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EQUILIBRIA, ENVIRONMENTAL EXTERNALITIES, AND PROPERTY RIGHTS: A COEVOLUTIONARY VIEW

by

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EQUILIBRIA, ENVIRONMENTAL EXTERNALITIES, AND PROPERTY RIGHTS: A COEVOLUTIONARY VIEW

I. INITIAL LINES OF INQUIRY.

Economists address a broad array of issues with only the aid of the neoclassical model of economics. We advise on tax policies to spur growth of the economy, payment-in-kind programs to encourage farmers not to plant, international trade policies to improve the balance of payments, aid programs for mothers of dependent children, and optimal fees to discourage pollution. Is the neoclassical model really this robust? Or have we so accepted Friedman's (1953) argument that the realism of a model's assumptions are irrelevant that we confidently apply the model to any problem that comes along. Should we not compare the problem's most important characteristics with the model's basic assumptions?

With respect to issues of resources and the environment, the basic assumptions of the neoclassical model do not fit the natural world. The model assumes that resources are divisible and can be owned. It acknowledges neither relationships between resources in their natural environments nor environmental systems overall. It assumes that the economy can operate along a continuum of equilibrium positions and move freely back and forth between them. Markets fail to allocate resources and environmental services efficiently because many resources and all environmental systems are not divisible, because environmental systems do not necessarily reach equilibrium positions, and because changes are frequently irreversible.

The economist's response to market failure is to advocate working markets. In some cases institutions can be improved to maintain the conditions the model assumes. Anti-trust institutions can be strengthened to maintain competition and law enforcement can be enhanced to maintain property rights. When economic institutions can be modified so that the model and reality have a better fit, then model can more appropriately be used to predict and prescribe. But to what extent can environmental realities be modified to fit the model? Can we "make" resources separable and environmental systems irrelevant along the lines of the model? What are the costs if we do?

This paper builds on three major premises. First, scientific models affect how we think and act and eventually become reflected in the characteristics of our institutions as well as the nature of our environments. Second, the neoclassical model is part of a broader atomistic and mechanistic world view that frames our technical decisions. Third, different models have comparative advantages for understanding and acting upon different types of problems. From these basic premises I argue that environmental problems result from the over use of the atomistic-mechanistic and neoclassical economic models for environmental problems. The coevolutionary development model (Norgaard, 1981, 1983, and 1984) would be more advantageous for understanding and resolving environmental problems because it starts with more appropriate assumptions about the relationships between people and their environment.

II. THE ATOMISTIC-MECHANISTIC WORLD VIEW.

A. A-M MODEL CHARACTERISTICS. The atomistic-mechanistic or A-M world view is based on the two most productive assumptions of Western natural science. The neoclassical model is atomistic in the assumption that land, labor, and capital are separate components. These components are like individual atoms which are only combined during the production of goods and services and only related to each other through their relative values determined in exchange. Mechanics and coal mining equipment operators, for example, are unrelated to each other in the model except for the manners in which they both can be combined in the process of mining the land or through their relative wage rates as determined in the market for their services. Similarly, the petroleum used to run coal mining equipment is only related to the iron in the equipment in the process of mining and through their respective exchange values. Mechanics and operators do not interact and affect each other through other social relationships such as families, labor unions, or churches. Petroleum and iron are separate components pretty much unrelated in their environmental settings, but this separateness is characteristic only of nonrenewable resources. Sunshine, wind, soil mosture, and the levels of agricultural pest populations clearly are not separable.

Early economists explicitly acknowledged their philosophical debt to Isaac Newton while the mathematizers of economics - Cournot, Jevons, Pareto, and Walras - formalized economics along the mechanistic models of Newton's (1686) Philoshiae Naturalis Principia Mathematica (Georgescu-Roegen, 1971; Blaug, 1980). The neoclassical model is mechanistic in the assumption that the economic system can operate in equilibrium at any position along a continuum and move back and forth between them. If more labor becomes available, the system adjusts so that more labor intensive goods are produced and are sold at lower prices relative to capital intensive goods, the returns to labor fall, and the returns to capital increase. If the quantity of labor returns to its previous level, the economy produces the previous mix of goods at the same prices and the earnings of labor and capital return to their previous levels. The model is comparable to a system of planets orbiting around a sun. If the mass of one planet for some reason changes, its orbit changes, the orbits of each of the other planets are affected, and each of these changes simultaneously further affect the orbits of all of the planets. Within limits, the system of planets reaches a new equilibrium pattern of orbits. If the mass of the initially affected planet returns to its original level, the planetary system returns to its original pattern. Mechanistic models are characterized by a range of stable equilibria and the reversibility of system changes.

B. ADVANTAGES OF A-M MODELS FOR PREDICTION AND PRESCRIPTION. There is a long history to the idea that the test of a science is its ability to predict (Scriven, 1959). From Bacon to Descartes on through with minor twists to Popper, this idea has dominated epistemology. Newton's Principia was clearly admired for both the simplicity and the definitiveness of the model's predictions. Complex and indefinite predictions have little practical value. Simple, definitive solutions are characteristic of equilibrium models. Comparative static models which abstract from the process and period of adjustment are especially attractive.

Predictions can only be made from models which are readily, frequently mathematically, tractable. Tractability entails simplification in the number of relationships and symmetry in their form. Lipsey and Lancaster (1956) created considerable controversy with their "Theory of the Second Best" simply by pointing out that predictions and prescriptions could not generally be derived if the conventional assumptions of divisibility and perfect, competitive markets were violated in more than but one instance. While mathematical economists have become much more sophisticated over the past quarter century, no significant generalizations have come forth in a "second best" world (see for example, Mittelhammer, Matulich, and Bushaw, 1981). Similarly, tractable models are reversible. A second minor furor erupted when the implications of irreversibility were pointed out by economists concerned with natural environments (Fisher, Cicchetti, and Krutilla, 1972; Arrow and Fisher, 1974; see also Kornai, 1971). Ironically, the economic model is powerful precisely for the very reasons that the assumptions on which it is based are weak. The model is tractable and produces unique solutions precisely because of its atomistic and mechanistic assumptions.

C. INSTITUTIONALIST'S CRITIQUE. Institutions within neoclassical economics have traditionally played a static role. Property rights institutions set the initial distribution of wealth. Educational and other institutions insure that economic actors are fully informed. Regulatory institutions insure that competition or market-like solutions are maintained. When institutions change, the market economy adjusts to a new equilibrium. Institutions simply affect the parameters of production and market relationships and thereby the equilibrium position of the economy.

Institutional economists do not accept the neoclassical model's emphasis on atomistic individuals and the implicit conception of society as no more than the sum of its individuals. They also reject mechanistic characterizations of economies (Commons, 1924; Polanyi, 1944; Lodge, 1974). Institutionalists have effectively described how institutions evolve on their own through a process of "circular and cumulative causation" where "there is generally no equilibrium in sight" (Myrdal, p774). Perhaps the best evidence that economics is indeed a social science is the endurance of the subdiscipline of institutional economics and its toleration by the profession at large.

In fact, the A-M world view has long proven inappropriate for prediction and policy prescription. Solutions have always proven temporary for equilibria and reversibility rarely exist. Operating in the A-M mode of thought, when rationally planned institutions evolve lives of their own, we ask why our institutions keep failing. Wildavsky (1979) expresses the recognition and acceptance of institutional failure succintly:

> During the period starting in the mid-sixties, one social program after another failed as measured by ostensible objectives - and the failure was common knowledge. The remarkable thing was that the very professionals who ran programs, their clients, and interested parties all acknowledged to themselves (and to others who were relevant) that these programs were unsuccessful. (p.43)

The rigidity of the A-M mode of thought plagues us increasingly. It is common today for administrators to complain of lost opportunities for cooperative management between agencies because of the difficulties of adapting fixed mandates to differences in circumstances over time and space (Ingram and Mann, 1980). To attain an expanding list of social objectives, mandates are piled atop mandates. During the past decade, state and federal regulations of petroleum refiners, for example, were established to meet onsite air quality standards, new facility siting objectives, production levels of unleaded gasoline, protection for small refiners and independent producers, and the distribution of the gains from multi-tiered crude oil pricing (U.S. Congress, 1980). So many contradictions arose from the sequence of mandates that the refiners have had difficulty making any changes to meet any of the objectives. Meanwhile, legislatures and administrations are trying to remedy the problems resulting from the naivete of the A-M sense of planning and control with even more complex additions to the agencies' fixed mandates.

D. ENVIRONMENTAL REALITY. The A-M world view embedded in the neoclassical model is no more appropriate for environmental systems than it is for social systems. The model does not abstract from environmental reality. As in the case of social relations, it simply assumes environmental relationships away.

Consider the classic example of an upstream paper mill discharging a single pollutant that directly, simply by its presence in the water, causes an external cost for a downstream brewery. The neoclassical model leads us to seek an optimal level of pollutant input maintained by either a tax or a subsidy. However, if the pollutant affects the ecology of the stream and thereby indirectly affects the water for the brewery, the environmental system may or may not reach an equilibrium condition for years even with the pollutant at a constant input level. The pollutant may differentially affect the survival rates of species such that they increase or decrease slowly over the years. Species better adapted to the polluted conditions may not be introduced into the stream for decades. Taking an even longer view, there are no equilibria. Every pollutant outright changes the course of evolution of species in the stream. The optimal tax framework clearly relies on a mechanistic world.

Multiple pollutants call the atomistic assumptions into question. Methyl compounds and mercaptans, for example, can come from separate pollution sources. Neither pollutant by itself is particularly troublesome. But the two chemically combine to form methylmercaptans which are literally distasteful in very low concentrations. Benign separate factors, through a chemical reaction, become malign. The damages cannot be assigned to either polluter separately. But chemical interactions are but the tip of the iceberg. Most pollutants interact biologically with an environmental system such that the combined changes are rarely the sum of the separate effects. If environmental systems reached equilibria quickly, optimal pollutant levels might be reached through a system of subsidies or taxes based on the incremental effects of each pollutant on the equilibrium outcome. The absence of equilibria in reality, however, compounds the problems of inseparability.

The development of federal pesticide policy documents the difficulties of applying the A-M approach in an evolutionary world. Many of the policy problems are largely attributed to the strengths and differences of the competing interests and the prior evolution of alignments of the agricultural support and research establishment (Perkins, 1981). These forces seriously test the democratic process. The discovery that numerous pesticide toxicity tests were faked marks the end of the era when information provided by scientists is automatically assumed to be true. The toxicity tests were undertaken by independent laboratories for the Environmental Protection Agency but paid for by the pesticide companies seeking registration of the pesticides (Science, 1983). There has been another less well known dimension of problems in the development of pesticide policy that is more important to the decline of the A-M world view. National regulations are difficult to develop while pest populations acquire resistance, new types of secondary pest outbreaks keep arising in different regions, and totally new chemicals, as well as biological control alternatives, become available. Each of these phenomena have been evolving in response to changes in the others. The plethora of behind-the-moving-target regulatory decisions has left all parties in the policy process thoroughly stale-mated and frustrated.

The economic reaction to the environmental assumptions of the neoclassical model provides further evidence that economics is indeed a social science. Numerous economists concerned with resources and the environment from K. William Kapp (1950) and Ciriacy-Wantrup (1952) to Adler-Karlsson (1977) and Swaney (1981) have criticized the neoclassical model more because it does not incorporate the most important characteristics of environmental institutions than because it does not incorporate the most important characteristics of environmental systems themselves.

E. RELATION TO PROPERTY INSTITUTIONS.

> "What we call land is an element of nature inextricably interwoven with man's institutions. To isolate it and form a market out of it was perhaps the weirdest of all undertakings of our ancestors."
>
> Karl Polanyi (p.178)

Institutionalists have documented how the philosophy of John Locke stems from the A-M world view (Lodge, 1974). Locke's arguments that the individual can best decide what is good lends support to the Western institution of individual property rights. It appears, however, that no one has elaborated on how the A-M conception of nature itself may have facilitated the rise of Western property institutions. A world seen as made up of of separable components can be divided up and allocated to individuals as private property. Ecological world views emphasize the indivisibility of environmental systems. In an A-M world, each particular use of property mechanically produces the same outcomes. A world view that posits definitive outcomes fosters the idea that there can be a transactions costs minimizing system of rights to use property which changes in response to increased population pressure, new technologies, and evolving tastes (Boserup, 1965; De Alessi, 1983; Demsetz, 1967; and Libecap, 1978). Evolutionary world views emphasize changing environmental relationships which themselves would indicate the need for changes in the system of property rights. Thus the A-M world view supports the Western institution of property rights through the Lockean treatment of individuals and society as well as through the treatment of resources and environmental systems.

G. FOLLY ON THE BOUNDARY. Natural scientists and philosophers seem to agree that models have comparative advantages related to the different emphases in the model's simplifications. Plasma physicists have limited use for the quarks and gluons of the particle physicists let alone the simpler molecular model that works so well for most chemists. Similarly, chemists have limited use for the evolutionary models of biologists or the Freudian models of psychologists. The particular simplifications of each model eventually define its useful boundaries.

Within economics, however, this understanding appears to have been repeatedly challenged. Economists of the Austrian School, especially von Mises (1933), have argued that the "laws of economics" such as diminishing marginal productivity and diminishing marginal utility are as universal as the law of gravity. That these laws themselves entail the assumption of separability between factors and between products do not bother this school. Friedman (1953) is famous for having argued that the neoclasical model must be judged simply on its ability to predict results accurately, not on the reasonableness of its assumptions. Both the argument of the Austrian School and that of Friedman seem to suggest that the economic model can be applied without regard to its assumptions. Though even Friedman notes that assumptions ought to be "sufficiently good approximations for the purpose at hand" (p.15), the tendency of economists to apply the model to diverse questions including how people pick marriage partners or owners treat slaves indicates that economists have not yet accepted comparative advantage as a working principle with respect to scientific explanations (see Frazer and Boland, 1983 for a recent discussion of some of these issues).

The neoclassical model evolved around questions of labor and capital markets and the role of the state. A model is most likely applicable for the types of questions around which the model evolved. Gradually, as one tries to apply a model to new questions further and further from the initial questions, the model becomes less appropriate until its use clearly becomes sheer folly. Land, other resources, and environmental systems have always presented special problems because the economic model over simplifies the natural world for use on these questions.

Nevertheless, Kearl et al (1979) found more agreement among economists on the proposition that pollution taxes were superior to pollution controls than on fiscal or monetary policy measures. Beckerman (1972) exudes the confidence behind this consensus at the limits of the model --

> "...the problem of environmental pollution is a simple matter of correcting a minor resource misallocation by means of pollution charges, and ...most of the common objections to such a policy can be demolished with the aid of no more economics that that which is the stock-in-trade of any second-year economics student." (p.327)

-- while acknowledging his own ignorance:

> "Now I know that you are saying, 'What do you know about science?' Well, you are right; I know very little about science." (p.328)

Natural scientists also do not always qualify their predictions and prescriptions as they approach the limits of their models. Toulmin (1982) argues that 'folly on the boundary' is a regular feature of science. In particular, Toulmin notes how scientists have repeatedly argued that the universe is winding down like a clock, ultimately all possible change will have occurred, and the universe will reach a homogeneous temperature, its entropy maximized. Though the second law of thermodynamics has thus far proven universely true for thermally isolated components of the universe, its application to the universe as a whole is dubious for a variety of reasons including the technicality of from what can the universe be thermally isolated (p40-49). Toulmin summarizes:

> "If things had worked out as we should have expected, nothing in science would have been less certain than our speculations about the very beginning of all things, and about their ultimate fate. Yet when scientists turn to discuss these topics, a sudden fluency descends upon them, as though the mist through which the past and future are seen was, when we reach the extreme limits, suddenly lifted, and a clear vision of the first and last events granted to us." (p.34)

Increasing specialization within science over the past century has multiplied the boundary areas on which to folly. Economists are clearly subject to this tendency. A century ago, economists were well versed in philosophy and comfortably addressed a broader range of subjects. They did so, however, more humbly than economists of today. Now, members of each discipline are irritated by the excessive confidence of members from other disciplines pontificating on their shared boundaries. The irritation encourages some to withdraw further into their specialization, creating even more boundary lines in the end. Unfortunately, this positive feedback reinforces the fragmentation of science.

III. ENVIRONMENTAL MANAGEMENT IN A COEVOLUTIONARY WORLD.

There are alternative world views which make more appropriate assumptions about the nature of resources and of environmental systems. More realistic models better describe the nature of environmental issues but are not readily tractable for deriving predictions and prescriptions. The coevolutionary world view synthesizes concepts from the literatures of biology, cultural ecology, and economics (Norgaard, 1981, 1983, and 1984). Only sufficient detail is presented here to contrast the coevolutionary world view with the A-M world view to derive new insights into environmental management.

A. THE COEVOLUTIONARY PROCESS.

Coevolution in biology refers to an evolutionary process based on reciprocal responses of two closely interacting species (Ehrlich and Raven, 1964; Baker and Hurd, 1968). Coevolutionary explanations have been given for the shape of the beaks of hummingbirds and of the flowers on which they feed, the behavior of bees and the distribution of flowering plants, the biochemical defenses of plants and the immunity of their insect prey, and the nature of numerous other closely interactive species or subcomponents of ecosystems.

The concept of coevolution can be broadened to encompass any ongoing feedback between two evolving systems including the interaction and evolution of social and ecological systems. To coevolve and coevolution refer to any positive (in the cybernetic sense) feedback or reciprocal interaction. Whenever the interaction between social and ecological systems is not immediately mutually destructive, the two systems are coevolving. Coevolutionary development is a coevolutionary process that benefits man. The coevolutionary world view does not solve the problems found in other perspectives of defining the term "benefit". In any case, this paper emphasizes the implications of the coevolutionary process rather than of alternative objectives.

Coevolutionary development has been taking place for millenia. The rise of paddy rice culture in Southeast Asia is an instructive example. The land extensive practice of slash and burn agriculture was gradually abandoned over many centuries as investments were made in dikes, terraces, and water delivery systems for increasingly intensive paddy agriculture. The benefits from this ecological transformation came in the form of superior weed control and greater nutrient retention in the soil. The environmental modification process, however, was not unilateral. To maintain the ecological system in its modified form and acquire the benefits of modification, individuals changed their behavior and social systems adapted to assist and reinforce appropriate individual behavior. In the case of paddy rice, the benefits from ecological transformation were acquired through complex social changes that facilitated property ownership, water management, and labor exchange (Geertz, 1963; Boserup, 1965).

Sociosystems and ecosystems are maintained through numerous feedback mechanisms. Coevolution occurs when at least one feedback is changed and an ongoing reciprocal process of change is initiated. One of the important features of this process is that feedbacks that previously helped maintain the ecosystem are assumed by or shifted to the social system. Eugene Odum (1969) characterizes agricultural development as a transformation of the ecosystem to reduced numbers of species and usually lower combined efficiency of nutrient recycling, higher but less stable rates of production, and low biomass stocks relative to natural conditions. As man pushes an ecosystem to suit his own needs, he intervenes in some of the nutrient cycles and disturbs some of the equilibrating mechanisms which had evolved within the natural system. Coevolutionary development occurs faster, or is perhaps only possible, if the sociosystem compensates for these losses to the natural system. New sociosystem functions might include managing legumes to replace portions of lost nutrient cycles, weeding to offset natural succession, and combating herbivorous insects to compensate for lost natural pest control mechanisms. These new sociosystem functions may entail managerial effort, the acquisition of knowledge, the use of natural resources, and the modification and support of institutions.

IMPLICATIONS. The A-M world view leads us to seek equilibrium solutions: optimal levels of pollutants, optimal charactaristics of environments, and optimal institutions. The A-M view supports the lawyers' rationally planned regulations and their associated bureaucracies as well as the economists' optimal property rights and fiscal incentives subject to transactions costs, tastes and technologies. Both lawyers and economists seek an institutional framework within which development takes place.

In a coevolutionary mode, environments are expected to change and markets, property right assignments, and bureaucracies to prove inappropriate. Appropriate continual institutional change is sought. Change is viewed as a natural process offering opportunities for coevolutionary development rather than as a problem of environmental instability or institutional failure. Boserup (1963 and 1981), Wilkinson (1973), and Simon (1977) build on the theme that institutional development occurs when population growth and technological progress change a society's relation to its environment. In the coevolutionary view, development may occur for this reason as well as because the environmental system itself is evolving new characteristics along with social changes.

The A-M world view supports the idea that development is a process of increasing the throughput of resources within a property-right framework. Specific property rights in the coevolutionary view, however, are merely a temporal aspect of a changing environmental and social interaction. As the interaction evolves, specific uses of property have different impacts, some of which are undesireable and must be reduced. On the positive side, coevolutionary development can come about in part through changes in the rights of individuals to use property. Changes in property rights are a necessary part of the process of coevolutionary development.

Over the past decade or so, economists have made tremendous advances in their formal treatment of uncertainty and attitudes toward risk. These advances have reduced the rigidity of the A-M mode and given economic thought increased realism, another lease on academic thought, and a superior basis for policy prescription. The uncertainty economists can now include in the neoclassical model, however, is limited. Certain properties of the uncertainty, if not the distribution itself, are presumed to be deducible directly from experience or indirectly from other information. Similarly, tastes for risk are either given or their evolution is in some sense predictable. Even with these assumptions, one of the conclusions of Epstein (1980, p.279) is typical: "the relationship between the qualitative effects of a change in prior uncertainty on the one hand and of the timing of the resolution of uncertainty on the other hand, is ambiguous".

Evolutionary uncertainty will not succumb to the economists attack. In evolutionary systems, there may be random changes about a mean, but the mean itself is unpredictable because relationships evolve over time. Indeed, even the rules by which relationships evolve over time also evolve (Scriven, 1959). Econometric models can still be useful, but evolutionary views of the world suggest that formal models are most useful for predicting the near future.

Similarly, their parameters had best be estimated from data of the recent past.

With the acceptance of the coevolutionary view, institutions would have to be more flexible. How might bureaucracies be adaptive, property rights be flexible, and "control" still be maintained? The coevolutionary perspective must be further developed before this question can be answered adequately. It appears, however, that institutions would probably be much more local in nature and greater social consciousness and peer pressure would probably substitute for much that is now formalized in law.

B. COEVOLUTIONARY POTENTIAL. Conditions for people improved over the past through the realization of coevolutionary development potential (Norgaard, 1983). The ultimate source of coevolutionary development potential is the energy of the sun. Humans have "captured" this energy by (1) modifying ecosystems and sociosystems so that more energy is photosynthesized, (2) modifying ecosystems and sociosystems so that more of the photosyntesized energy goes into products that benefit man, and (3) modifying sociosystems through changes in tastes and technologies so that man effectively consumes more products lower in the food chain.

IMPLICATIONS. The idea of coevolutionary potential sheds additional light on the concept and nature of property rights in the two world views. In the neoclassical view, income is a return to property rights properly acted upon. New technologies are developed and adopted, in part, to enhance the private income from property. But the private income from property is but one aspect of a new technology, for every technology changes a society's relationship with its environment in a multitude of ways. Changes which do not affect private income through the market are external effects in the neoclassical view of the world.

In the coevolutionary view, income reflects the nature of the relationships between the social and ecological system. Better relationships are adopted to improve income. Since the coevolutionary view encompasses all relationships, there are no external effects. In principle external effects would exist if the coevolutionary model takes takes too narrow a formalization. In practice, there would be external effects simply because of our limited ability to encompass all relationships in our thinking, let alone in the communications and transactions necessary for coevolutionary institutional change. Nevertheless, environmental externalities are not concomitant with the coevolutionary view per se as they are with the A-M, neoclassical world view.

The distinction between the emphases of one view on parts and the other view on systems can be developed further. Superior resources in the A-M world view have more concentrated parts. Good mineral deposits have greater percentages of ore; good agricultural lands are more fertile. In this view, resources have quantifiable attributes to which an income return can be "attributed". From the coevolutionary view, however, favorable, compatible qualities of ecological and social systems together are resources. In this view the characteristic of having equilibria or of reversibility might be a resource. The management implications of ecosystem properties such as stability, amplitude, complexity, elasticity, hysteresis, and malleability are considered by May (1973), Goodman (1975), Van Voris (1976), and Westman (1978). A complementary social system literature is needed for the full development of the coevolutionary model.

Our institutions today are designed to facilitate the use of stock-exploitive technologies stemming from the A-M world view and to offset the costs external to the A-M view from the use of these technologies. Those who favor development are "progressive" in the sense that they support the continued application and expansion of technologies stemming from the commonly held A-M world view. Similarly, environmentalists are "reactionaries" in the sense that they are trying to slow, reverse, and otherwise guide the use of A-M based technologies.

Environmentalists are reactionaries largely because they do not have an alternative solution. They can point out that the costs of utilizing A-M based technologies are too high, but even their sense of the costs stem from either the A-M world view or but limited applications of an ecological world view. We have been underestimating the costs of stock-exploitive technologies by not considering the coevolutionary potential that is lost through inappropriate ecosystem transformation and sociosystem development. Environmentalists have become more progressive over the past decade through their support of energy conserving technologies, the use of solar energy, and integrated agricultural pest management. Environmentalists, however, could become a truly new progressive movement if they could (or would) recognize coevolutionary potential and promote some forms of ecological transformation coupled with appropriate social change.

C. CULTURAL KNOWLEDGE. We may be unique among all species not simply because of how much we know but because we know we know. Not only do we know we know on an individual level, but there is such a high level of agreement between individuals about what is known that we have been able to act collectively on a scale and level of complexity far excess of any other "social" species. Since the rise of science over the last three hundred years, western societies have attributed their collective success to objectively tested scientific knowledge. But people have been working together for millenia, beginning long before the development of key concepts or the epistemology of western science. Furthermore people collectively knew they knew. To be sure, they may not have categorized what they knew or developed a formal rationale as to why they knew. Indeed, the knowledge was frequently embodied in habits, rituals, and social values. But this knowledge aided in the realization of coevolutionary potential, living conditions improved, and the earth became "peopled". This latter type of knowledge can be thought of as cultural knowledge. It develops through a process of cultural adaptations -- through random or partially deliberate variations -- which survive if they make the culture more fit (Lumsden and Wilson, 1981).

Individuals and societies have interacted with their environment for quite some time, up to three and a half million years depending on how you feel about ancestors. This is a sufficient period for people, through cultural knowledge, to have had considerable influence on the evolution of other species. Approximately seven thousand years of agriculture practices, for example, have indirectly affected the course of evolution of organisms with rapid regeneration times, from microrganisms to insects, and directly affected the selection of species , from corn to cows, through the "artificial" selection for reproduction of individuals with preferred characteristics.

IMPLICATIONS. The addition of the concept of cultural knowledge to the coevolutionary world view brings an important issue to the forefront. The coevolution of cultures with ecosystems is most easily conceived for relatively small groups of people in relatively isolated environments. For small, fairly closed systems, it is easy to see how societies and ecosystems can coevolve and how cultural knowledge develops. Can this world view be applied on a larger scale? It appears that the model simply sheds more light best on local level development. It is at this level that we can apply the model and learn from it. To the extent that ecosystems and social systems were numerous and different in times past, coevolution "should" have continued at the local level. Different intermediate points for both systems in different locales would almost inevitably lead to the continuation of unique coevolutionary courses and unique coevolutionary knowledge.

This is in sharp contrast to our conception of objective knowledge as universally applicable and the role we think objective knowledge can play in scientific planning. Objective knowledge - accepted by, or at least imposed upon, all regardless of locale - has played and continues to play a large role in the process of centralization. Through centralization and the application of objective knowledge, the uniqueness of both social and ecological systems has been reduced throughout the world. Swaney (1981) argues along the more general lines of Hirsch (1976) that environmental externalities are increasing because sense of community, social standards of conduct, and social pressure are declining. Restated in the coevolutionary framework, social and ecological relationships are not being managed as well as they were because mass culture -- based on objective knowledge and associated technologies and institutions -- has displaced local cultural knowledge.

Nevertheless, there is still a role for what remains of cultural knowledge today. There are still important social differences due to variations in educational levels and cultural histories and important ecological differences due to climate, topography, and evolution. The coevolutionary world view leads us to prefer more decentralization so that the coevolutionary potential of specific social and ecological systems can be captured through cultural knowledge and social values.

There is a second, related implication. Cultural knowledge has developed through a process of trial, error, and natural selection. Today, institutions still survive because they work, and new institutions are still designed around the experience of the past. Nevertheless, in an A-M, objective knowledge mode, countless billions are spent appling objective knowledge to the design, implementation, and management of institutions. The resource management agencies have expanded their research branches as well as their expenditures on contracted research in order to "rationalize" their organization and decisions. Congress has also mandated that the agencies undertake environmental and other impact analyses prior to committing to a course of action. Fewer inappropriate actions are perhaps being undertaken due to "analysis paralysis", but it is difficult to document whether the additional objective knowledge itself has improved many decisions. Carpenter (1983) describes the dismal results of bringing objective knowledge into the courts to settle environmental issues. Congress itself is spending more and more on research. Improvements in performance, if any, have been less than dramatic.

Research and the use of knowledge are not thrown out with the acceptance of the coevolutionary view, but these activities do assume new dimensions. Coevolutionary development can be accelerated by experimenting with institutional and ecological change, by utilizing monitoring systems, and by developing criteria for predicting how institutions might best evolve and ecosystems might best be pushed under different situations. In short, experimentation, monitoring, and learning become much more endogenous to the process of development, necessarily more subjective since people are the experimenters and part of the experiment. This emphasis on experimentation strengthens the arguments for decentralization. Clearly, it is risky to change institutions and ecological systems globally. Risks are reduced and opportunities to learn are enhanced by the law of large numbers.

The foregoing paragraphs illustrate an important policy dilemma. The suggested institutional modifications are built into the coevolutionary view much the same as the neoclassical model implies that there should be perfect competition and individual property rights because the model starts with these assumptions. Models are never neutral. The social dilemmas and contradictions presented by multiple models lead most scientists to seek or argue for one best model for determining social policy. At the other extreme, Feyerabend (1978), accepts the correctness of every model, even "unscientific" models and is led to argue against the use of science for the design of institutions for social development or control other than for the protection of freedom of individual thought and expression. I prefer a healthy mix of pluralism with respect to formal models, a better understanding and acceptance of cultural knowledge, and social trust and participation over either scientific autarchy or anarchy.

D. STOCK-EXPLOITIVE DEVELOPMENT AND ENVIRONMENTAL PROBLEMS IN A COEVOLUTIONARY WORLD. The last century of U.S. agricultural development can be viewed from the coevolutionary perspective. A once small scale, labor intensive, polycultural, near subsistence interaction with the ecosystem coevolved to a large scale, mechanized and energy intensive, monocultural, commercial farming interaction. This new interaction is maintained by a highly complex system of institutions. The social and ecological interaction depends on farm implement and agrochemical industries; a highly developed marketing system; and government institutions to generate and disseminate knowledge, develop new inputs, regulate markets, absorb risk, subsidize capital, limit the distributional impacts of adjustments, and control environmental and health externalties. The various institutional elements evolved to a large extent because of the nature of the responses of the agricultural ecosystem to human activities. While monocultural systems brought increasing returns to scale with mechanization, their instability and the increased risk borne by farmers with a single crop encouraged the use of agrochemicals and risk-spreading institutions. Similarly, ecosystem responses to agrochemicals have led to new institutions to regulate pollution as well as to new research programs in agricultural experiment stations to relieve detrimental pressures on the environment. Equally important, the institutional responses frequently entailed positive feedbacks. Crop insurance and regulated markets, for example, have reduced the risks of monocultural production and made it more attractive. Today's agricultural systems have soil features, weed dynamics, and insect-crop interactions which reflect coevolution with the sociosystem while today's agricultural institutions reflect the vulnerability of disturbed soil to wind and water erosion, the dynamic adaptations of insect populations to chemical control, and the susceptibility of monocultural systems to variations in weather.

IMPLICATIONS. From the coevolutionary perspective, we see new patterns in the development of U.S. agriculture. But was this agricultural history a case of coevolutionary development? A century ago, social changes induced beneficial ecological changes and vice versa. Cultural knowledge was embedded in institutions. But increasingly agricultural development became a process of adding more inputs to production rather than of modifying systems directly. Throughput was increased by enhancing the availability of water and nitrogen and increasing the rate of laborious tasks through mechanization. Agriculture was transformed by the success of the A-M world view, by the objective knowledge and technologies developed around this world view with its applicability to physical -- and therefore typically stock -- resources. Similarly, agricultural institutions increasingly reflected the use of objective knowledge. To be sure, social and ecological systems transformed together. But they did so on an increasingly global scale using objective knowledge to offset the detrimental effects of stock-resource inputs in agriculture rather than on a more local scale using cultural knowledge to capture the potential of coevolutionary development. Frequently in the process of offsetting the detrimental aspects of stock-exploitive technologies, corrective institutions enhanced the attractiveness of these technologies. The coevolutionary feedbacks have been positive with respect to stock-exploitive technologies that can be applied globally rather than with respect to the realization of local coevolutionary development potential.

IV. CONCLUSIONS.

Every model gradually becomes less appropriate as it is applied to questions further from those around which the model initially evolved. Moving away from the initial issues entails moving into areas in which the most compromising assumptions were made. The applicable ranges of different models may overlap, but for each question one model will have a comparative advantage, though each model will probably give some insights. The neoclassical model of economics drastically simplifies the characteristics of the natural world; indeed, it abstracts from ecological systems entirely. The model atomistically assumes natural resources can be divided into separable factors without ecological relations between them and mechanistically assumes social and ecological systems can operate along a continuum of possible equilibria and move freely between them. These assumptions make the model tractable for predicting outcomes and for prescribing policies. They entail only minor compromises for questions such as how the international terms of trade will change if the capital stock of one country is increasing faster than another. For questions related to resources and environmental management, however, the assumptions entail major compromises.

The coevolutionary alternative model starts with more realistic assumptions about resources and ecological systems but is less tractable for deriving predictions and prescriptions. Coevolutionary models will probably never "compete" with the neoclassical model for prescriptive simplicity. Six decades ago, Alfred Marshall assessed the situation well.

> "The Mecca of the economist lies in economic biology rather than in economic dynamics. But biological conceptions are more complex than those of mechanics; a volume on Foundations must therefore give a relatively large place to mechanical analogies; and frequent use is made of the term 'equilibrium', which suggests something of a static analogy."
>
> (from the Preface to the Eighth Edition, 1924)

Even at its current level of development, however, the coevolutionary model provides interesting insights into how social systems evolve, the role of property rights, the effect of stock resource use on this evolution, the appropriate areal level of evolution, the role of social consciousness and pressure, the idea of cultural knowledge, and the value of institutional and ecological experimentation. It also challenges economic thinking on the nature and applicable limits of the neoclassical model.

One insight is especially critical. The use of different types of knowledge affects the process of coevolution and thereby the characteristics of future social and ecological systems. Hirsch (1976) forcefully argues that in the process of implementing the capitalist model of economic development, the materialistic and individualistic values assumed by the model have become socially accepted. Indeed, the system rewards those who adopt the assumed values. With the strengthening of individualistic values, social values such as honesty, the work ethic, and concern for others are being lost. These vestiges of early social philosophies have proved essential for the implementation of economic philosophy and the evolution of the capitalist system. They facilitate exchange and work relations and soften the harshest aspects of market outcomes. Development, Hirsch argues, is eventually limited, perhaps permanently setback, whenever a society accepts the individualistic assumptions of, and evolves too closely around, the capitalist model.

Like social systems, environmental systems begin to reflect the assumptions of the predominant world view. Environmental systems have been ignored because they are assumed away in the A-M, neoclassical view. In ignorance, institutions have been established, technologies have been adopted, and individual economic behavior has been encouraged which have destroyed many of the relationships assumed away in the first place. The complexity and potential of ecosystems increasingly reflect our empty abstractions. Is not our development being constrained, perhaps permanently being setback, because we have accepted to too great an extent the environmental assumptions of, and evolved to closely around, the neoclassical model?

The development path made apparent by the A-M world view has become more difficult to traverse and far more precarious. From the coevolutionary perspective, an orderly retreat is called for. The coevolutionary world view, however, also indicates new pathways to pursue.

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