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SCARCITY AND GROWTH: HOW DOES IT LOOK TODAY*

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Twelve years ago, in a book entitled Scarcity and Growth, Barnett and Morse demonstrated that the labor and capital required to extract most resources had declined strikingly since 1870. The economics profession, intent at the time on accelerating our economy faster than competing socialist models, cited this analysis when asked why Keynesian systems were constructed without natural resource constraints. The continued existence of New Frontiers was a supposition of both political oratory and economic theory.

We are neither so naive or confident today. The environmental crisis; the Arab oil embargo; and the subsequent reanalyses of our resources, technologies, and institutions have swept us over an awareness threshold toward the "economics of the coming spaceship earth" (Boulding). Our pessimism, however, probably stems from our having accepted other realities--that we have not succeeded to eliminate domestic poverty, to globally spread democracy and capitalism, and to grapple with environmental dilemmas. For example, we are far more aware today than a decade ago that environmental interrelationships are numerous, sensitive, and largely unknown. Yet, we have not developed satisfactory methods of adjusting our actions in light of this now widespread conciousness. Consequently, we have become prudently skeptical of our ability to safely manage extensive, incompletely understood systems. This skepticism fuels the rising attack on the breeder reactor program in particular and labyrinthian technologies in general (Kneese). To relieve our doubts, we are allocating more resources to environmental impact analysis, land-use planning, technology assessment, and R&D diversification--in short, to thinking ahead. Small, stable systems are increasingly being perceived as beautiful (Schumacher). In summary, our concern over scarcity and growth today is based on the long-standing issue as to whether we are developing technologies as fast as we are depleting high-grade resources. But our perception of this race is more sophisticated due to our increased awareness of the inevitable, the potential, and the sometimes irreversible environmental and social consequences of rushing ahead.

Economists are giving extensive thought to resource scarcity for the first time since classical economists defined the issues. Contributions are being made in three areas: empirical analysis of the race between technology and resources, extensions of the Hotelling model of stock resource allocation over time, and the application of natural laws to economic systems.

Nordhaus (1974) compared the relative prices of minerals to labor between 1900 and 1970 and concluded that the historic decline in resource extraction costs analyzed by Barnett and Morse continued through the 1960's. Brown and Field, in an exploratory paper on alternative definitions of resource scarcity, illustrate that the prices of many resources have increased over time relative to the prices of quality adjusted capital and labor. New technology offset only 73 percent of the increased costs due to resource scarcity in U. S. petroleum development between 1939 and 1968 (Norgaard). These studies help document past developments in the race between technology and resources but have yet to help clarify our more recent, broader concerns for the future.

Many economists have developed a new interest in models of stock resource allocation over time. Models such as Hotelling's have been further developed; and the impacts of alternative market structures, taxation schemes, and technologic and resource conditions have been analyzed (Peterson; Dasgupta and Heal; Nordhaus 1973; among others). Dasgupta and Stiglitz have begun to examine market structure and innovation strategy under uncertainty. In addition, optimal growth models have been modified to include stock resources, flow resources, technological change, and population growth (Ingham and Simmons; Stiglitz). Theory has progressed at the rapid rate one would expect in an area long ignored. We can look forward to significant policy implications when both social risk aversion and opportunities to reduce risk through exploration, research, and resource diversification are incorporated in these models.

Further elaboration of the above two deficiencies provides an appropriate transition to the remainder of this paper.

Society's major concern over resource scarcity today is not so much that there is too little but that our resources and technologies are uncertain. We do not know whether there are three or thirty years worth of oil on the outer continental shelf, whether we can utilize oil shale with tolerable environmental side effects, or whether we can develop acceptable institutions to prevent plutonium diversion from breeder reactors. This uncertainty, in turn, can be reduced by gathering information through exploration, research and development on diverse energy sources and conservation techniques, and environmental and social assessment.

Except for Wantrup (especially Chapter 18), few economists have considered the concept of social risk per se. In the definitive article on why uncertainty can be ignored by public decision-makers, Arrow and Lind carefully delineate the limits of their argument (p. 373). Social risk must be considered when a collection of interdependent public decisions has a large influence on welfare directly attributable to the public sector. Further, social risk is even more likely to be important if the covariance between these decisions and national income generated in the private sector is also large and positive. Even assuming risk neutrality, Arrow and Fisher have shown that irreversible uncertain decisions should be discounted for risk when further information will be available in the future (see, also, Henry). The myriad of decisions with respect to energy research and development, exploration, leasing, taxation, import controls, power plant siting, pollution control, and efficiency standards now loom large in the public sector. The strong correlation between energy availability and income generated in the private sector was experienced during the oil embargo. An economic model which incorporates social risk aversion, interdependent decisions, and the opportunity to reduce uncertainty through information collection could be fruitfully applied to public-sector decisions with respect to resource allocation over time.

Several economists have made interesting beginnings at applying natural laws to economic systems (Daly; Georgescu-Roegen; and Kneese, Ayers, and d'Arge). Considerable conceptual difficulties are hindering the development of a new paradigm. Nevertheless, Daly and others argue that some sort of a steady state system relying largely on flow resources would both reduce many environmental and social problems and be viable over the long run. An invigorating, productive debate has not developed largely because economists have ignored or put down the challenge.

An Economic Model of Planning Ahead

Historically, new technologies and the exploitation of new resources or ecological relationships were initiated freely. Under this state of the law, many impacts--especially external effects resulting from changes--were discovered through experience. Bad experiences have become increasingly common as we use our resources more fully and as our technologies become more pervasive. Consequently, society increasingly constrains initiators through legislation requiring research and information dissemination with respect to all conceivable impacts of proposed changes. The following model provides a framework for describing this observed historical transition in our social institutions from a system of learning from experience to a system of planning ahead. The term "planning" has many connotations to economists. This paper is concerned with only information-gathering activities and, further, with only those undertaken for the purpose of reducing the likelihood of making mistakes today which affect future welfare. The development of more productive technologies is an aspect of planning ahead which is not considered due to space limitations. Some planning ahead has always occurred, but today we are experiencing a dramatic increase in the form of environmental impact assessment, technology forecasting, land-use planning, and applied research diversification. The model rationalizes or explains this transition; no prescriptions, however, stem from this approach.

The trade-off between welfare in time periods 1 and 2 under the conventional assumption of perfect information is represented by the frontier labeled PIF. Given imperfect information, society chooses between two institutional frameworks, learning from experience represented by the frontier labeled LEF or planning ahead represented by PAF. Welfare in time period 2 is uncertain under each strategy as indicated by the dotted lines bordering LEF and the broken lines bordering PAF which represent one standard deviation from the respective expected values. The solid frontiers shown are less than the expected values (less than midway between the standard deviation) because of risk discounting. The risk discounted frontiers of the two strategies intersect because planning ahead utilizes resources in time period 1 which do not contribute to welfare in time period 1 and because learning from experience has more uncertainty resulting in more risk discounting for time period 2. Historically, society has been on the LEF frontier because that frontier has had a tangency with a higher welfare social indifference curve (SIC) than the PAF frontier (not illustrated for clarity).

A comparative static view is attained by comparing subsequent choices. Figure 2 illustrates an initial situation in which society is indifferent between the two strategies. Relative to the learning from experience optimum at point A, less welfare in the present and more in the future is preferred at the planning ahead optimum at point B. The slope of the social indifference curve indicates society's time preference. It is interesting to note that the rate of interest--the slope of both the frontier and the SIC at the tangency--is greater at the PAF optimum than the LEF optimum indicating that after planning ahead both the perceived returns from and willingness to forego consumption in the present are greater. LEF' and PAF' represent frontiers for two subsequent time periods. New technology has apparently improved the lot of mankind since these curves are generally above and to the right of the previous set. The shift to the right, however, is greater than the shift up because the uncertainty of resources and technologies is greater than before. As drawn, society now definitely prefers to plan ahead due to its risk aversion.

Fortunately, the conditions leading to the transition between learning from experience to planning ahead can be stated more formally. Norgaard and Hall developed an analogous model to describe the conditions under which society would switch from a legal structure in which polluters have the right to pollute and must be compensated to prevent pollution to a legal structure in which pollutees have the right to a clean environment and must be compensated for their toleration of pollution. Using constant elasticity of transformation frontiers, we know from this earlier work that technological change over time that increases in uncertainty in the future time period results in an interesting phenomena. The intersection between the LEF and the PAF frontiers falls toward the W_1 axis such that the PAF frontier encompasses increasingly more of the LEF frontier. This occurs whether or not technology outraces resource scarcity. If society prefers to consume between the two periods in fixed proportions (W_1 and W_2 being perfect complements resulting in a constant rate of planned growth or decline), then eventually planning ahead will be preferred (Norgaard and Hall, pp. 255-256 and appendix).

Planning ahead will also eventually be preferred under less restrictive assumptions. V. Kerry Smith, in a related model of technological change, juxtaposed constant elasticity of substitution indifference curves with constant elasticity of transformation consumption possibility frontiers. Extending this approach, the results of Norgaard and Hall indicate that planning ahead will eventually be preferred as long as the elasticity of substitution between welfare in the two time periods is between 0 and 1 (pp. 257-258 and appendix). Within this range the social indifference curves neither cross or become asymptotic to the axes indicating that some positive level of welfare in each period is preferred and that, eventually, further increases in total welfare are not possible without increases in both periods. These characteristics appear to be consistent with our observed preference for a future existence.

In conclusion, though analysis is only in the formative stage, it appears that the model can be generalized. Intermediate strategies of more or less planning ahead could be considered rather than the two extreme cases analyzed. Given an elasticity of substitution less than one, we can expect incrementally more planning ahead to be preferred over time as the uncertainty of resources and technology with a growing population increases. This model rationalizes the observed transition toward planning ahead. No conclusions can be drawn, however, as to whether we are actually doing too much too soon or too little too late to coordinate resource use and environmental management over time.

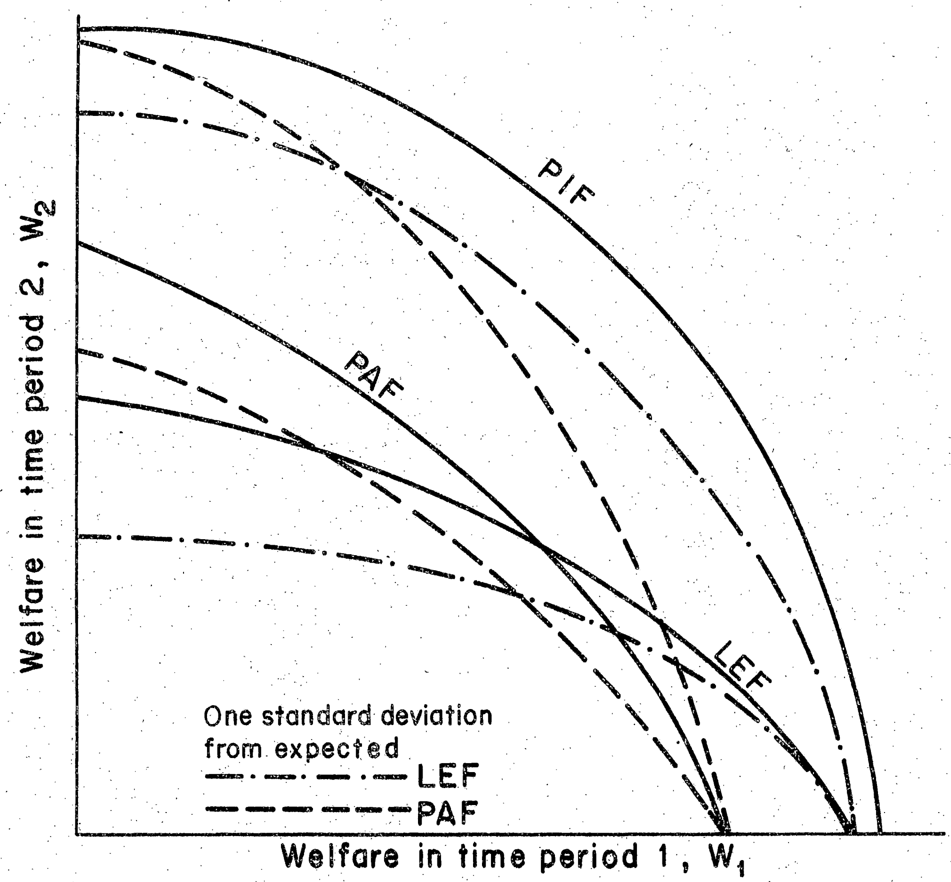

Figure I. Alternative Consumption Possibility Frontiers

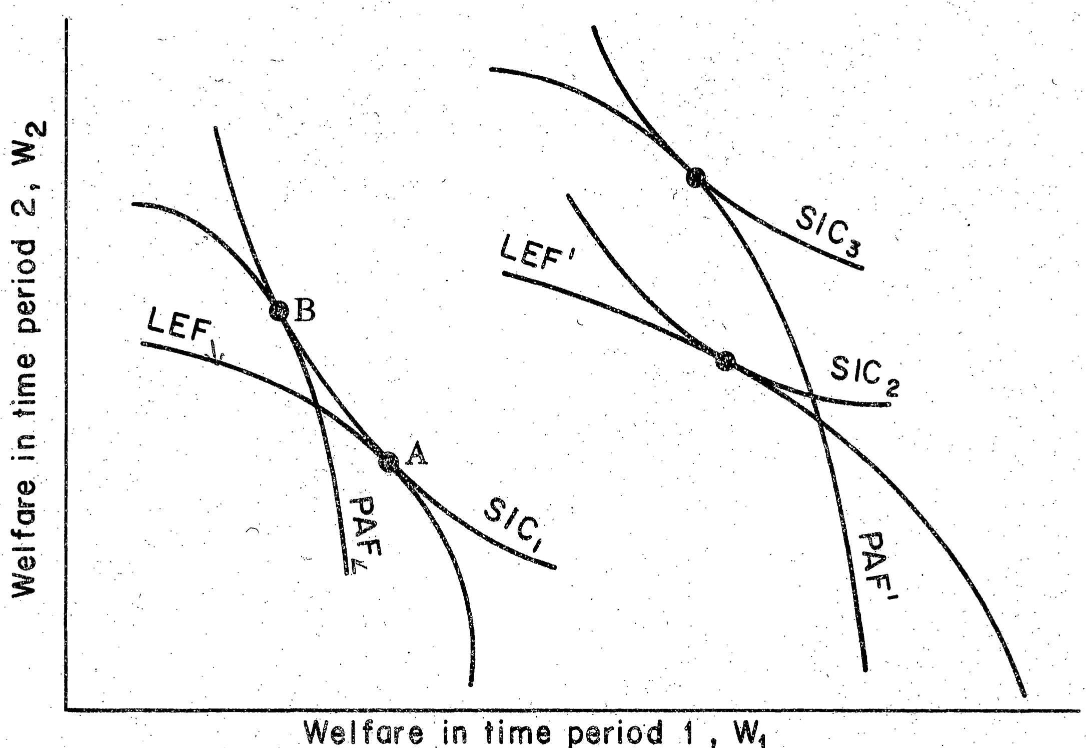

Figure 2. Technological Change More Than Offsetting Resource Sarcity

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