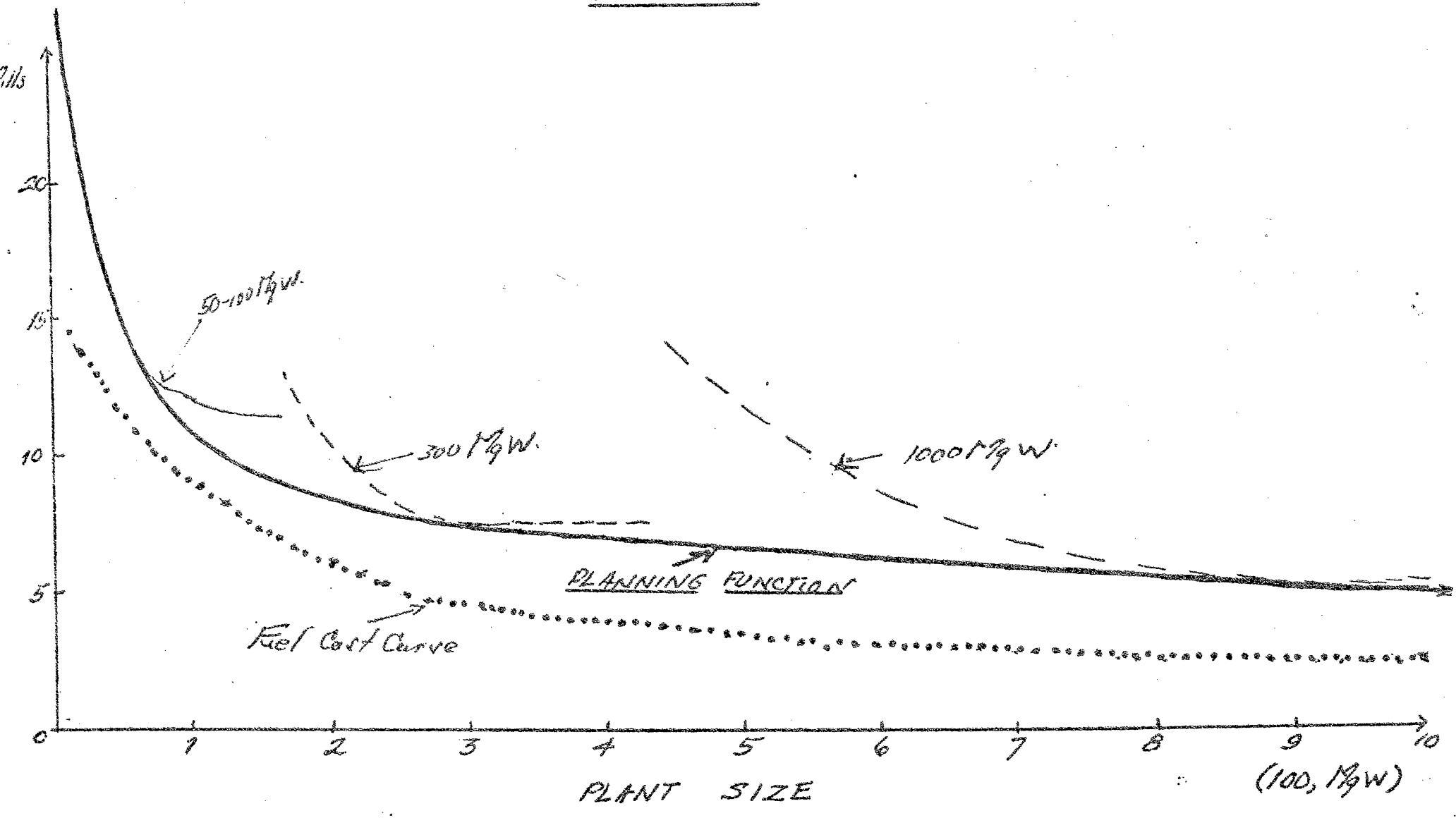

Figure 1. Model for evaluating the economics of plant size

Economic theory has helped in deriving and formulating these hypotheses to be tested against observations of the real world. These hypotheses may be confirmed or refuted when compared with the facts. Perhaps we should at this point underscore the term hypotheses not only because these serve as guides but also because economists like to use the term. In general, hypoteheses in economic research are tentative statements of relationships among variables or elements of a problem. The main variables in this problem are costs and size of plants.

Let us pause for a moment and try to relate the components of equation (1) with some other economic concepts. We will notice that C_1 is an approximation of the "fixed cost" component for short run cost curves in economic theory; and the sum of C_o, C_m and C_f would represent the "variable costs". In our present formulation, all the cost components are treated as variables changing with size, and implicitly, with output. The formulation is also based upon the premise suggested by theory that resources related to these costs are "complementary", that is, we won't be able to produce any electricity without a combination of resources. Whether the combination is good or bad is not an issue at the moment. It should suffice to recognize that the utilization of a resource cannot be analyzed in isolation because of complementarity of resources in production.

Choice of Statistical Techniques:

Our next step is to choose the appropriate techniques for putting these hypotheses to the test. Because the hypotheses formulated have to do with functional relationships, we should immediately thing about the possibilities of regression analysis, as a statistical technique. Having decided that regression analysis is appropriate, we will go further to decide what the mathematical form of the function should be and the specific statistical tests to be used. It must be noted that other types of statistics could also be applied, but from the theoretical construct the regression seems to be most promising.

The data (or facts) to use in fitting the regression can be obtained from secondary sources such as records or from purposely designed surveys of plants. Or, the functions can be fitted with engineering data. The procedure and problems in fitting these functions are however out-of-scope for our present discussion. Let it suffice at the moment to recognize that this is where we will get the facts and observations of the real world to test our hypotheses as to whether they are true or false.

A Recapitulation:

The theoretical analysis has, I believe, served its three purposes indicated at the outset. These are: (1) identifying relevant variables which in this case were costs and size of plant; (2) specifying relationships, which was that the cost per unit of output is a declining function of plant size; and (3) selecting appropriate statistical techniques which was regression analysis. The principal theoretical concept applied

was the "planning function" or long-run envelope cost curve, from which were derived the hypotheses to be tested by applying the relevant statistics. Thus the theory has pointed toward hypotheses to be tested and the method of testing them.

We must note, however, that the analysis in the present illustration will not be enough to give all the information needed to resolve the problem of allocation and efficiency in producing electricity or in conserving and developing our energy resources. Many simplifications have been made in the interest of clarity and brevity. In particular, economic determinations especially on the demand side will need to be evaluated along with the determinations on the production side. In addition the costs of transmission and distribution systems to reach various load centers and individual consumers must be taken into account; and the rate of utilization of plants may be a confounding factor if it is not controlled statistically.

IV. RELEVANT ECONOMIC THEORY AND CONCEPTS

We may now ask ourselves, what other economic theory or concept may be relevant for research in resource economics. Metaphorically, the set of theories available represents a "cafeteria" from which we can pick such concepts as the "planning function" as a tool to be applied in the analysis and solution of real problems. The various theories reflected in the titles given to academic courses, books and journal articles are, however, quite frequently just "variations of the same theme", in which fundamental concepts or principles are the same.

Resource economists have no general theory of their own, perhaps for an obvious reason. That is, resource economics as an applied branch of economics draws upon the concepts developed by the various "theoreticians" or "theorists". However, a historical survey would show that some of the theories now applied in some resource economic studies have evolved as a result of concern by economists or social philosophers about contemporary social problems of the real world.

The rent theories, for example, which have direct applicability in resource economics, have evolved because of concern about the possibility of food shortages, and the sources and distribution of income. Location theories may also be attributed to people concerned with problems of the real world. Recent theories on income and employment which are relevant in regional resource development studies have also evolved because of social concern about depression, stagnation, economic instability and so forth.

For studies in resource economics, one might be inclined to look first to the theories relating to "producers", rather than "consumers", the forces affecting their behavior, how they behave, and the consequences of their behavior with particular reference to the utilization of resources. The theories relating to "consumers" will of course be useful in many instances.

The interdependency of behavior and decision in the various economic sectors makes it necessary to have at least some familiarity with the theories relating to all resources, activities, and sectors of the economic system. Among the theories that I believe the resource economist will most often find useful are those relating specifically to (1) production and costs, (2) investments and (3) welfare. How can these help? Let us consider each of these briefly.

Production and Cost Theory

The concept of a "planning function" referred to earlier, is derived from the theory of production and cost. But there are other useful concepts in resource economics from production and cost theory. It also gives to us the fundamental concept of production function which describes the way in which output depends upon the quantity and quality of resources. This function along with prices of factors form the underlying explanation for the shape and level of the planning function. The theory also gives decision criteria on the levels of production, the combination of productive factors, and the combination of products for efficient allocation of resources. Of these criteria, we should all be familiar with that of marginal cost equal marginal revenue in production. This criterion is often applied in resources-economics studies.

Investment Theory

Because resource conservation and development involves "time" and large financial outlays, concepts in investment will be useful in many conceivable situations. This theory helps to provide principles and procedures for discounting returns and costs associated with production occurring at different dates. Another class of investment theory, involving "multiplier" effects of investment, may be found applicable in studies of investments for resource development of a region, where income and growth are paramount.

Welfare Theory

As the resources economist is often concerned with the problems of "externalities" (defined earlier), he will find some use directly or indirectly for welfare theory which stresses this phenomenon. It attempts to develop the concept of "social" as compared to "private" costs and benefits which is useful in evaluating resource development and use.

Other Relevant Theories

Choice of the foregoing theories is personal and to an extent arbitrary. Other theories will also have much to contribute. It is assumed, however, that some of the other theories not yet mentioned would be considered as co-requisites for an appreciation of production, cost, investment, or welfare theory.

Of these, demand theory may be singled out. The fundamental concept of demand elasticity for example has wide applicability. The resource economist must frequently consider the derived demand for resources as raw materials, including changes in quantities of resources demanded because of population, income or other changes. Estimation of demand is almost always a necessary first step in the analysis of resource allocation or development.

Other relevant theories include those on rent, interest rates, taxation, inter-regional trade, income and employment. In short, all these theories will have something more or less to contribute but they must be known and put in the kit of tools for research.

IV. HIGHLIGHTS

1. Natural resource economics was referred to as an "umbrella" for a wide range of studies pertaining to primary as well as secondary natural resources. Thus within this field there are specialists in economic studies relating to land, water, energy, forest, fisheries and other related subjects.

2. As a branch of applied economics, natural resource economics has become popular only within recent years. Land economics may be regarded as the main antecedent to it.

3. A justification for natural resource economics as a field of studies is that the task of dealing properly with all resouces in a complex economic system is too great for any single person. Division of labor along resource lines is probably as good as any, because resources have some characteristics of their own.

4. Natural resources have been classified in different ways. One classification is according to "stock" (or non-renewability) as opposed to "flow" (or renewability). For stock resources, much of the attention has been centered on the possibilities of depletion; while for flow resource, attention has been centered on deterioration in quality. Economic issues stem from the use of both types of resources.

5. A problem in resource economics is one in which the ownership, management, allocation or development of a natural resource is critical from the viewpoint of either production, income or general welfare.

6. Many contributory studies are under way for solution of these problems. The characteristics of natural resources and the institutional framework within which they are used call for many studies that are, more or less, of an interdisciplinary or multidisciplinary nature.

7. The immediate objectives of each contributory study varies according to the information sought, or vice versa. The role of economic theory will depend upon these objectives, and the "economic purity" of the particular study.

8. Each study, however, may be said to be conducted in 2 main phases -- a conceptual and an empirical phase. In the conceptual phase, economic theory as needed is brought to bear. In the empirical phase, the need for statistics will depend upon the type of information sought.

9. Theoretical analysis was said to serve at least 3 purposes: (1) Identifying relevant variables and units of measurement which were costs and size of plant in the illustration used; (2) Specifying a relationship, which was that cost per unit of output is a declining function of plant size; and (3) Selecting appropriate empirical techniques which was regression analysis in our illustration.

10. The point was also made that the resource economist has no general theory of his own but draws extensively upon various concepts such as "planning" function developed by theoreticians. Many of the theories, such as those on rent now applied in studies of resource economics evolved however because of concern about contemporary social problems.

11. Finally, it was implied that a resource economist will need to have in his kit of tools for research other concepts beside the planning function or rent. Concepts from theories relating to the behavior of producers was given personal priority; even though demand theory was also singled out for special comments. In essence, the theories that a resource economist should have as a minimum relate to production and costs, investments, welfare and demand. Other theories were suggested as co-requisites or pre-requisites.