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The Measurement of Change in Natural Resource Economic Scarcity

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Introduction

NOTE: Part of this paper draws upon a larger collaborative study undertaken by Professor Chandler Morse and myself for Resources for the Future, Inc., and to be published in book form by this organization. I wish also to acknowledge helpful suggestions from other colleagues.

MANY economists and the general public believe that natural resources (hereafter resources) are scarce and becoming more so, and that this has economic significance. The belief is that resource scarcity inflicts diminishing returns, in some sense; and that these impair economic welfare and growth. The notions seem to be simple and straightforward. Indeed such views are usually expressed as factual statements requiring no proofs.

I am sure that the concepts are not simple and straightforward, and I do not know whether they are true. At the conceptual level, I find much ambiguity and some confusion as to the forms which natural resource scarcity take, and the nature of the diminishing returns which scarcity inflicts. Sorting out the concepts as best I have been able, I have uncovered a multiplicity of theoretical propositions. It appears to me, further, that these propositions are not factual ones, but hypotheses. I have learned, also, that, because of the implicit or explicit assumption that "facts" need no empirical proof, they have had none in the literature. And, finally, I have discovered that, because of the ambiguities and complexities in the simple view of natural resource scarcity and effect, empirical testing is rendered difficult, as much from uncertainty as to what should be tested as from how to test it.

PUBLIC OPINION

I first briefly discuss non-economist public opinion, in order to show that the scarcity doctrine is socially important. The literature is quite voluminous and it is weighted strongly in the belief that the natural resource scarcity problem is significant and urgent. Some of the expressions are of alarm, while others of them are merely of serious concern.

Samuel Ordway, prominent contemporary conservationist, believes that, within foreseeable time, increasing consumption of resources can produce scarcities serious enough to destroy our present culture.[1] The American Association of School Administrators, a department of the National Education Association, states that unless we in the United States use natural resources more prudently, we shall soon be on the road to lower living standards and national decline.[2] William Vogt believes that unless world populations are reduced, there will be drastic lowering of living standards, and that there is not time for reliance upon voluntary population adjustments.[3]

Recent years have seen a spurt of similar literature from outstanding physical scientists. Among others, Harrison Brown, Sir Charles Galton Darwin, Dr. Allen Gregg, Dr. A. J. Carlson, and Robert C. Cook have stated that natural resource scarcity is inconsistent with contemporary growth rates of living levels and population numbers. For example, geneticist Cook writes, "The world's growing population will force the use of marginal lands, which in general are extremely expensive to exploit. More and more human energy will have to be devoted to the basic problem of producing food, and the standard of living, instead of going up, will remain at the subsistence level in the areas where it now stands at that, while the wealthier areas will find their standards of living declining. Already the pressures of population in most parts of the world have compelled an unwise exploitation of the good lands."[4]

At the level of high government policy, the natural resources platforms of both political parties in this country, as well as a long list of state and federal statutes, are concerned with natural resource scarcity and its adverse economic effects. Governmental concern is not confined to peacetime domestic welfare alone. The State Department warns Foreign Service officers that the industrial and military power of the United States is due in part to its mineral resources; and "that unfortunately mineral resources are exhaustible, from which it follows that the faster a nation grows in industrial strength and military potency—a growth made possible largely through increased mineral output—the faster it liquidates the very basis of its power." Admiral Rickover, in response to a recent question as to

[1] Samuel H. Ordway, *Resources and the American Dream* (New York, 1953), Foreword.

[2] *Conservation Education in American Schools*, 29th Yearbook, American Association of School Administrators, department of the National Education Association, p. 11.

[3] William Vogt, *Road to Survival* (New York, 1948), p. 265.

[4] Robert C. Cook, *Human Fertility, The Modern Dilemma* (London, 1951), p. 296.

whether he was concerned about using up our natural resources and our natural sources of power, answered, "Yes, I am. We are using our energy sources at a very great rate, not only fuels but also minerals . . . If we keep on using minerals . . . and fuels . . . at the rate we do, there is no question that within a generation or two there will be a shortage. It is my firm conviction that that nation which controls energy sources will become the dominant nation in the world."[5]

These public views of natural resource scarcity and diminishing returns do not derive from examination of U.S. economic history. Diminishing returns in the simple meaning of declining output per unit labor input has not occurred. Rather, the record is of increasing returns averaging about 1½ to 2 per cent per year compounded, since 1870 at least. Perhaps the general public believes that diminishing returns from the natural resource scarcity phenomenon apply to the extractive sector alone, but the tables of output per unit labor input in extraction, presented in this volume by my colleagues, Potter and Christy, also show a trend of increasing average returns of 1½ to 2 per cent per year. And if output is measured in a net manner, this would produce similar results. Still another commonsense type of measure might go this way: the extractive sector is hypothesized to experience diminishing returns and increasing costs; and, therefore, the size of the nation's bill for extractive goods will increase relative to GNP, and the fraction of the nation's labor force required for the extractive sector will rise. But the facts do not bear out such theorizing. In modern U.S. economic history, the percentage of the U.S. labor force engaged in extraction declines steadily from about 56 per cent in 1880 to about 14 per cent in 1955.

I think lay opinions on natural resource scarcity and diminishing returns therefrom derive substantially from the teachings and writings of professional economists.[6] "The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood."[7]

[5] United States Government, Department of State, Division of Foreign Reporting Services, November 1945. Economic Manual (*A Guide for Reporting Officers in the Foreign Service of the United States of America*), Dept. of State publication 2556, Chapter 10. Admiral Rickover in an interview on "See It Now" TV program manuscript, November 18, 1956, Columbia Broadcasting System, New York. Cf. H. J. Barnett, "The Changing Relation of Natural Resources to National Security," *Economic Geography*, July 1958 (also available as a reprint from Resources for the Future, Inc., Washington, D.C.).

[6] Concerning origins of the scarcity doctrine see H. J. Barnett, "Malthusianism and Conservation." Available as a preprint from Resources for the Future, Inc., Washington, D.C.

[7] J. M. Keynes, *The General Theory of Employment* (London, 1936), p. 383.

ECONOMISTS

It is easier to come to grips with economists' views on natural resource scarcity and its effects than with lay opinions. There are ambiguity and confusion here also but they stem from neglect, brevity of statement, omission, or error, rather than from basic incapacity of the discipline or its practitioners to form the propositions adequately.

Economists seem to present two propositions concerning natural resource scarcity and effect. First is a classical static model in which natural resource scarcity is assumed to be present and to inflict diminishing marginal returns to labor and capital. This concept is then mentally dynamized, and the scarcity force is viewed as occurring among other forces which work in the contrary direction. The hypothesis does not, therefore, require that the historical course of returns be diminishing, since favorable forces can more than offset the adverse natural resource influence. But in such conceptions natural resource scarcity is present and does, *ceteris paribus*, inflict diminishing marginal returns to labor and capital. Thus, for example, Schultz refers to land, the nonreproducible factor, always acting as a drag on economic growth because of the element of diminishing returns.[8] But he sets this in a discussion of favorable influences to returns, such as improvement of the quality of people as productive agents and improvement of the level of productive arts. Bach presents a similar formulation, and other similar presentations occur in Mill and Marshall.

The second form of the scarcity doctrine starts with the proposition just described and embodies it in a prognostication and policy judgment. It suggests that the natural resource scarcity force has a tendency to become stronger with the passage of time, and that in the contest between natural resource scarcity on the one hand, and favorable dynamic influence on the other, the former threatens to become dominant or at least relatively more important. For example, Spengler recently expressed the opinion that "our demands on the resources which cannot be augmented by technological progress will soon result in large-scale scarcities and the prohibitive prices and costs which accompany scarcities."[9] Villard has written on related lines, and Ise, Pigou, and Mitchell expressed concern over resource depletion in such a way that I infer that they project increasingly adverse influence from natural resource scarcity.

[8] *The Economic Test in Latin America* (Ithaca: August 1956), pp. 19–20. Also Theodore W. Schultz, "Latin-American Economic Policy Lessons," *American Economic Review*, XLVI 2 (May 1956), p. 431.

[9] Joseph J. Spengler, "Population Threatens Prosperity," *Harvard Business Review*, (January–February 1956), p. 88.

My interest here is to test empirically the first of the above economic doctrines of natural resource scarcity and impulse to diminishing returns. Clearly, the appropriate way to make a start at improved understanding of the effects of this scarcity, and operational testing of the doctrine, is to formulate explicitly the static models which underlie the doctrines. In this attempt my first task is to distinguish the several different natural resource scarcity conceptions, define the diminishing returns which flow therefrom for a simplified, essentially static situation, and relate these to economic welfare and growth.[10] I then puzzle over how to test these empirically in a dynamic economy. Finally, I suggest a device for measuring natural resource scarcity and its economic effects in a dynamic economy, and in a preliminary and tentative way apply it to U.S. history since 1870.

Simple Static Scarcity Models

Let there be a static, linear, and homogeneous social production function of the type

$$O = f(R, L, C),$$

where O=units of output, R=units of natural resources, L=units of labor, and C=units of capital. Each of the three inputs and the output is a homogeneous, physical variable. Labor and capital are assumed available in constant-proportion doses. The function is assumed to be what Allen has termed a "more general normal type," specifically

$$O = \sqrt{2H(L+C)R - A(L+C)^2 - B(R)^2},$$

where A, B, and H are positive constants such that H^2 is greater than AB.[11]

The expansion path for *resource plenitude* (=no scarcity), and no institutional basis for limiting resource use or charging for use, is OG in Chart 1 (in this chart $H=2$; $A=B=1$).

We can now immediately define the first case of natural resource scarcity—*Malthusian-type scarcity*—by specifying that total resource availability is r_1. In this case, the expansion path is OEH. Given sociotechnical conditions, we find that:

1. *Natural resource scarcity* is defined as a small limit of R availability relative to $L+C$, small being further defined as an amount less than r_1/a_1.

[10] For elaboration on these models, see C. Morse and H. J. Barnett, "A Theoretical Analysis of Natural Scarcity and Economic Growth" (published in 1960 in an SSRC-RFF Conference volume, by The Johns Hopkins Press, Baltimore).

[11] R. G. D. Allen, *Mathematical Analysis For Economists* (London, 1947), pp. 288, 322.

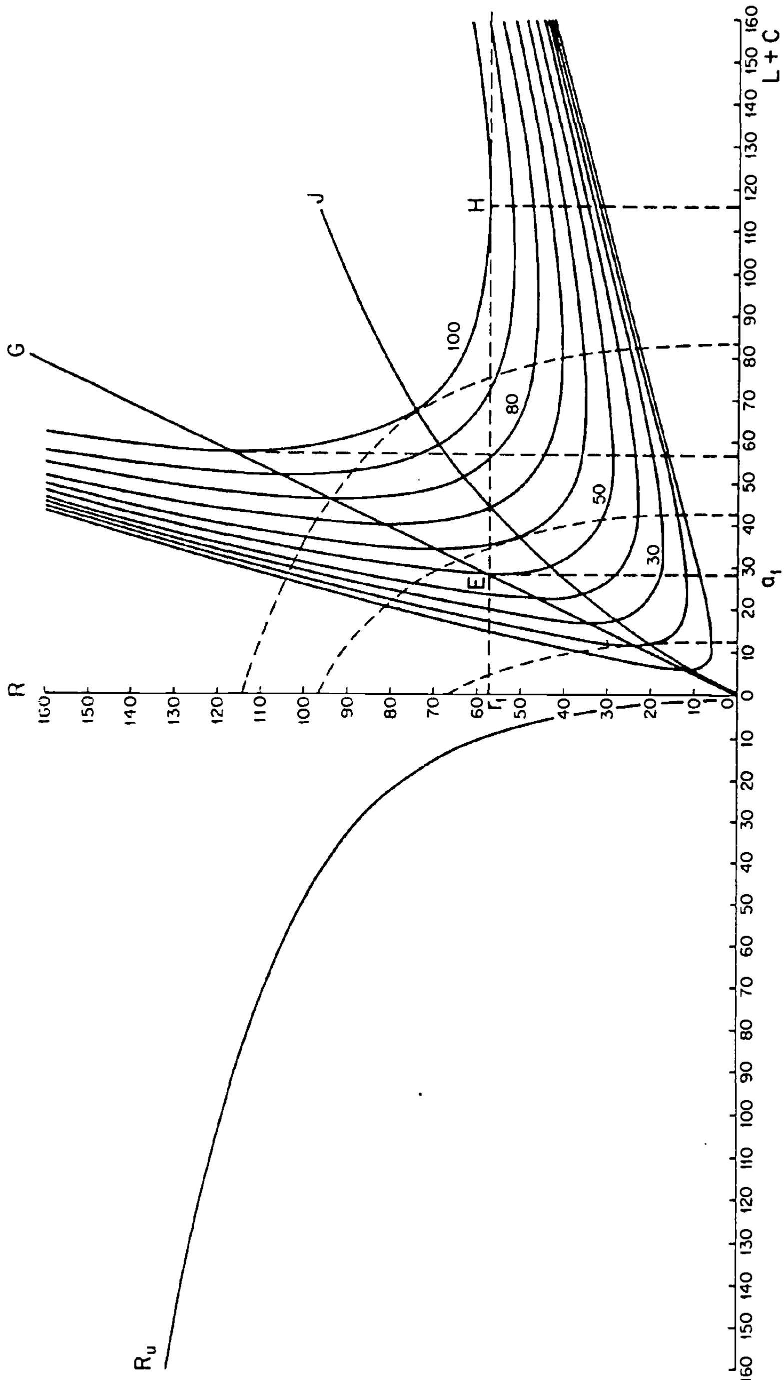


CHART 1

2. *Diminishing returns from natural resource scarcity* is defined as the decline, which occurs from E onward, in marginal productivity of $L+C$, due to the small limits of R availability.

3. *Impairment of economic welfare* from natural resource scarcity is defined as the decline in output per capita, when this begins to occur at E.

4. If we stipulate that economic growth is increase in total output, then *impairment of economic growth* from natural resource scarcity is limitation of output at a level not exceeding 100. Let there be a conventional or physical "subsistence" level per unit $L+C$ equal to kO, where k is greater than $100 \div L+C$, and let $L+C$ always increase to the limit of subsistence. Then impairment of economic growth from natural resource scarcity is the stabilization of output at some point on the path EH short of H. The exact point depends on the value of k. Such cessation of growth contrasts with endless increase in output along OEG, in the resource plenitude case.

In the second case of natural resource scarcity—*Ricardian scarcity*—there is no limit on total resources available, but their economic qualities decline steadily as a function of volume employed. This relaxes the earlier assumption of constant quality. To represent this case, the original social production function is modified as follows:

$$O = f_1(R, L, C) - f_2(R_u).$$

R_u represents resources of steadily declining economic quality, but is equal to R in quantitative physical units (e.g., acres). If we assume the social production function is the same one, except for the retardation term, there is a special case in which we may use the same isoquant diagram, and handle the absorption of labor and capital required to upgrade R_u to R economic quality on a bent axis. The original equation,

$$O = \sqrt{2H(L+C)R - A(L+C)^2 - B(R)^2},$$

becomes in this case

$$O = \sqrt{2H[(L+C) - e^{R_u m}]R_u - A[(L+C) - e^{R_u m}]^2 - B(R_u)^2},$$

where m is any positive constant (in Chart 1, $m = .03912$). The new expansion path, derived by employing natural resources to the point where marginal productivity of $(L+C)$ is maximized (which is the point where marginal productivity of resources equals zero), is OJ. We find that:

1. *Natural resource scarcity* is the decline in quality of resources, irrespective of unlimited total quantity.

2. *Diminishing returns from natural resource scarcity* is the immediate and steady decline in marginal productivity of $(L+C)$, due to steady quality decline of incremental resources.

3. *Impairment of economic welfare* from natural resource scarcity is the decline in output per capita, along OJ.

4. Again stipulating that economic growth is increase in total output, that there is a "subsistence" level per unit $L+C$ of kO, and that $L+C$ increases to this limit, then *impairment of economic growth* from natural resource scarcity is stabilization of output someplace along OJ, where $O/(L+C)=k$, rather than endless increase along OG.

The scarcity effect is now characterized for the case of small limits of total resource availability relative to population and sociotechnical conditions, and for qualitative decline in resources as a function of scale of employment of such resources.

The third case of scarcity, a depletion conception, cannot be shown in the chart without relaxing the assumption of a static model, since resource extinction is a function of time, among other things. But Chart 1 can help us visualize the economic effects of depletion. We must try to imagine successive Chart 1's in time. Then depletion eats away the resource axis from the bottom. If resource availability is that of the first case, the expansion path, OG, remains unchanged because there are always more constant quality resources than are needed, and there is neither scarcity nor effect. If resource availability is that of the Malthusian case, then the horizontal portion of the expansion path, EH, falls to successively lower levels, corresponding to the successive depletions of resources. If resource availability is that of the Ricardian case, OJ, then it is the bent axis which is depleted (gnawed away from the bottom—best resource first), and a flatter and lower expansion path results. It must be emphasized that the depletion case does not exert an economic scarcity impulse or produce a scarcity effect if grafted on to our resource plenitude situation. It is only if a Malthusian or Ricardian scarcity exists, or can be brought into being by depletion, that depletion then becomes economically operative. Then:

1. *Natural resource scarcity* is the extinction of resources where the quantity availability was already limited and small; or the extinction of high quality resources, where quality was already declining; or both.

2. *Diminishing returns from resource scarcity* and *impairment of economic welfare* are as given in the first two cases, but with aggravated severity.

3. *Impairment of economic growth* is eventual decline in total output, a contrast with the other scarcity cases in which growth merely ceased.

I do not develop here various other cases which are combinations of Malthusian, Ricardian, and depletion scarcities. For example, there could be a large but limited volume of high quality resources, and then endless quantities of declining quality ones. Resource qualities could exist in quantity plateaus, and the decline of quality as a function of quantity be in discrete, rather than continuous, steps. Depletion affects Malthusian and Ricardian scarcities differently. Quality depletion is possible, in addition to quantity depletion, and so forth. I also do not attend to another interesting set of scarcity propositions. It is possible to conceive of the variety of natural resources as a system of interdependent variables in "ecological balance." Then scarcity of quantity limits or of qualities can be conceived from the fact that man's resource needs, although small relative to total resources, have a different composition from the natural ecological balance, and scarcity is experienced from quantity or quality limits of a single resource. Further, aggregate natural resource availability can experience manifold reduction from depletion of individual key resources.

Relaxation of Conditions

If all of the assumed conditions are present, then it is easy to detect scarcity effects in the ways described above. What happens if we relax conditions?

Assume, for example, that the static social production function is characterized by increasing returns to scale. Then the appearance of diminishing marginal returns to labor and capital due to (say) Ricardian scarcity can be indefinitely delayed, depending on the strengths of the opposing forces. But the scarcity force would still be operative, and effects would still be experienced. Thus, let us assume we could compute an expansion path of output as a function of labor plus capital for the conditions of increasing returns to scale and resource plenitude and, holding other things constant, compare this with the actual (say) Ricardian scarcity case. We would find the latter to be lower, even though perhaps accelerating. The scarcity effect is represented by the difference between the two paths.

Let us admit, now, great improvement in manufacturing technology. Then again it would be true that with (say) Ricardian resource availability, an expansion path might show output as a function of labor and capital to be accelerating. But nevertheless this path would fall below the comparable expansion path under conditions of resource plenitude. There would thus be scarcity effect which, in theory, is measured by the difference between the paths.

In general, the same continues to be true no matter what other conditions are relaxed, no matter how dynamic the economy, so long as (say) Ricardian scarcity is to be a continuous, dynamic force.

This poses our next questions.

WHAT DOES RESOURCE SCARCITY MEAN? IS IT FACT OR HYPOTHESIS?

Cosmologists hold different views on whether the universe is limited. For our purposes here, however, let us take it as fact that the natural resources available to man are physically limited. From this, however, it does not follow that Malthusian *economic* scarcity of natural resources must exist. Economic scarcity, as distinguished from physical, requires the additional assumption that the limits of resource availability be small relative to demands placed on them. The size of demands, in turn, depends upon the size of population and capital stock and the sociotechnical parameters. But if the presence or absence or Malthusian economic scarcity depends upon these economic determinants of demand, then it is a relative matter which cannot be deduced from the fact that the physical environment has bounds. Adam and Eve lived in a resource-limited, but not a resource-scarce, world. I conclude, then, that Malthusian economic scarcity of natural resources must be viewed as a hypothesis, and not accepted as fact.

Ricardian economic scarcity as defined, requires as one assumption —taken here as a fact—that the world's natural resources be viewed as heterogeneous in physical properties. However, it also requires that society be able to array the physically varying natural resources in a declining order of *economic* qualities, and that the order remain invariant through time; that it use them in this order; and that the decline in economic quality not be permanently interrupted by access to indefinitely great expanses of unused resources of unchanging marginal economic quality. To elaborate:

1. Ordering according to economic quality clearly requires relating known and stable physical properties of resources to equally known and stable sociotechnical parameters in such a way as to arrive at a *unique and permanent economic ordering*. Yet historically, for example, copper and tin came into use early, iron later, and the light metals last. Consider, similarly, the order of use of energy commodities.[12] If we view both knowledge (ignorance) and production

[12] See, for example, H. J. Barnett, *Energy Uses and Supplies* (Washington, 1950) Charts A and E and Table 18.

parameter stability (instability) with hindsight, it would seem that success in translating physical properties into economic qualities should not be viewed as fact, but hypothesis.

2. Even if translation of physical properties into economic qualities were always successful, does society necessarily use resources in this order? For a number of reasons, the answer would seem to be, "not always." Impediments are international trade barriers, government reservation of resources, distances from population centers, recognized by Ricardo as an influence distinct from intrinsic physical properties, and institutional obstacles (such as the hunting preserves of former European nobility), etc. On the other hand, there is powerful economic motivation to use resources in order of physical properties, where economic quality can be determined to be a function of physical properties.

3. Assume now use in declining order of economic quality. Is the decline necessarily an economic continuum? It is relatively so for certain things, particularly if these are defined narrowly, like northeastern cherry wood or high-grade manganese in Virginia. But it is not for others, such as sea water magnesium, taconite, aluminium clays, low-grade manganese ores, lateritic nickel, uranium in granite, solar energy, and so forth.

All three propositions are hypotheses rather than facts.

Finally, is depletion of natural resources an economic fact? In a sense it is, although, because of physical laws of conservation of matter-energy, it is not an ultimate physical fact. But the notion of depletion as an economic scarcity force must be subjoined to Malthusian or Ricardian economic scarcity, which I have just argued should be viewed not as facts but as hypotheses. And, so, even if we accept depletion as an economic fact, depletion as an economic scarcity force which produces some kind of economic scarcity effect must be viewed as a hypothesis.

The question to answer empirically is not the size of the scarcity effect. It is, rather, whether or not there has been scarcity force in the first instance.

SUMMARY AND TENTATIVE CONCLUSIONS

Our scarcity models are invalid as descriptions of reality. Since the logic is correct, though briefly stated, the invalidity of the models must be found in one or more of the premises or assumptions. Thus the notion of a social production function characterized by a static law of variable proportions, as manifest in the general shape of the output isoquants in Chart 1, could be at fault. The assumption that such function is characterized by constant returns, in addition, is today being sharply challenged. The assumption of invariant sociotechnical parameters is erroneous.[13] Finally—and this is what concerns me here—it is possible that resources are not economically scarce, after all.

The diminishing returns scarcity effects in the models derive from *all* the assumed conditions, not just from resource scarcity. The failure of historical evidence to show diminishing returns does not disprove such economic scarcity. Scarcity could be present while returns were increasing if, for example, improved sociotechnical parameters increased output more rapidly than resource scarcity retarded it, the social production function were characterized by increasing returns to scale, or capital were increasing at a rate sufficient to more than offset such scarcity.

In liberating the embarrassing question of whether natural resource economic scarcity exists, how empirically to prove that it does or does not, and how to measure it, we must somehow disentangle the single condition of resource economic availability from its milieu of widespread parametric change, possibly increasing returns to social scale, and other forces.

NATURAL RESOURCE SCARCITY IN INCREASING RETURNS ECONOMIES

For progressing (dynamic increasing returns) economies our problem is to devise a method for data observation in which other things are held constant, in order to learn from examination of returns whether resource availability in an economic sense, as defined in the models above, is economically poorer in period t_n than in t_o. Elsewhere I have considered, and found possibly useful, but not very promising, the prospect of learning this for the economy as a whole from examination of physical stocks or inventories of resources. The one way I deal with the question here is as follows.

I first assume an identifiable extractive sector (E) to which natural resources are a significant productive input. There is an identifiable N sector, the remainder of the economy, to which natural resources are not a significant productive input. I characterize agriculture, mining, forestry, and fishing as extractive, and all other economic activity as nonextractive. The trend of labor productivity performance in the two sectors would, *ceteris paribus*, tend to be the same, in a mobile economy such as that of the United States. But natural resource economic scarcity if present would produce a tendency toward

[13] The growth of what Earl Stevenson has felicitously termed "molecular engineering" is particularly responsible. For insight into the magnitude and significance of the chemical industry advances, see H. J. Barnett and F. T. Moore, "Long Range Growth of Chemical Industries," *Chemical and Engineering News* (April 1958), pp. 78–84, 142.

diminishing returns to labor in E but not in N, and this tendency would operate with greater effect in E than in $N+E$.

I now assume that all other dynamic, scale, and institutional forces in the economy are neutral. This means, for example, that changes in capital-output ratios and changes in purchased materials-output ratios impinge with equal force in both E and N, and that the effects of demand changes upon the E and N sectors are neutral too. The result is that except for resource scarcity, *changes* in gross productivity of labor between t_o and t_n would be identical, that is:

$$\left(\frac{E_L}{(N+E)_L}\right)_{t_n} - \left(\frac{E_L}{(N+E)_L}\right)_{t_o} = \Delta = \text{zero},$$

where E_L stands for labor input per unit E output, and so forth. But if resource economic scarcity develops or increases between t_o and t_n in the E sector, then the improvement in gross labor productivity in the economy as a whole $(N+E)$ will be greater than in the E sector. This will force increases in the ratios $E_L/(E+N)_L$ as time progresses, and make the successive Δ's positive figures.

I now go further and assume that there is such mobility of factors—labor, capital, and purchased materials—between E and N that their rates of remuneration per unit input are either equal, or if not equal, maintain a constant ratio through time. I also assume that prices of products are competitively set at the sum of labor, capital, and purchased material costs. These tentative assumptions together with the productivity hypothesis above produce the result that extractive goods prices will rise relative to all $(N+E)$ prices through time, if natural resource economic scarcity occurs and increases through time.

Tentatively, therefore, I expect that natural-resource economic scarcity if present will produce (1) an increasing trend of labor input per unit of output in extractive sectors relative to the whole economy, and (2) an increasing trend of unit prices of extractive goods relative to all goods.

This will be true, given the assumptions, for any of the economic scarcity forms defined in the Malthusian, Ricardian, and depletion models, above. All the models yield adverse real cost effects in any sector (E) in which resource scarcity exerts a diminishing returns force relative to any sector (N) which may be taken as a stand-in for economic activity not subject to this influence. My task will be to measure the trends of relative productivity and relative price, assuming that they are indicators of relative real cost changes.

The results must be viewed as only *tentative* indicators of the presence or absence of scarcity. This is because of the strenuous assumptions that other parametric change would be identical as between the two sectors; that demand changes have neutral effects; that scale changes would not affect the sectors differently, except with respect to natural resource availability; that ratios of capital/output and purchased materials/output in E to those in $(N+E)$ did not change significantly between t_o and t_n; etc.[14]

Development of resource scarcity in the progressing economy can only be detected if other influences on cost are held equal. The above proposal holds other things equal in a somewhat unorthodox way. The proposal does *not* hold other things constant in the conventional way, which would compare the ratios of t_o and t_n by utilizing the production function of period t_o. The device of focussing on change in ratios of E productivity and price to N productivity and price, in effect, holds change other than resource availability between t_o and t_n to be equal, or in the proportions of t_o in the two sectors. Consequently changes in resource availability include not only possible recourse to lower qualities, depletion, and other adverse resource circumstances, but also possible favorable ones, as, for instance, discovery of new resources and new ways to use old ones. Our interest is resource availability in the dynamic economy. To hold other things constant between t_o and t_n in the conditions of t_o would test the rationality of the t_o economy, not the differential resource economic availability in t_o as compared with t_n.

Quantitative Test

In this quantitative test, unless otherwise stated, I use data from the paper prepared by my colleagues, Potter and Christy, in this volume, and from the manuscript, *U.S. Natural Resource Statistics, 1870–1956 —Measures of Price, Output, Foreign Trade, Consumption, and Productivity*, of their study for Resources for the Future, Inc. I refrain from repeated cautions concerning index-number problems, alternative-weight indexes, and possible errors in early data. I am fully aware that these warnings apply with even greater force than usual to

[14] Jaroslav Vanek has suggested that I should not feel so uncomfortable about my heroic assumption of "neutrality," as between the E and N sectors, of all influences other than resource availability. He observes my approach is essentially to view natural resource scarcity as having economic meaning only in a dynamic, general equilibrium setting, which includes resource endowments, technology, tastes, etc. Then movements of relative prices (and, possibly with some reservations, relative labor productivities) are value indexes reflecting relative scarcities of products from the two sectors, a significant and operational economic conception. In this conception, conditions (1) and (2), above, become definitions in themselves. If the problem is viewed in this way, he points out, the assumption of neutrality, as between E and N, of influences other than resource endowment is not needed. Vanek is right. Putting the question this way tends to limit further inquiry into the *reasons* for the relative price and productivity movements, however; and this is why I have chosen the present, more complex formulation.

extremely long-term, highly aggregated data, taken from an uncompleted study. My presentation here is a preliminary effort to test the scarcity hypothesis. Thus when I do not seek explanation of the movements of aggregates in individual commodity series, this does not imply lack of interest or intent. My test is confined to the 1954 weighted extractive indexes; the Potter-Christy index constructions based on 1929 and 1902 weights, as well as the comparisons with other weight indexes, were still being computed at the time this paper was prepared. In all respects, therefore, the present test should be viewed as trial run, the major purposes of which are reconnaissance and exploration.

RELATIVE PRICES OF EXTRACTIVE GOODS

Between 1870 and 1956, there was approximately a 10 per cent increase in unit prices of extractive goods (agriculture, minerals, timber, fish) relative to the BLS wholesale price index. This is tentative evidence in support of the resource scarcity hypothesis. But the relative price change is small in several respects. It is small relative to the length of period, the size of short-term fluctuations, the possible deficiencies in validity of the data, and my impression of variability among group prices indexes from causes other than resource scarcity.

During the eighty-six year period, for example, there were almost twenty short-term, plus or minus movements in relative extractive prices of equal or greater magnitude. These short-term changes reflect primarily cyclical, weather, and war influences, unrelated to the long-run scarcity hypothesis. By indicating that if either terminal date is shifted, the size of relative price change could change substantially, they weaken our ability to test the scarcity hypothesis and are adverse to it. A long-term change no greater than numerous short-term ones raises doubt about the social significance of the hypothesized phenomenon.

In addition to concern over terminal dates, there are two other reasons for breaking the long span into subperiods. One is that pre-1900 data are poorer than later data. The other is that the scarcity hypothesis in general contemplates that resource availability becomes increasingly adverse as a nation grows; this is particularly relevant for our long period. See, for example, Boulding's paper in this volume, where he states,

> ". . . in the United States . . . at least since about 1890 the 'land' factor has certainly expanded much less than the labor and capital factors. The assumption of equal proportional increases of factors is not perhaps wholly inapplicable before 1890, but this is a rare type of episode in

human history: for the most part labor and capital expand against a much less expansible land and resources barrier."[15]

We therefore reconstruct the relative extractive price data in subperiods:

	Percentage change from beginning date
1870–1900	−13
1900–29	+31
1929–56	−2
1900–56	+25
1870–1956	+12

The 1900–56 relative price change helps the hypothesis; and the noncontinuance or reversal of the 1900–29 increase during the 1929–56 period hurts it.

Finally, the course of 1954 weighted relative extractive prices 1870 to 1956 is presented in Chart 2. As I interpret these data I find an absence of long-term trend until World War I, a higher level, but again without trend in the 1920's, sharp declines during the depression 1930's, sharp increases during World War II, and a steady, gradual decline since the war. The only long-term movement that looks at first as if it might support the scarcity hypothesis is a steady, gradual up-drift from 1905 to 1945. But 1945 is clearly an undesirable final terminus for observing long-term "normal" movements.

We now turn to the major components of the extractive index where it is valuable to look at the components separately. Signs of scarcity or plenty will be clearer in them than in the alloyed, heterogeneous extractive total.

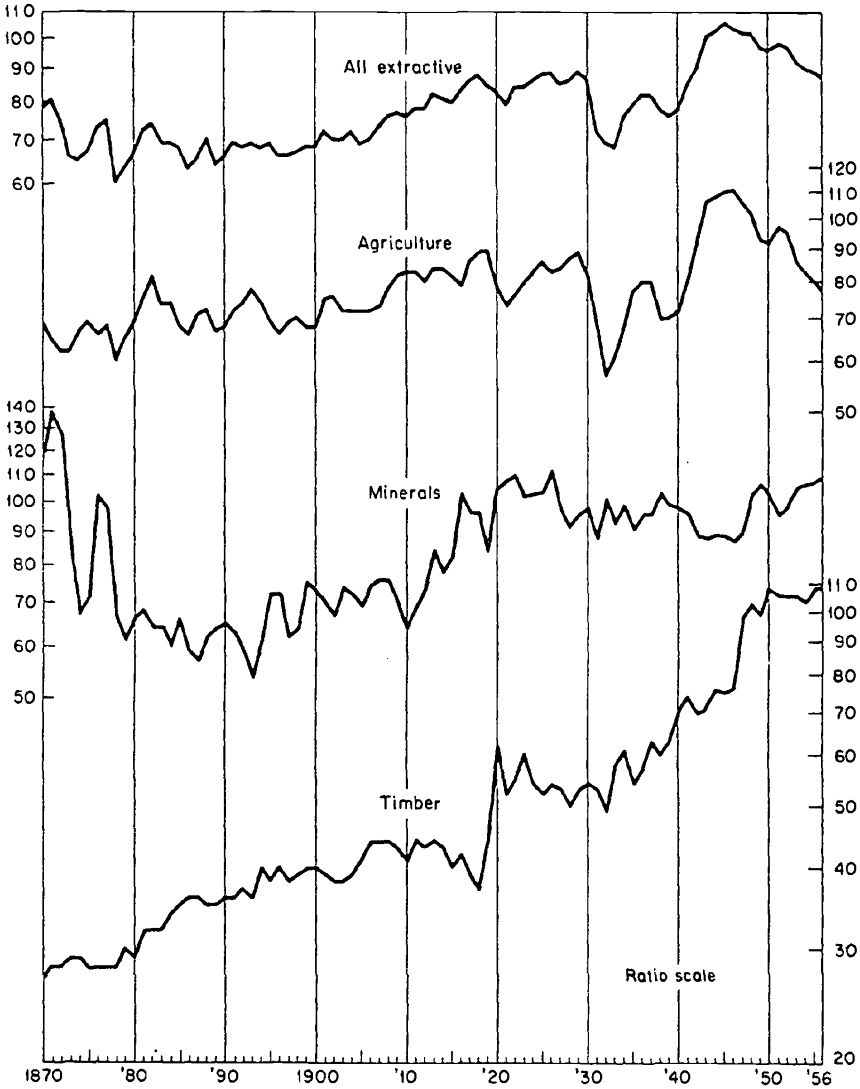
In 1870, almost 90 per cent of the total value of extractive output was agricultural. Since that time, the importance of agriculture in the extractive total has declined steadily and substantially, but today, agriculture still acounts for approximately 60 per cent. The figures are virtually the same if value added is used instead of total value of output. Agriculture, therefore, dominates the extractive index.

Over the 1870–1956 period, relative agriculture price also increased about 10 per cent, composed of no change, 1870–1900; a 30 per cent increase, 1900–29; and a 13 per cent decrease, 1929–56. All of agriculture's major relative price movements, from our long-term viewpoint, are so similar to those of the extractive total that it is not

[15] I think it was the Census Bureau which, on the basis of an arbitrary population density benchmark, originated the statement that the frontier disappeared about 1890. Actually, more original land entries took place in the 1900–10 decade, due to the Homestead Acts, than in any other decade in history; and the entries for 1910–20 were almost as large.

CHART 2

Extractive Product Prices (1954 weights) Relative to BLS Wholesale Price Index (1947–49 = 100)



Source: Appendix Table.

worthwhile to comment in detail here. Repeating the conclusions for all extraction, there is a relative price increase which could be the effect of scarcity, but it is very small, and its time sequence is disturbing to the hypothesis.

The next most important extractive industry is minerals—about 5 per cent of value of output in 1870 and 30 per cent in 1954. The value added percentages are similar. The change of relative mineral prices, 1870–1956, is dull for our scarcity hypothesis—a 5 to 10 per cent decline.

The picture becomes more interesting if we ignore the first thirty years when minerals output was economically insignificant and data are poor. We find that relative mineral prices increased by about 50 per cent between 1900 and the present. This is more promising for the scarcity hypothesis, particularly for the Ricardian and depletion forms of it.

The long-term mineral series shown in Chart 2 may be characterized as having two subperiods. There is a level course which runs from before 1900 to the first World War; and there is another level trend, about half-again higher, following that War to the present. The absence of more steady rise is strongly disconcerting for the scarcity hypothesis. The abrupt rise would appear, initially at any rate, as likely to reflect differential parametric change—industrial organization and market structure changes, for example—as diminished economic availability of resources. I therefore judge that, while interesting, the case is less promising than it at first appeared, and reach the conclusion that further investigation is needed.

The final component I consider is timber products—about 6 per cent of extractive output in 1870, and 8 to 9 per cent in 1909 and 1954. This category is interesting enough to show the data at approximately ten-year intervals, for the timber products total, and for its two major components, lumber and pulpwood. The data appear in Table 1.

TABLE 1

Timber Product Prices (1954 Weights) Relative to BLS Wholesale Price Index (1947–49 = 100)

	All	Lumber	Pulpwood
1870	27	22	
1879	30	24	
1889	35	28	
1899	40	32	94[a]
1909	43	38	76
1919	44	42	60
1929	53	50	65
1939	63	62	67
1949	99	99	98
1955	109	109[b]	102

[a] 1900.
[b] 1953.

Source: Potter and Christy, *op. cit.*

Relative prices of all timber products quadrupled over the eighty-five year span. And, moreover, they increased steadily. There is an increase in every interval of roughly a decade shown in the table. This is very promising evidence in support of the scarcity hypothesis. There is further support in the fact that present output levels are no greater than at the turn of the century (peak output was reached a bit later, in 1907), while present relative prices are almost treble those of 1900. It is interesting that lumbering, which was of major influence in inciting the original conservation movement, yields the only striking preliminary evidence of scarcity effect. If the price evidence is evidence of resource scarcity, then Gifford Pinchot was correct in his forecast of price increases, although not in his forecast of disastrous general economic consequences:

"For example, it is certain that the rate of consumption of timber will increase enormously in the future, as it has in the past, so long as supplies remain to draw upon. Exact knowledge of many other factors is needed before closely accurate results can be obtained. The figures cited are, however, sufficiently reliable to make it certain that the United States has already crossed the verge of a timber famine so severe that its blighting effects will be felt in every household in the land. The rise in the price of lumber which marked the opening of the present century is the beginning of a vastly greater and more rapid rise which is to come. We must necessarily begin to suffer from the scarcity of timber long before our supplies are completely exhausted.

"It is well to remember that there is no foreign source from which we can draw cheap and abundant supplies of timber to meet a demand per capita so large as to be without parallel in the world, and that the suffering which will result from the progressive failure of our timber has been but faintly foreshadowed by temporary scarcities of coal.

"What will happen when the forests fail? In the first place, the business of lumbering will disappear. It is now the fourth greatest industry in the United States. All forms of building industries will suffer with it, and the occupants of houses, offices, and stores must pay the added cost. Mining will become vastly more expensive; and with the rise in the cost of mining there must follow a corresponding rise in the price of coal, iron, and other minerals. The railways, which have as yet failed entirely to develop a satisfactory substitute for the wooden tie (and must, in the opinion of their best engineers, continue to fail), will be profoundly affected, and the cost of transportation will suffer a corresponding increase. Water power for lighting, manufacturing, and transportation, and

> the movement of freight and passengers by inland waterways, will be affected still more directly than the steam railways. The cultivation of the soil, with or without irrigation, will be hampered by the increased cost of agricultural tools, fencing, and the wood needed for other purposes about the farm."[16]

The separate lumber and pulpwood columns present interesting additional information. Until World War II, the relative price rise in the total series was entirely due to the lumber component. Woodpulp relative prices were approximately level from 1903 to 1939, except for some violent fluctuations, which canceled out, associated with World War I. And they have been without trend since 1940, as well, but at a level 50 per cent above the former one.

RELATIVE LABOR PRODUCTIVITY

The Potter-Christy paper for this volume makes its major contribution in the measurement of productivity movements. This permits brevity here as to whether movements of labor productivity in extractive industry, relative to labor productivity in the whole economy, indicate resource economic scarcity:

1. Labor productivity in the extractive sector has, since 1880, increased faster than real GNP per unit of labor input. The trend of relative labor productivity was level until the beginning of World War II. Since then, it has increased by half. Both pieces of evidence are, tentatively, adverse to the resource-scarcity hypothesis.

2. The relative labor productivity series of agriculture tells the same story.

3. Labor productivity in mining relative to labor productivity in the economy as a whole has trended upward since 1880. The rate of improvement in the relative series has increased significantly since the close of World War I. The relative series (1947–49=100) show a 20–25 per cent improvement, in the first half of the seventy-five year period, and a 70–80 per cent improvement in the second half. This evidence is, tentatively, in severe opposition to the scarcity hypothesis.

4. The labor productivity record in timber, relative to that in the economy as a whole, tentatively strongly supports the scarcity hypothesis. Except for an interruption in the 1900 data, the time series show steady decline in timber's labor productivity, relative to that in the economy as a whole, during the entire period. Relative labor productivity in timber has fallen by 70 to 80 per cent. That is, labor input per unit of timber output relative to labor input per unit of real

[16] Gifford Pinchot, *The Fight for Conservation* (New York, 1910), pp. 15–17.

GNP quadrupled from 1880 to 1950. This is also the positive scarcity indication which the relative price series gave us.

SUMMARY

I summarize the quantitative exploration with relation to the scarcity hypothesis as follows:

	Relative Price Indicator	*Relative Labor Productivity Indicator*
All extraction	Does not support hypothesis	Adverse to hypothesis
Agriculture	Does not support hypothesis	Adverse to hypothesis
Minerals	Supports hypothesis ambiguously	Adverse to hypothesis
Timber	Supports hypothesis	Supports hypothesis

Differential Parametric Change

Adverse conditions of natural resource availability will be reflected in adverse trends of prices and productivities in the E sector relative to those in the N sector or the whole economy $(N+E)$ because the adverse force is *differentially* operative in the E sector. But I must warn again how strenuous the assumptions are which have to be made in order for the relative trends to be interpreted as definitive indicators of increasing or decreasing natural resource scarcity. Any other influences differential between the two sectors will also be reflected in these trends.

I shall not attempt to incorporate consideration of differential parametric changes in my quantitative tests. Rather I provide an incomplete catalogue of economic influences which operate on my "scarcity indicators," but which I neutralized with a blithe *ceteris paribus*. The check list will serve as warning on how distant the analysis here is from firm conclusions.[17]

FOREIGN TRADE

We have to decide whether we are testing the scarcity hypothesis for a self-sufficient United States or for the United States as part of the world economy. If the former, then the tests have to be redesigned in order to eliminate the influences of net imports of foreign supplies on extractive goods prices and labor productivity. If the latter, then there is no need to consider the sources of the supply. I dissent from the current view that the switch from net exports to net imports of minerals, which occurred in the twenties and thirties, by itself supports the hypothesis of domestic minerals scarcity. This is like saying that teenagers mow lawns because adults are incapable of doing so.

[17] See, however, Vanek's comment in footnote 14.

DIFFERENTIAL CHANGES IN FACTOR REMUNERATION RATES

The hypothesis involves movements in real cost per unit of extractive goods relative to all goods. If wage, interest, profit, and other rates change differentially in extraction as compared to nonextraction, these affect the relative price scarcity indicator and have to be taken into account. Differential changes in labor rates and degrees of market control seem particularly important. The relative productivity scarcity indicator is not directly affected.

GOVERNMENT INTERVENTIONS

If government behavior changes between t_o and t_n and this differentially affects the extractive *vs.* the nonextractive sector, then relative prices and relative productivities or both will be affected. The range of actions which have to be considered before we can properly interpret the scarcity indicators include farm price support and minerals price incentive statutes, differential tax preferences and more direct subsidies, production limitations, such as acreage and oil quota controls, and public investment in resource improvement.

PURCHASED INPUTS—CAPITAL AND MATERIALS

The productivity measures involve total output relative to labor input. If the ratio of purchased inputs (capital and materials) relative to labor changed differentially between the extractive and nonextractive sectors, relative productivity would have to be adjusted before it could be interpreted as a scarcity indicator. The relative price scarcity indicator, on the other hand, covers all inputs (costs) and is not subject to this defect. Differential movement of purchased inputs could be the reason the relative minerals productivity ratio improves so markedly following World War I, while relative prices increase significantly.

TRANSPORTATION AND LOCATIONS OF PEOPLE AND ECONOMIC ACTIVITY

The influence of transportation changes and economic location changes on scarcity indicators, and on the entire scarcity conception, is very great. Conceptual work is needed on these influences in a dynamic setting before we can even talk about taking them into account in scarcity indicator analysis. Ricardo's fundamental law of diminishing returns was based on the dual factors of cost of transportation and land quality decline, and Mason has shown that over a long period, transportation innovation was more important an influence in

TABLE 2

Extractive Product Prices (1954 Weights) Relative to BLS Wholesale Price Index (1947–49 = 100)

	All Extractive	Agriculture	Minerals	Timber	Fish
1870	78	69	119	27	37
1871	80	65	137	28	33
1872	75	62	126	28	38
1873	66	62	86	29	35
1874	65	67	67	29	40
1875	67	69	71	28	50
1876	73	66	102	28	38
1877	75	68	98	28	48
1878	60	60	67	28	40
1879	63	65	61	30	39
1880	66	69	66	29	38
1881	72	76	68	32	41
1882	74	81	64	32	60
1883	69	74	64	32	67
1884	69	74	60	34	69
1885	68	68	66	35	62
1886	63	66	59	36	63
1887	65	71	57	36	65
1888	70	72	62	35	80
1889	64	67	64	35	78
1890	66	68	65	36	38
1891	69	72	63	36	83
1892	68	74	59	37	35
1893	69	78	54	36	72
1894	68	74	61	40	68
1895	69	69	72	38	66
1896	66	66	72	40	43
1897	66	69	62	38	63
1898	67	70	64	39	95
1899	68	68	75	40	83
1900	68	68	73	40	82
1901	72	75	70	39	81
1902	70	76	67	38	65
1903	70	72	74	38	44
1904	72	72	72	39	41
1905	69	72	69	41	61
1906	70	72	74	44	32
1907	73	73	76	44	52
1908	76	78	76	44	54
1909	77	82	70	43	55
1910	76	83	64	41	52
1911	78	83	69	44	62
1912	78	80	73	43	58
1913	82	84	84	44	29
1914	81	84	78	43	29

(TABLE 2 concluded)

	All Extractive	Agriculture	Minerals	Timber	Fish
1915	80	82	82	40	29
1916	83	79	103	42	25
1917	86	86	96	39	52
1918	88	89	96	37	46
1919	85	89	84	44	41
1920	83	78	105	62	44
1921	79	73	108	52	50
1922	84	76	110	55	49
1923	84	80	102	60	41
1924	86	83	103	54	49
1925	88	86	104	52	52
1926	88	83	112	54	37
1927	85	84	97	53	52
1928	86	87	92	50	67
1929	89	89	96	53	66
1930	86	82	98	54	71
1931	72	68	88	53	76
1932	69	57	101	49	64
1933	68	61	93	58	63
1934	76	68	99	61	57
1935	79	77	91	54	56
1936	82	80	96	57	55
1937	82	80	96	63	57
1938	78	70	103	60	45
1939	76	70	99	63	78
1940	78	72	98	70	92
1941	85	81	96	74	90
1942	90	92	89	70	101
1943	100	106	88	71	111
1944	102	108	89	76	105
1945	105	110	89	75	105
1946	103	111	87	76	104
1947	102	106	90	98	88
1948	102	102	103	103	108
1949	97	93	107	99	103
1950	96	92	103	108	78
1951	98	97	96	106	97
1952	97	95	99	106	96
1953	92	86	106	106	85
1954	90	83	107	104	84
1955	(89)	(80)	(108)	(109)	
1956	(87)	(77)	(110)	(109)	

Source: N. Potter and F. T. Christy, Jr., *U.S. Natural Resource Statistics, 1870–1956*. To be published by Resources for the Future, Inc., Washington, D.C. Data are preliminary, pending completion and review of the manuscript. The authors state that the fish data, particularly, are subject to radical revision.

reducing delivered energy cost than innovation in the energy sector proper.[18]

DIFFERENTIAL TECHNOLOGICAL CHANGE

If for any reason technological change is not uniform as between extractive and nonextractive sectors, then both the relative price and relative productivity scarcity indicators will be affected, and this will obscure the influence of resource availability. Tomato and tobacco cultivation, for example, are less susceptible to efficiency improvement than most manufacturing processes. I am impressed by the phenomenon of technological change induced by economic pressure. Schumpeter would, as a third view, have expected technological change to be differential as among industries on the grounds of differential susceptibility to market control.

URBAN LAND

I have not yet been able to figure out whether urban land scarcity should be within or outside the scarcity hypothesis I am testing. It is now outside.

OTHER DIFFERENTIAL SOCIAL AND INSTITUTIONAL CHANGES

This caption is inserted to warn that I have given only an incomplete list of influences, other than resource scarcity, which could be responsible for differential parametric change in the two sectors and which thereby would influence my relative price and relative productivity ratios.

COMMENT

WILLIAM VICKREY, Columbia University

In a world of perfect competition and no uncertainty about the future, scarcity of nonrenewable, appropriable resources must be considered a relative matter, not an absolute one. In a world of perfect foresight, the price at which a well-defined body of ore would change hands would advance through time at a rate corresponding to the ordinary money rate of interest, otherwise investment in the purchase of such an asset would be attractive or unattractive relative to other investments. The rate of advance in price would be the same whether the mineral in question were rare or plentiful relative to current and anticipated needs. It is therefore likely to be misleading to take price

[18] Edward S. Mason, *Productive Uses of Nuclear Energy*, Report on Energy Requirements and Economic Growth, National Planning Association, Washington, D.C., pp. 20, 21.

trends as a measure of "diminishing returns" traceable to the limited total stock of nonrenewable natural resources. Indeed, in a world of certainty, it is difficult to define the economic criteria for distinguishing one nonrenewable mineral as being "scarcer" than another, in any way that reflects the imminence of exhaustion. One resource may be cheaper than another, assuming some common value unit to have been selected, but that is all.

To be sure, sometimes relative cheapness may be so extreme as to create a difference almost in kind rather than in degree. If Adam had offered to sell Seth a coal mine which he had discovered, but which was of a nature not to be economically exploitable before the twentieth century, the discounting of the modern price for 6,000 years, even at minimal rates of interest, would yield a price far below the smallest coin available.

If prices of nonrenewable resources *in situ* deviate from this normal interest-rate-determined trend, it must be as a result of changing expectations. One possibility would be changing expectations regarding interest rates, which would affect all mineral properties alike: inauguration of a cheap money policy might then be falsely interpreted as an increasing scarcity of natural resources. Other possibilities are changes in expectations about demand through the development of new uses, or of substitutes, or of better methods of processing; or about supply, almost entirely through further exploration of the extent of deposits and possibly the development of new means of exploiting hitherto unworkable deposits. Prices trends of resources are thus not a measure of absolute scarcity, or even of scarcity at a given time relative to current rates of use, but are rather an indication of the extent to which the evolution of prospects for interest rates, demand, and supply deviate from previously held expectations, an entirely different matter.

In practice, comparable prices or price indexes for resources covering extended periods of time are not readily available, and instead prices of the products derived from the natural resources after more or less processing are used. In this price the depletion factor, representing the contribition of the scarcity element to the total cost, will rarely contribute more than 30 per cent. In the "Malthusian" case of a resource limited in total stock but of uniform quality and accessibility, putting i for the rate of interest and d for the share of depletion in total cost, one could expect that under conditions of constant technology the price would increase at the rate of id per year regardless of the rate at which the fixed stock is being exhausted.

The "Ricardian" case of a total stock of variable accessibility and quality is not so different from this as might at first appear. Suppose a simple case of a resource existing in two grades: grade A requiring processing costs of $2 per unit of marketable product, and grade B requiring processing costs of $4 per unit. Suppose that the exhaustion of grade A occurs at time t_a, and that at that time the general scarcity of the resource is such as to induce a price of $5 for the finished product, thus yielding $3 per unit in royalties to the owner of the last unit of A processed, and $1 in royalties to the owner of the first unit of B processed after time t_a. Before t_a, the product price must have been increasing at a rate of $i \cdot \$3$ per year, assuming constant technology, if the holders of the grade A deposits were to get a normal return on their investment. After t_a the requisite rate of price increase is only $i . \$1$ per unit, since it is now the B grade that is controlling. Before t_a it is unprofitable to process grade B: owners of this grade can get a better net discounted return by waiting to process it until some time after t_a. Similarly owners of grade A would only stand to lose if they waited until after t_a to process their deposits in the hope of a better return.

The intertemporal equilibrium situation is then correctly stated as one in which deposits are exploited in order of increasing processing costs. But if we assume perfect foresight on the part of the owners of the raw resources, the trend of the price of the finished product will not indicate the degree of Ricardian scarcity. Increasing scarcity as measured by the degree to which the poorer deposits are used will be reflected in two ways: by a *decline* in the *rate of increase* of the price of the finished product, and by a *decline* in the share of the total cost represented by depletion charges. For nonrenewable resources in a context of constant technology and perfect foresight, it is accordingly difficult to see any direct relation between long-term trends of the price of the finished product and the degree of Ricardian scarcity. A better indicator would be the rate of deceleration of the price increase, or perhaps the decline in the ratio of depletion charges to total costs.

Transfer of these conclusions from a hypothetical world of perfect foresight, constant technology, and competitive markets to a real world of changing expectations, advancing technology, and imperfect competition of course requires major qualifications. Nevertheless, it would seem that for the nonrenewable sector, observations of price trends of marketable products is more nearly indicative of technological advance and changes in expectations about demand, supply, and interest rates, than they are of absolute levels of ultimate resource availability as viewed at a given point of time.

One specific source of bias in any comparison of price trends between extractive and other industries may be worth pointing out. Products priced as the proximate output of the mining industry are, generally speaking, standardized items retaining their essential characteristics over long periods of time, whereas the outputs of the economy as a whole, or of the manufacturing sector in particular, are so much more subject to innovation and quality improvement through time that it is difficult to evaluate them for the purposes of constructing productivity, price, or quantity indexes. If we say that the price of copper has exhibited such and such a trend, or even that mining products generally have risen or fallen in output or price by such and such a percentage, we know fairly well what we mean. If we say that automobiles or refrigerators have increased in price or in physical output by a specified percentage, we are much less sure of what we mean. On the whole it seems likely that technological improvements reflected in a changed quality of output are less important in mining than elsewhere, and that there is here a possible source of persistent bias that would cause an overstatement of the relative productivity advance in the mining sector.

There remains to be examined the question of whether there are circumstances which would justify treating a nonrenewable resource that is expected to be in limited supply some time in the future as a free good, in its raw state, in the present, aside from the obvious possibility that the value to be imputed by reason of long-term discounting may be so small as to be negligible, as in the case of Adam's coal mine. We may take the maximization of the value of the heritage as the social objective to be passed on to future generations, given the maintenance of a specified current consumption level. Under a perfectly competitive regime uncomplicated by economies of scale or imperfect foresight, all resources that would ever have a price would always have a positive price, and the production pattern so defined would be one that would maximize the social heritage under the given constraint as to current consumption. If, however, there are economies of scale in the extractive process, or if there are external economies tied up with the utilization of the nonrenewable resource, a situation may occur where the social heritage would be maximized by making the resource available at no charge for depletion, even though in private hands it would be held at a positive value. Unfortunately it is not at all easy to determine whether or where such situations in fact exist.

The analysis of the renewable sector of course differs in that the possibilities for intertemporal transfer are more limited. Soil depletion and the cutting of virgin timber may be important factors in a newly developed area, but for long-settled areas these factors become relatively insignificant. Here there is opportunity for diminishing returns due to scarcity of natural resources to be reflected in price trends, and with appropriate care it may be proper to draw conclusions on relative scarcity or the tendency to diminishing returns from an examination of the price trends.