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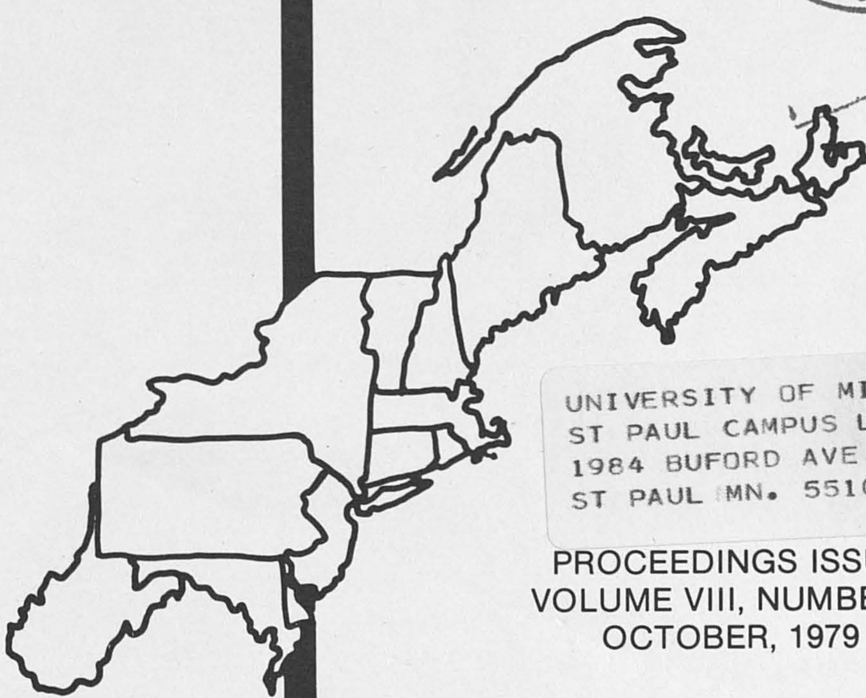

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RESEARCH ISSUES IN NATURAL RESOURCE ECONOMICS

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My task was to survey a field of staggering breadth and yet to avoid being superficial. It was complicated by the intent of providing something of professional interest to a group of economists without resorting to blackboards ro equations.

I decided to organize my remarks into three overlapping bundles. The first describes some special features of natural resource systesm. This may seem "old hat" to the resource economists of the audience, but it is presumed that not all of you are resource economists. In any case, this material may spark a debate over whether there is really anything unique about resource economics. I am stimulated to include this section by a recent conversation with Dan Bromley. He was concerned that, while an analysis of natural resources issues which ignored these special features would rest on weak foundation indeed, we must be careful not to become so narrow in our specialty that we overlook the theory and methods of traditional economics.

The second part describes the major issues in natural resource economics. Not all issues are given equal weight, nor even the weights indicated by the numbers of pages in the literature. Rather the weights are given dictatorially on the basis of my preference system, with the view that to discuss all relevant issues would result in superficial treatment, an overrun of allotted time, or both. The discussant may wish to develop some of the issues which were slighted here. The final part of this paper suggests important future areas of research in natural resource economics implied by this discussion of issues. Again, claim is made neither for completeness nor objectivity regarding which are the most pressing research needs.

Special Features of Natural Resource Systems

Natural resources are typically regarded as renewable or non-rewable (exhaustible). Fisheries, forests, and water serve as examples of renewable resources; resources which exhibit economically significant rates of regeneration. It has become rather commonplace to use fisheries to illustrate the distinguishing characteristics of the renewable resource. Despite the resemblance of fisheries models to modern capital theory,[1] there are critical differences as well. The first peculiarity of models involving biological species relates to their natural regeneration processes, or biological growth functions. Thus, extraction of these resources differs from other production processes since yields in any period influence subsequent yields by changing the stock of remaining resources. Indeed,

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production functions for a single renewable resource typically include three factors: time, to allow for technological progress and other processes; some measure of effort (say, fishing); and resource stocks.

Some of the most intricate and interesting models in economics have been developed in response to questions like: (1) What is the optimal rate of fishing effort? (2) Does this rate correspond with maximum sustainable yield? (3) Will extinction occur under normal conditions? (4) Is this bad? (5) Does optimal behavior correspond with behavior under a competitive regime? These models exhibit multiple equilibria, involve dynamic optimization, recognize externalities, and examine resource exploitation under various institutional structures and policies.

Another distinguishing characteristic of these natural resource models is the presence and importance of the user cost concept -- the decrease in the value of an asset associated with use. In the fisheries example, the marginal user cost (shadow price) of fish in their natural state is the quantity by which the present value of the fishery at that point in time is diminished by the removal of one unit of the fish resource. This quantity is not generally observable, but rather must be imputed using present and projected prices, technologies, and stocks of the resource.

The prevalence of the common property status and problem is a further distinguishing characteristic, which interacts with and magnifies some of the other peculiarities of natural resources problems. Gordon's [1954] seminal paper on this subject shows that in the absence of cooperative agreements, firms in a common property fishery will enter and exit freely and drive rents to zero in the process. Congestion externalities created and user costs associated with depleting fish stocks will be ignored by the individual firms, generally resulting in greater effort and lower stocks than are optimal.

Models of non-renewable resources, like oil, coal, and minerals, also possess a number of distinguishing characteristics. Economic frameworks for evaluating these resources involve optimally depleting a stock, with no signigicant natural regenerative possibilities and recycling (artificial regeneration) limited by economic as well as natural processes. For this reason, the theory underlying these models has been termed "theory of the mine."

One characteristic for this class of resources which is similar to renewable resources but not other production processes is that user costs should be considered alongside extraction costs in deciding stock depletion rates. That is, for non-renewable resources user costs (determined by the future time paths of prices and costs) represent an endogenous depreciation cost as contrasted with the usual notion of depreciation which depends only on the passage of time.

If exploration is important in a particular exhaustible resource, models of extraction become more complex (Koopmans [1973], Peterson and Fisher [1976]). There are numerous motives for exploration, of course. Monopolists may wish to discover deposits in part to raise barriers to entry by keeping these stocks out of the market. Alternatively, firms may devote too few resources to exploration due to the uncompensated external benefits of the information they supply others in the process.

While uncertainty is not exclusive to the domain of natural resource systems, it is difficult to imagine areas in which uncertainty plays as large a role as, for example, drilling decisions for oil and natural gas. The uncertainties of supply[2] -- location, quantities, quality -- are enormous. Since the value of a stock depends on the stream of future prices, there are substantial uncertainties on the demand side as well. Uncertainty as regards future demands is compounded by the fact that substitutes and new technologies may develop (Dasgupta and Stiglitz [1975], Peterson and Fisher [1976]).

One type of substitute for some of these extractive resources is represented by the secondary materials from recycling. While some have argued (e.g., Weinstein and Zeckhauser [1974]) that, in the absence of externalities associated with waste disposal, the free market results in optimal levels of recycling activities, such absences are not frequent in the real world. Since recycling acts in both the role of substituting for exhaustible resources and in reducing pollution, failure to recognize these externalities leads to an under-allocation of resources to the recycling activity. We will return to this link between extraction and the environment below.

A characteristic of some of the most recent contributions to the literature in extractive resources is that rather than operating from the paradigm of the behavior of a firm out to maximize the present value of a resource, they presume the view of a planner seeking to optimize some more broadly conceived social welfare function. Questions arise concerning intergenerational welfare. Should utilities be discounted? How can we justify depriving one generation because of a greater gain to another? What are the consequences of the Rawls [1971] notions of distributive justice wherein a "maxi-min" criterion is adopted, where social welfare is established on the basis of the least privileged generation, for growth, capital formation, etc?

Another distinguishing characteristic of models of natural resources is the importance of information from other disciplines. As Peterson and Fisher 1976 suggest, economists presently employ geological and engineering information in their natural resource models and recently "there has been a flurry of activity".

In brief, renewable and non-renewable natural resources have special characteristics which distinguish them from other economic processes, which stimulate different problems and questions to be posed, and give rise to more complicated modeling efforts. If a resource is exhaustible, but has a close subtitute given current or foreseen technology, is it appropriate to discuss policy problems in the naroow context of exhaustibility?

The problem of changing resource concepts is also real. Scarcity of natural resources is a function of current technology as well as many other social factors which are not economic in nature. As societies evolve, the focus on particular primary inputs for production may change. How do present policy models accommodate these types of shifts? Finally, natural resource issues cannot be intelligently analyzed without reference to common property problems and external effects.

Issues in Natural Resource Economics

The preceding discussion of distinguishing features of natural resource systems unavoidably suggested issues as outcomes of features. Let us now focus on these issues, beginning with exhaustible natural resources as limits to future economic well-being.

The perceived fixity of the natural resource base coupled with the historical growth in demands for material goods have given rise to periodical examinations of the link between resource scarcity and economic health. While concerns can be documented throughout the history of the U.S., the real flurry of activity has taken place post-World War II. During this period two presidential commissions filed reports, which in part led to the establishment of Resources for the Future. In 1963, Barnett and Morse published their findings of scarcity and growth, evaluating trends in real unit costs and relative prices for the period 1870 to 1957. They concluded that, excepting forest products, there was no evidence to support the notion of increasing resource scarcity.

The approach they took was neo-classical (neo-Ricardian), focusing on the services provided by natural resources and the difficulties of extracting them. While the physical properties of the natural resource base initially impose contraints on growth, substitutability, technology, and organizational wisdom were seen as forces capable of relaxing these constraints. Thus real unit cost was taken to be a measure of the "natural" prices of the classical economists and the problems associated with these cost indexes parallel the classical model limitation.

The limitations of the Barnett and Morse concept of scarcity have been discussed recently by Brown and Field and by Smith, among many others. They show that the Barnett and Morse concept of resource cost is inadequate -- both as a proper concept of cost and in its use of cost as an indicator of scarcity. Both papers provide alternative, but not entirely satisfactory, measures of scarcity.

Randall provides a lucid critique of all of these attempts. Simply put, scarcity should increase resource rents as reflected in "prices". While one would normally expect increasing extraction and related costs, the fact of increasing efficiency in resource extraction should hardly be interpreted to signal a declining scarcity of exhaustible resources. And this increasing efficiency at exhausting natural resources should not be seen as proof that our resources are inexhaustible (the implication of the neo-classical model). On the same theme, his "common sense" indicates that much of our technological progress has led to increased rate of resource exhaustion (and larger transfers from future generations to the present) rather than to expand the useful dimensions of the "spaceship earth". On the other hand, he admits that developments which permit substitutions from stock to flow resources, from less plentiful to more, etc., offer some relief from the scarcity dilemma. Thus the decline of known stocks of currently useful resources is not an adequate indicator of resource scarcity. The real condition lies somewhere between the position of the Cassandras of doom and the Camelot position of the late neo-classicists. But where?

Another confounding factor pointed out by Smith and by Smith and Krutilla is the definition of natural resources as restricted to goods exchanging in private commodity markets (hence excluding environmental common property resources). To the extent that reactions to materials scarcity may involve the "consumption" of some of these unpriced environmental resources, these economic measures of resource scarcity would be biased.

Nicholas Georgescu-Roegen suggests that, in breaking away from the linear thinking of those who considered only physical measures of scarcity, economists have gone a bit too far. He suggests (p. 353) that "...the Entropy Law is the taproot of economic scarcity. Were it not for this law, we could use the energy of a piece of coal over and over again, by transforming it into heat, the heat into work, and the work back into heat. Also, engines, homes, and even living organisms (if they could exist at all) would never wear out."

Out of the field of thermodynamics came the distinction between available and unavailable energy and the concept of entropy -- roughly an index of the quantity of unavailable energy in a thermodynamic system at a particular point in its evolution. The First Law of Thermodynamics, that man can create neither matter nor energy, is not particularly troublesome by itself. The implications become severe when the Second Law, the Entropy Law, is added. The earliest version is that heat flows by itself only from the hotter to the colder body. In a more involved version, it says that the entropy of a closed system monotonically increases to a maximum. It says that energy is steadily transformed to heat, which dissipates so that it is no longer usable. The Entropy Law also states that matter is subject to continued and irrevocable dissipation as well.

Thus, while green plants store part of the solar radiation which would otherwise dissipate into high entropy heat, all other organisms speed up the rate of entropy. And man occupies the highest rung on this ladder. Further, distinguishing between available and unavailable energy does not mean that we can use all available energy. It must be accessible to be of value (Georgescu-Roegen, p. 354). Solar energy and its by-products are accessible at virtually no cost (use of available energy). In all other situations, work and materials must be expended to use a source of energy. Thus even if we were to find petroleum on the moon, the available energy would not be accessible if it will take more than the equivalent energy of a barrel accessible on earth to bring a barrel from the moon. The bottom line is that the earth is a thermodynamic system closed with respect to materials and open only with respect to solar energy. And recycling can never be complete. We shall return to this issue in a materials balance context.

Robert Solow [1974][3] reinterprets Hotelling's 1931 classic, "The Economics of Exhaustible Resources", wherein the "fundamental principle" of the economics of exhaustible resources is seen as a simultaneous condition of flow equilibrium in the market for the ore and asset equilibrium in the market for deposits. But he admits that there is ample reason to suspect that equilibrium conditions seldom obtain. Rather, he suggests (p. 7), "...resource markets may be rather vulnerable to surprises. They may respond to shocks about the volume of reserves, or about competition from new materials, or about the costs of competing technologies, or even about near-term political events, by drastic movements of current price and production."

It is my guess[4] that this notion of disequilibrium in resource markets in part stimulated Richard Day's discussion at Blacksburg on "Adaptive Economics and Natural Resources Policy". Adaptive economics "...begins with an assumption that change evolves from current conditions, and focuses on the economizing of partially informed agents whose transactions are imperfectly coordinated, who use various adaptive procedures...and whose numbers, activities, rules of behavior, and organizations evolve. It is primarily the study of how economies adapt in disequilibrium and secondarily whether or not, and if so, how equilibria or states of adaptedness are achieved" (p. 277).

His conclusion is that as much as some of the fine contemporary examples of neo-classical dynamic equilibrium economic analyses are to be admired, they are of limited use in developing an economics of natural resources policy. They simply gloss over too many fundamental issues. One of these is "surprise". Adaptive models caution us to expect surprises during the evolution of the economic system. A conclusion is that perhaps policy should be directed more at preparing for surprise rather than focusing on economic efficiency. This can be done in part by allowing "slack" (surplus resources, redundancies, less than maximum growth). Another way is by acquisition of knowledge, pursued without a goal or identifiable economic motive.

Another fundamental issue involves intergenerational exchange. If we admit the possibility that the market rates of interest exceed the rate at which society would wish to discount future utilities, the unbridled economic system would exploit the resource too fast. As observed by Randall and others, the discounting rule is not only dictatorial, it is a quite selfish form of rule. The cavalier dismissal of future generations attributed to Keynes ("in the long run, we are all dead") is of no intellectual assistance. Likewise Baumol's suggestion that present generations need not worry about future generations, since historically generations tend to have been wealthier than their predecessors, is a rather blunt form of linear thinking. Particularly in exhaustible resources and environmental issues, the balance between the present and the future is delicate and the choice of a discount rate is too important to be casual about it.

A concept that the theory of exhaustible resources makes apparent is the importance of the long view and the value of information about such things as reserves, technology, and distant future demands. Indeed, Conrad recently demonstrated that option value and existence value can be viewed as deriving from the fundamental concept of expected value of information. The notion of irreversibilities is relevant here in the use of the environment as well as in resource exhaustion. While some, including the discussant, have argued that this is a quite polar case, the concept has caught on in many modeling efforts and has led to further complexity in natural resources frameworks.

While the absence of markets for future claims (intertemporal equity) is perhaps the most profound aspect of the issue of exhaustible resources, it should be re-emphasized that there are numerous biases in our economic system which exploit natural resources excessively rapidly even if preferences of only the current generation are considered. Points made earlier bear this out and need not be repeated. I do recommend Allen Kneese's recent work featuring, as you might guess, environment-related issues on this point. He concludes in part that the use of unpriced common porperty resources in combination with a light tax burden has led to artificially cheap energy and thence to the stimulation of energy intensive industries in our economy, and ultimately to excessive rates of resource depletion and massive environmental pollution.

Whether the environment is the main issue, as Kneese sometimes seems to suggest, or whether resource depletion is likely to be a relatively more severe problem, as Georgescu-Roegen suggests,[5] is not important. They would both agree that natural resources, as narrowly defined, and environmental resources are not independent. They are intertwined in important ways so that perhaps even the traditional divisions of subject matter into resource economics and environmental economics courses merits some rethinking. Boulding's famous description of a "spaceship earth", in which materials can neither enter nor exit, and the general equilibrium model of Ayres and Kneese, which incorporates the materials balance concept, make clear this tie between the environment and resource extraction.

Recently a fair amount of attention has been directed toward valuing non-market natural resources with a hedonic technique. Previous work began with Harold Hotelling's efforts for the National Forest Service on valuation of a recreation site. The procedure developed has come to be known as the "travel cost" or Hotelling-Clawson method. This specialized technique for valuing a single characteristic shares a common element with the more general hedonic valuation approach initially suggested by Gorman. That is that non-market goods or characteristics can be valued if different expenditures can be matched with different measured rates of use, other things being the same. Thus if individuals spend more on good one than good two, and the two are identical except that one is safer, then the price difference is the marginal value of safety.

In a more sophisticated version of the method, property values are regressed on the characteristics of the property and the marginal value (benefit) functions of the characteristics are represented by the derivation of this expenditure function with respect to the characteristics. The approach has been used to value characteristics such as air quality and undeveloped shoreline.

These approaches have both come under extensive criticism of late. It now seems clear that important resource allocation decisions which critically depend on values of unpriced environmentally intensive activities should not turn on the results of travel cost studies. This procedure cannot handle complications beyond a single purpose trip for a single location. Nor is the concept of a "day" a generally appropriate measure of the good rendering utility, and it is unlikely to exhaust the characteristics of, e.g., the recreation experience. And the willingness to pay or bidding game techniques, in which the essential ingredient is a set of hypothetical questions, have likewise been seriously questioned -- in part on the basis of the types of response elicited by hypothetical questions.[6]

The hedonic approach involves using the implicit prices from the expenditure function to estimate a properly identified set of demand and supply functions for a single or a set of characteristics (see Rosen [1974]). This approach, too, has been criticized (Pollak and Wachter [1975]), although less severly than the less general and less analytically sound travel cost method.

Quite recently, Gardner Brown [1978] used such a hedonic model for valuing wildlife (estimating value of days and bag or catch for four game categories: waterfowl, small game, deer, and big game). His work represents one of the first attempts to use the hedonic approach in the recreation area and, despite its acknowledged limitation, represents quite promising beginnings in the search for improved procedures for valuing unpriced resources. I understand a symposium on this topic is scheduled for this afternoon.

As indicated earlier, many of the characteristics of the renewable natural resources are similar for the exhaustible ones. Most of the issues are rather well-known and need not take much space here. User costs, common property consideration, and dynamics play important roles in the analysis of issues such as proper rates of use of fisheries resources. And uncertainty, as in the case of extractive resources, plays a major role. Biological growth functions and abundance measures for most species are poorly understood and production functions, and functional forms, are typically developed in an exploratory context.

These considerations suggest that adaptive economics is particularly relevant in this area. One form of adaptive economics has been termed adaptive programming or dual control. Under this paradigm, the decision maker considers the benefits which might be obtained by allocating current resources to learning about the system through conscious experimentation, relative to the allocation of these resources for maximinizing current performance, given current levels of knowledge about the system.

Aoki's 1977 survey provides examples of the application of the approach, and Conrad uses a numerical example to illustrate the essence of the value of learning concept. The point must be made, however, that the more inclusive is the range of decision variables to be explicitly considered in such a framework, the more complex, expensive, and time-consuming is the solution technique. Because these costs increase exponentially with detail, the models developed in practice must be extreme simplifications of reality.

Research Directions

The issues and observations just made have implications for promising lines of research. Some thoughts on broad areas on inquiry as well as several illustrative examples are developed in this final part.

To begin with a specific area, consider the topic of energy economics. One important subject for good economic alaysis is the question of interfuel substitution. A great deal of work has been done on this subject, but it generally begs many of the issues and distinguishing features we have discussed. Disequilibria, imperfectly competitive markets, unceratinties, unpriced environmental impacts, price distortions by governmental actions, and other complications are often ignored. Thus, for example, if we take it as fact that given the present political structure the federal government will continue to subsidize producers and consumers of conventional energy sources, there is a clear case to be made for subsidizing solar energy development and consumption. Conventional sources tend to be overused (even from a present generation viewpoint) because of the large subsidies given during the past six decades,[7] due to the typical average price arrangements for petroleum-related sources relative to the marginal price basis operating for solar technology, and on the basis of the largely unpriced environmental effects. At the same time, capital market imperfections, public good externalities associated with innovation, and risk lead to an under-use of solar radiation. Thus, while a first best solution would involve removal of subsidies to conventional energy producers and consumers, if this is politically impossible a second best solution would be to subsideze solar energy development and consumption. While too great an amount of energy in total would still be produced (even from only a present generation viewpoint), at least in a relative sense, this would lessen distortion in interfuel competition. The clever resource economist could provide a valuable analysis of the level and type of subsidy which would accomplish this.

Similar comments apply to nuclear power. How can so many people know the answer - be pro- or anti-nuke? Even if we decide we should have X amount of energy, the proper combination of sources is unknown and the price system doesn't tell us due to the tremendous subsidies, environmental tradeoffs, etc. And the"if" is one of the largest facing the country today. To contrast with the "moral equivalent of war" characterization of the energy situation, the handwriting on the (men's room) wall is "Give me cheap electrical power, or give me death!"

At another level of energy analysis, there has been a flurry of activity in the past several years. The work of Berndt and Wood, Griffen and Gregory, Field and Grebenstein, and others involves a more macro approach to examining the role of aggregate energy and growth on a national and even international basis. Rather than invoking separability <u>assumptions</u>, as has been done in past value-added studies, which estimate aggregate production or cost as a function of only capital and labor, these works estimate these functions with energy and materials[8] included. They then estimate elasticities of substitution between the various inputs. Their real concern, however, is primarily with determining whether capital and energy are substitutes or complements, and if so, to what degree. The econometric estimates of different researchers vary and a substantial degree of effort is underway to reconcile these findings. The focus on energy-capital elasticities is revealing. The concern is that if energy and capital are complements, then higher energy prices <u>ceteris paribus</u> should lead to lower capital accumulation and thence to slower growth in national output. Horrors!

Given the issues discussed here, however, should we not be equally concerned with labor-energy, capital-materials, and labor-materials substitution?[9] And surely these coefficients are, or can be, endogenous. High energy prices need not cause a slow-down in capital accumulation when the federal government is in possession of selective instruments (incentives) to influence this rate. However, this work represents a vastly superior generation of analysis to the previous value added studies. It is a good start, but much more needs to be done at the conceptual as well as methodological levels. For example, the levels (and likely problems) of aggregation are enormous in this work. There is need for some analysis on a regional basis, and this will take a great deal of effort in acquiring and preparing data. But it is important to do.

Not all of us need to address only regional issues, of course. There are some "lofty" issues that perhaps a few more minds from the region should address. We need to continue to rethink the discount rate and intergenerational transfer issues. There is currently a revival of sorts in thinking along these lines (Ferejohn and Page 1978). Most recent works are couched in terms of axioms. As Rawls suggests, however, we shall ultimately need more than an axiomatic approach if we are to do much with it in practice.

We also need to rethink measures of scarcity and the lessons from entropy suggest that somehow a physical measure must be included in the economic indicator. Why? Because we are not likely to defeat the Law of Entropy - there will be an end to the human race - yet we would probably agree that it would be nic for it to survive at least, say, another several centuries. And while the topics haven't been linked, I believe the future extensions of the Berndt and Wood sort of analyses of substitutability will need to merge with the development of these improved measures of scarcity.

Institutional economics is ripe for exploitation as well. In this area we need better theories (theroies which recognize the distinguishing features discussed here) and we need more measurement. More solid work exploring likely impacts, on the economics of natural resources and the environment, of imperfectly competitive industries, as well as of alternative social organizations, is called for. A new wave of institutionalists who will understand other economists and vice versa is needed, and ultimately the adjective "mushy" will not necessarily precede "institutionalist" in the vocabularies of many. An institutionalist colleague once told me (from memory), "My major professor said to me after completion of my Ph.D., 'You are the only one I know who went through the entire economics program without being affected by economics.' And you know, I was proud of that." It seems clear that this sort of badge of honor can stand in the way of good economic analysis - for both institutionalists and for traditional economists.

I think that an increasing proportion of our future work in resources will take form using systems methods with a dynamic setting. While important insights will come from this approach, the costs will be high. These models will initially serve primarily in the area of teaching and only gradually will they take over in empirical applications, as algorithms (and computer hardware) are developed capable of solving problems of reasonable dimensions. However, there are good examples to date - Brown and Hammack, for management of migratory waterfowl, and Spence, for optimal use of the blue whale population, among others. And these applications are growing in numbers, and in diversity of topic, in the Northeast as well as elsewhere.

However, work in this area cannot seriously be referred to as a "flurry of activity," in part because of the entry costs. Not many of us will ever be mathematically sophisticated enough to master the complexities of an adaotive control framework. Nor are we, in the Northeast, all blessed with the last word in computer software and hardware capabilities. There remains a great deal to be done in additon to formulating and solving dual control problems.

Relatedly, we need to pay more attention to sensitivity analysis is our work. I wonder how many of you were present at Ron Cummings' presentation at Blacksburg. In discussing his optimum control formulation of geothermal energy development at Los Alamos, he recalled how he gleefully called home to his mother to tell her that at last he had had an impact! His sensitivity analysis indicated a very low value of information from pursuing the planned direction of engineering research and the high value of pursuing an alternative line of research. And the engineers revised plans accordingly!

But the analysis need not be of the level of sophistication of Cummings' control formulation to be of value. Recently, Joe Diamond, at Connecticut, did some sensitivity work on a very standard analysis and found that resolving uncertainties about one of the several components had little or no effect on the outcome. While he did the sensitivity analysis after the fact, he could as well have done it before the fact and used the results to reassign research priorities. In this case, it is just as well he didn't, since the "low priority" work was being done by University of Massachusetts and the "high priority" work was his own.

We in the Northeast typically do a great deal more of what might be called "short run pragmatic" analysis than contributing to the thinking through of the "lofty issues." This is due largely, I suppose, to the characteristics of our support in the Northeast land grant universities. This situation probably won't change too much in the near future. We can have an impact here by improving the <u>conception</u> of the issues and by providing analyses likely to lead to short run efficiencies. Even if we are not equipped to know <u>optimum</u> yield, we might at least indicate how to reduce effort to achieve a given yield.

Relatedly, while we need to continue to work on developing more sophisticated economic methodologies, we might do well to spend relatively more time in learning to use correctly the methodologies we already have. I have been hearing pleas for methodology sessions from Joachim Elterich since I moved East in 1972. We often use standard techniques in such a rote way that when we arrive at results, to borrow from Samuelson, "We are not so sure what it is that we know." Since we are in many ways an impoverished bunch of small departments, perhaps we should use economies of size at meetings such as this to have special sessions on methodologies.

My comments have rambled; subjects have appeared, reappeared, and overlapped. This is so partly because I have resisted taxonomic tendencies. To separate natural resources from environment, for example, tells an incomplete story in my view. If there is a theme, it is that natural resource economics is different, yet not <u>that</u> different from traditional economics; it takes the long view and sees the system moving through phases of disequilibria; it sees the unfettered market system as quite inadequate to deal with the allocation of natural and environmental resources; and there is much to be done.

Traditional economic logic[10] might suggest less work to be done and fewer of us needed to do it. Instead, the picture painted above suggests there is more, and increasingly complicated, work to be done. A lot of it. And we must be willing to understand and work with many others - from physicist to political scientist. The evolution of forms of social, legal, and political organization has much to say about rates of resource exploitation, intergenerational transfers, and environmental issues. Institutional studies (oh, I never thought I would hear myself say this) may have a very high contribution indeed.

FOOTNOTES

[1]See Clark and Munro [1975].

[2]The rather substantial volume of recent literature on bidding models is relevant here. A potential lessee of a mineral bearing property wishes to know its worth and how much to pay. One interesting suggestion from recent work is that often prospective lessees are led to gather excessive duplicate information to reduce uncertainty and gain an edge in purchases of leases.

[3]Solow seems to be a late convert to the position that the Entropy Law is fundamental to the issue of natural resource scarcity. In this article he suggests, "That is why I think it takes economics as well as the entropy law to answer our question" (p. 11). In Solow [1973] he took a more traditional position.

[4]Partly because he coined the word "surprise" to express one of his three fundamental issues.

[5]"Because pollution is a surface phenomenon which also strikes the generation which produces it, we may rest assured that it will receive much more official attention than its inseparable companion, resource depletion" (p. 377).

[6]We have recently experienced our first execution by the state of an unwilling victim in over a decade. A poll taken before the moratorium on capital punishment in the 1960's indicated 41 percent of Americans to favor the death penalty. The same poll in 1979 indicated 61 percent to be in favor. Why the difference? Have we become more blood thirsty? Or might the 1979 response have been merely a hypothetical response to a hypothetical question, since no one in recent history has been executed?

[7]See Yokell [1979] on this point.

[8]For lack of data Griffen and Gregory were forced to omit materials.

[9]As Solow (p. 11) suggests, using the most simplified and aggregative model, one can show that if the substitution elasticity between exhaustible resources and other inputs is one or more and if the output elasticity with respect to reproducible capital exceeds that with respect to natural resources, then a constant population can maintain a constant level of consumption. Further, the level of this maintainable consumption is an increasing function of the initial stock of capital. If either of these conditions does not hold, the largest sustainable consumption level with a constant population is zero.

[10]As remembered by Richard Day (p. 276), Joe Stiglitz suggested at a recent

conference on resource scarcity that "there is little evidence to suggest the existence of a resource problem, and even if there were, we should probably do nothing about it."

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