Volume Title: Demographic and Economic Change in Developed Countries

Volume Author/Editor: Universities-National Bureau Committee for Economic Research

Volume Publisher: Columbia University Press

Volume ISBN: 0-87014-302-6

Volume URL: http://www.nber.org/books/univ60-2

Publication Date: 1960

Chapter Title: Population Change and Resources: Malthusianism and Conservation

Chapter Author: Harold J. Barnett

Chapter URL: http://www.nber.org/chapters/c2395

Chapter pages in book: (p. 423 - 456)

Population Change and Resources: Malthusianism and Conservation

HAROLD J. BARNETT

RESOURCES FOR THE FUTURE, INC.

AND WAYNE STATE UNIVERSITY

1. *Social Importance*

CONTEMPORARY society holds the belief that there is an imbalance of some kind between the economic availability of natural resources and population growth. More specifically, it is thought that natural resources (hereafter usually "resources") are scarce in an economic sense, and that this makes economic growth more difficult.

Two of America's leading physicians have recently made forceful statements of their beliefs that resources are economically scarce relative to the number of human beings and their consumption of goods. The late Allen Gregg, Director of the Rockefeller Foundation medical division, asked, "Is Man a Biological Cancer?"

> There is an alarming parallel between the growth of a cancer in the body of an organism and the growth of human population in the earth's ecological economy. (*Population Bulletin*, "Hidden Hunger at the Summit," August 1955, Volume XI, no. 5, p. 74.)

A. J. Carlson posed the same dilemma with a different simile:

> The number one problem facing man today and tomorrow is overpopulation and starvation. . . . If we breed like rabbits, in the long run we have to live and die like rabbits. ("Science Versus Life," *Journal of the American Medical Association*, April 16, 1955, Vol. 157, pp. 1437–1441)

Other leading life scientists have also spoken out about resource scarcity and its adverse consequences for social welfare and economic growth. Sir Charles Galton Darwin (grandson of the originator of the modern theory of evolution) is quite pessimistic.[1] He believes that society

[1] *The Next Million Years*, Hart-Davis, London, 1952.

Note: This paper is drawn from a much larger Resources for the Future research project, on the economic theory of resources and growth, in which Chandler Morse and I are collaborating. It is intended that most of the results will be published as a book by Resources for the Future, Inc. I wish to acknowledge helpful comment on this article from Professor Morse, Henry Jarrett, and other colleagues. In addition, the final draft has benefited from criticisms by Professors L. E. Craine, E. M. Hoover, E. S. Mason, T. W. Schultz, and from the editor of this volume, Mr. C. J. Dwyer. But I have not fully accepted all criticisms, and am alone responsible for remaining errors.

as a whole will tend to breed without limit. And, further, it is precisely the poorest intellectual stock, he believes, which will breed at the highest rates. Given a shortage of resources, the result is a tendency of civilization relatively to proliferate its lesser quality specimens and to shrink the numbers of its abler ones. The "weak" shall inherit the earth.

Outstanding men from the other physical sciences have also supported the doctrine of resources conflict. For example, Harrison Brown has recently written:

> A substantial fraction of humanity today is behaving . . . as if it would not rest content until the earth is covered completely and to a considerable depth with a writhing mass of human beings, much as a dead cow is covered with a pulsating mass of maggots. (*Challenge of Man's Future*, Viking Press, New York, 1954, p. 221)

Similar views are also widespread among social scientists, although perhaps less so than among the physical ones. We find (ignoring, for the moment, economists and demographers) statements from political scientists, sociologists, the legal profession, and representatives of the other social disciplines. Occasionally, the expressions are of alarm or urgency; occasionally they are as simple and straightforward as some of the physical scientist expressions in flatly asserting a contradiction between a limited earth and a burgeoning population and standard of living. For example, lawyer Samuel Ordway, in a recent book is no less forceful than the physical scientists quoted.[2] More usually, however, the social scientists hedge their statements on the conflict between resource scarcity and economic growth. Examples are recent writings of Craine, Gulick, Griffith, and Hertzler, among others.[3]

The social importance of the doctrine of resource scarcity is thus demonstrated by the simple fact that there is widespread belief in one form or another of the proposition.

But the social importance of the doctrine of resource scarcity goes beyond the fact of wide public belief. In many countries, this belief has, rather naturally, found expression in laws and modes of governmental (and private) behavior. In this country, the platforms of both political parties contain policies for "scarce" natural resources. Public policies based upon the doctrine of resource scarcity are, in part, responsible for

[2] *Resources and the American Dream*, Ronald, 1953.

[3] Lyle Craine, "Natural Resources and Government," *Public Administration Review*; Luther Gulick, "The Cities' Challenge in Resource Use," and Ernest Griffith, "Main Lines of Conversation Thought and Action," both in *Perspectives on Conservation*, Resources for the Future, Johns Hopkins University Press, 1958; J. O. Hertzler, *The Crisis in World Population*, University of Nebraska Press, 1956.

federal or state land reclamation programs, resource reservation practices, and controls on rates of use of some natural resources. Prominent examples are: forest reservations, limitations on the use of oil and gas, and preferential tax treatment in certain natural resource industries. Many foreign countries also have public policies based upon the doctrine of resource scarcity. The situation of the oil-rich, underdeveloped countries is particularly interesting. Their problem is sometimes visualized as that of reinvesting the income from their petroleum sales so as to assure the development of their economies before the reserves run out.[4]

Thus the doctrine of natural resource scarcity is an important social question for two reasons: because thoughtful public opinion views it as such; and because public policies based upon these views are being adopted.

2. *Contemporary Economist and Demographer Writings*

In general, economists and demographers are not in the vanguard of alarmed writers on the resources-growth dilemma. In this sense, their views are similar to those already characterized for other social scientists. Here also there are exceptions, such as demographer Robert Cook, editor of the *Population Bulletin*. Among economists, it is possible to interpret some recent pieces by Spengler and Villard as exceptions; I regard them, however, more as forceful presentations of the natural resources-population dilemma.[5]

Although probably not really alarmed concerning resource scarcity, economists (and, so far as I know, demographers) also generally believe that this scarcity in the economic sense truly exists, and that it is a drag on economic advance. Advances in output per capita from technological improvement and other causes are subject to a degree of offset from this scarcity. Exceptions to the idea of limited natural resources as an obstacle to growth in economic writings are very few. So far as I know, the strongest appear in Erich Zimmerman's monumental volume.[6] Other exceptions take the form primarily of denying major importance to this

[4] C. Kindleberger, "Exhaustible Resources, Foreign Trade and Foreign Investment" (M.I.T. manuscript, 1958); S.V. Ciriacy-Wantrup, *Resource Conservation—Economics and Policies*, University of California Press, Berkeley, 1952; A. Scott, *Natural Resources: The Economics of Conservation*, University of Toronto Press, 1955.

[5] Joseph Spengler, "Population Threatens Prosperity," *Harvard Business Review*, January–February, 1956; Henry Villard, "Some Notes on Population and Living Levels," *Review of Business and Economic Statistics*, May, 1955.

[6] *World Resources and Industries*, Harper, 1950. See particularly ch. 50.

negative influence, rather than quarreling with its presence. For example, George Stigler in a recent paper states:

> A larger economy should be more efficient than a small economy: this has been the standard view of economists since the one important disadvantage of the large economy, diminishing returns to natural resources, has proved to be unimportant. (Conference on Income and Wealth, National Bureau of Economic Research, Oct. 17–18, 1958)

Similar derogations of the significance of an adverse resource influence in modern industrial societies, although less flatly stated, appear in writings of E. S. Mason and Harold Moulton.[7] In general, however, the major body of literature takes seriously the retarding force of resource scarcity as an important obstacle in economic growth—for example, the recent thoughtful book on Asia by Harold Belshaw.[8]

In view of the wide belief that economic scarcity of resources in fact impairs economic growth in modern societies, it might be thought that it has been theoretically and empirically proved. But this is not the case. Rather, the proposition is assumed to be a factual statement. Either it is considered sufficiently obvious to need no proof, or else there is simple reference to "Conservation" or the "Malthusian dilemma." Elsewhere, Chandler Morse and I have examined the economic theory of resource scarcity as an impediment to growth.[9] And, elsewhere, I have argued it is an hypothesis, not a fact, and made a preliminary and exploratory empirical analysis of whether it is possible to observe any development of resource scarcity in the U.S. economy between 1870 and 1956.[10] The results of these efforts, so far, have not removed my uncertainty as to whether there is necessarily, in a growing modern economy, a development of resource scarcity which operates to retard growth and threaten future welfare.

Stimulated by this finding for modern industrial societies, I have set myself the task of trying to chase down and examine the origins of the doctrine. Perhaps by examination of resource scarcity doctrines *in situ*, I can find elaboration which will show, as modern writing does not, under what circumstances the widespread belief is justified, or which will at least explain why the belief is widespread.

[7] E. S. Mason, "An American View of Raw Materials Problems," *Journal of Industrial Economics*, Vol. 1, no. 1, 1952; Harold G. Moulton, *Controlling Factors in Economic Development*, The Brookings Institution, 1949.

[8] *Population Growth and Levels of Consumption*, G. Allen, London, 1956.

[9] Forthcoming Resources for the Future book.

[10] "Measurement of Natural Resource Scarcity and Its Economic Effects," paper presented to Conference on Research in Income and Wealth, October 17–18, 1958.

In economic literature, the principal lead for such historical investigation is what has been termed the "first American conservation movement." So closely has resource scarcity doctrine been identified with this movement that the terms "conservation problem" and "natural resource scarcity" are frequently used as synonyms, the former being the more common. For example, two of the major professional books on the economics of natural resources are titled *Resource Conservation—Economics and Policies* (S. V. Ciriacy-Wantrup) and *Natural Resources: The Economics of Conservation* (A. Scott). A. C. Pigou, in his statement that the resource scarcity problem generates a danger which justifies public policy concern, also points to the conservation movement for authority:

> But there is wide agreement that the State should protect the interests of the future *in some degree* against the effects of our irrational discounting and of our preference for ourselves over our descendants. The whole movement for 'conservation' in the United States is based on this conviction. It is the clear duty of Government, which is the trustee for unborn generations, as well as for its present citizens, to watch over, and, if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation. (*Economics of Welfare*, Macmillan, London, 1946, pp. 29–30; italics in the original)

In general, I think most American economists believe that "conservation" is concerned with the problem of resource scarcity relative to welfare and growth.

Among non-economists, the signs pointing to the conservation movement as a means of understanding the problem of resource scarcity and growth are even clearer. Leading expositors of the resource scarcity view today, in fact, frequently see themselves as descendants of the first conservation movement and inheritors of its reform mission.

Contemporary demographic and economic literature also suggests going back a hundred years earlier and examining Malthus for this inquiry into the origins of the resource scarcity-growth doctrine.[11]

3. *Malthus*

An elementary statement of the Malthusian view of the economic scarcity of resources and the retardation of growth therefrom is about as follows: The doctrine of resource scarcity and its economic effect reflect natural law. By the laws of nature, resources are limited and population multiplies. In the absence of social preventive checks, population increases to

[11] I have also examined other historical writings as possible keys to the resource scarcity gospel. Some of these, particularly works of Ricardo, Mill, G. P. Marsh, and W. S. Jevons, I have found to be of equal or greater importance as origins of the doctrine.

the limits of subsistence. The dynamics of economic growth are thus dominated by the scarcity of resources and the law of population growth.

With respect to resource scarcity, Malthus believed,

> . . . Man is necessarily confined in room. When acre has been added to acre till all the fertile land is occupied, the yearly increase of food must depend upon the melioration of the land already in possession. This is a fund, which, from the nature of all soils, instead of increasing, must be gardually diminishing. (*An Essay on the Principles of Population*, Ward, Lock, London, 1890, p. 4)

With respect to the law of population growth, Malthus believed that there is

> . . . the constant tendency in all animated life to increase beyond the nourishment prepared for it (*ibid.*, p. 2) . . . population invariably increases where the means of subsistence increase (*ibid.*, p. 14)

The theory was, thus, that man's propensity for breeding was in conflict with the world's limited availability of natural resource and his ability to extract economic goods therefrom.

Is Malthus the originator of the doctrine? It appears clear from the *Essay* that his generalization of the problem of population pressure on scarce resources derived more from the contemporary policy problem of the Poor Laws, and from social observation and empirical analysis, than from purely abstract thought. In part, the social conditions of the time generated his ideas, and the ideas were therefore unlikely to be wholly new. Keynes in his sympathetic biography of Malthus states that, "his leading idea had been largely anticipated in a clumsier way by other eighteenth-century writers."[12] Malthus, therefore, did not originate the doctrine that resource scarcity restrains economic growth, but rather provided a clear and forceful statement on an attractive generalized level.

It is also possible to quarrel with the characterization of Malthusianism as the origin of subsequent doctrine on natural resource scarcity and effect on three other grounds. First, the *Essay* is far more an analysis of population than of natural resources, and resource scarcity and its effect are more asserted than demonstrated. Second, while the Malthusian doctrine describes a resource scarcity effect upon economic growth, it does not entail an economic scarcity effect in a stationary society. And, third, Malthus apparently did not raise the problem of depletion at all. All of these points are valid. Their implications, however, do not deny to the Malthus *Essay* the role of intellectual parent of the family of subsequent views on resource scarcity and its economic effect. But they do suggest that resource scarcity doctrine has developed since Malthus.

[12] *Essays in Biography*, New York Press, 1951, p. 100.

Although for its subject matter the Malthusian theory far surpassed its contemporaries in logic, precision, and clarity, it is not a complete statement, in the modern economic model sense, of the relation between resources and economic growth. It is useful to attempt the construction of such a model, by using his text as a basis for filling in gaps and providing a modern formulation.

Static model. First, there is posited a social production function consistent with Malthus' view:

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

where O is physical national output, R is physical quantity of resources employed, L is physical quantity of labor employed, and C is physical quantity of capital employed. The functional relationship is a description of all possible efficient combinations of the inputs to produce output with given techniques and social parameters. Each of the variables—the three inputs and the output—is either homogeneous in quality, or is characterized by an invariant frequency distribution of quality. This difficult assumption is necessary if the function is to be a meaningful, precise mathematical statement.

In order to yield a specific output figure under these conditions, the availability of natural resources, labor, and capital, and the extent of their employments, must first be specified. Under Malthusian assumptions, as they are simplified and imputed to him for exposition here, the following may be specified as the availability and employment of the three inputs. The quantity of available natural resources is fixed; natural resources are indestructible. The available quantities of both labor and capital are variable. If fully employed, labor's marginal productivity equals subsistence, and capital's marginal productivity will be positive. If natural resources are free and not yet fully employed, their marginal productivity will be zero. Once they are fully employed, marginal productivity will become positive. Reservation policies in regard to the supply of any factor from existing stock may be adopted for institutional, psychological, or other reasons. Since these would affect marginal productivities, let it be assumed that each individual reservation policy, if adopted, is persistent and independent of the other reservation policies.

The form of the Malthusian static social production function is required to be such that the marginal productivities of labor and capital individually and together are monotonically declining. And, therefore, the second partial derivatives of output with respect to labor, capital, or both, are negative.

Growth model. The final conditions are those needed to convert the above Malthusian static model into a Malthusian growth one. That is, rules are needed for changes in factor quantities and in technological and institutional parameters. For simplicity, the labor force is assumed to be a fixed proportion of population. The population level, in turn, increases exponentially as a function of time, subject to two biological constraints. Its rate of increase may not exceed that permitted by the maximum biological rate of reproduction characteristic of human females (increase from improved longevity is thus ignored); and the level of population may not exceed that set by the biological minimum of food and other subsistence goods required to sustain life. Capital availability increases no faster than population. Natural resource availability is invariant. And technology and institutional conditions are invariant. Finally, we need a time horizon, and for this we assume a very long term. This completes the Malthusian long-term growth model.

In summary, the Malthusian growth model constructed here has five conditions:

A. A very long term
B. An exponential population-increase function and appropriate limits on capital increase
C. Given natural resources
D. Unchanging technology and institutional conditions
E. Homogeneous or constant-composition input and output variables; a law of variable proportions (eventually diminishing marginal productivity) for labor and capital applicable to this static social production function, as stated above under "Static model"

This model is illustrated in Charts 1 and 2. If resource stock is fixed at r_1 and the whole stock is employed, then output increases less than in proportion to increases in labor plus capital. The output expansion path is *EHM*. As labor and capital increase from a_1, their marginal productivity $[\Delta O/\Delta(L + C)]$ declines steadily, reaching zero when labor + capital are equal to a_2. The decline in output per capita from o_1/a_1 to o_2/a_2 may never be reached, since the latter figure may be below the level of subsistence. Or, if o_2/a_2 is above subsistence, population will continue to grow even though output declines, so that eventual stable output might be o_3; then output per capita will be at subsistence, at o_3/a_3, a level below o_2/a_2. Thus while we are sure that output growth will cease someplace on the path *EHM*, we don't know at which point unless

CHART 1

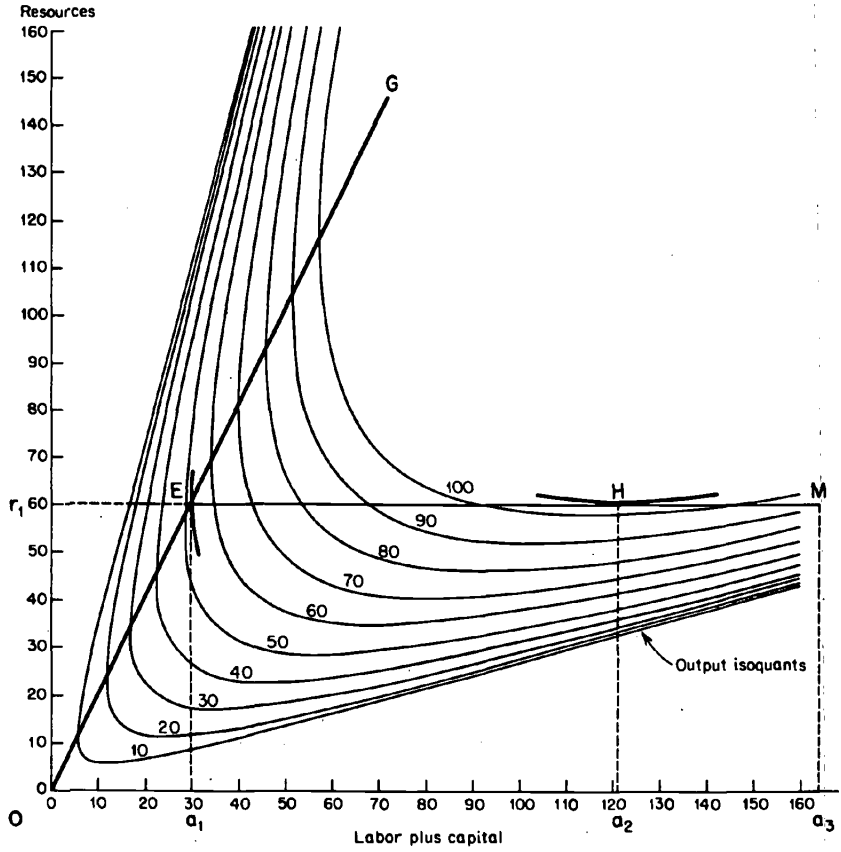
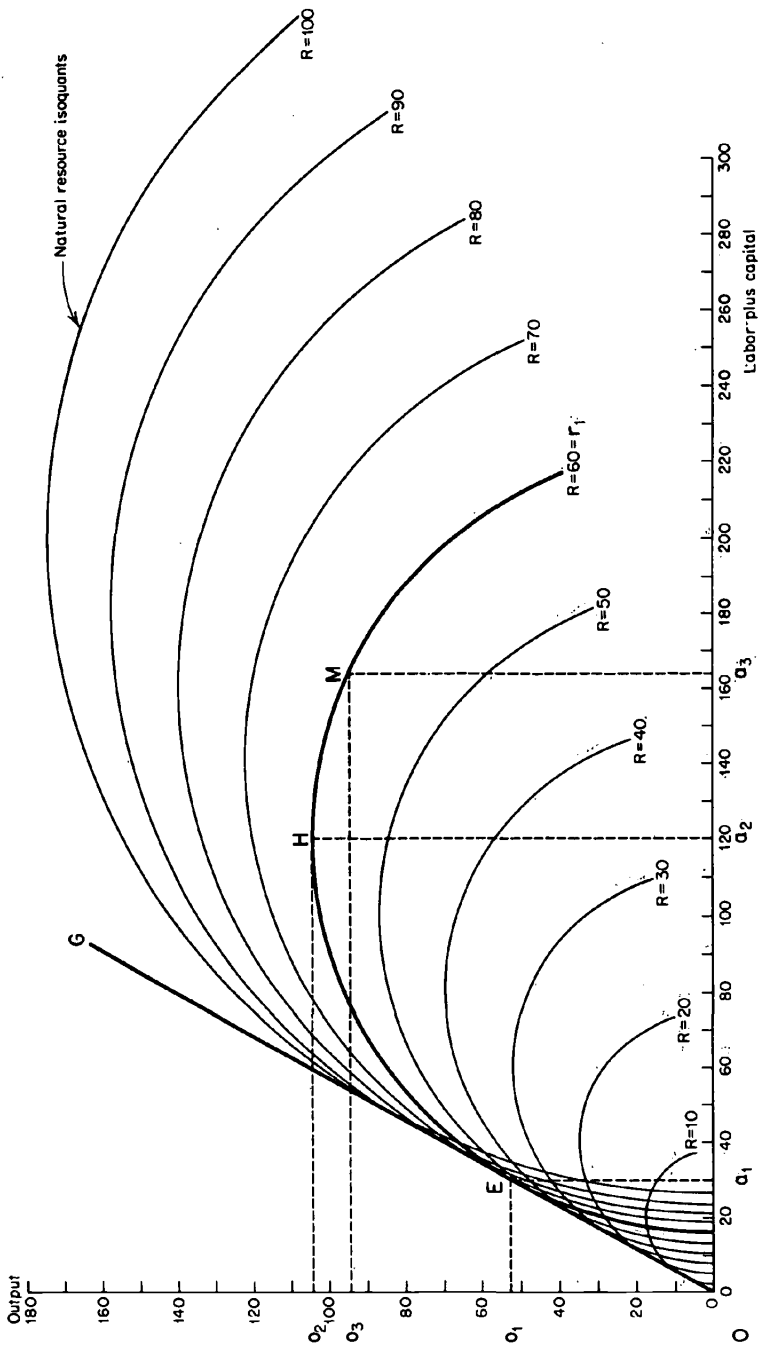

Resources
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
G
E
H
M
100
90
80
70
60
50
40
30
20
10
r_1
Output isoquants
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
O
a_1
a_2
a_3
Labor plus capital

CHART 2


Natural resource isoquants
R=100
R=90
R=80
R=70
R=60=r₁
R=50
R=40
R=30
R=20
R=10
G
H
M
E
Output
180
160
140
120
100
80
60
40
20
0
O₂
O₃
O₁
O
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
a₁
a₂
a₃
Labor plus capital

we can define subsistence. Note that alternative social definitions of subsistence are possible.

The charts show that the assumed conditions inevitably produce resource scarcity eventually. But they also show that the mere definition of a fixed physical world does not, in itself, amount to economic scarcity of resources. To be economically scarce, the fixed natural resources must be of small amount relative to $L + C$ and the socio-technical parameters. In our charts "small" is defined as an amount less than r_1/a_1. From this it follows that while a fixed world (or universe) always contains a threat of resource economic scarcity, nevertheless onset of scarcity depends on the other conditions as well. So long as resources are large enough to permit output expansion along the path *OEG*, resource economic scarcity is not yet experienced.[13]

If economic growth is defined as increasing output, then Malthusianism is a simple, extreme case of a general hypothesis of inhibition of economic growth from limited natural resources. The beginning state of the model is irrelevant to the eventual outcome of population being limited by food subsistence. Timing of the outcome, however, is influenced by the beginning state. Any outside disturbance in effect creates a new beginning state. If the closed model is disturbed by, for example, improved technology, the Malthusian limitation will at that point be avoided. But provided the impulse is a "one-shot" affair, the economy will absorb the impact of the disturbance and immediately thereafter again tend toward a new Malthusian equilibrium combination of total output, population, and subsistence levels of living.

The conditions described are sufficient for an eventual Malthusian outcome of subsistence living and cessation of economic growth, namely, stable population and no increase in output per capita. The following five classes of conditions are also necessary:

A. It is only in the very long term that the model necessarily operates to its equilibrium solution. In a short term, there can be economic growth, since resources do not become scarce until the ratio of population to resources rises beyond a critical level (a_1/r_1 in our charts).

B. Except for persistent population increase and appropriate limits on rate of capital increase, there is not necessarily sufficient labor to drive average returns to the limit of subsistence. The critical population/resources level has to be reached via population growth. And of course

[13] The charts are drawn to follow R. G. D. Allen's "more general normal type" of production function in *Mathematical Analysis for Economists*, Macmillan, London, 1947, p. 288. In my charts, $O = [\,2H(L + C)R - A(L + C)^2 - B(R)^2]^{1/2}$, where $H = 2$ and $A = B = 1$.

Malthus' "exponential rate" of population increase and my assumption of capital increase at the same rate yield one case of such growth.

C. Except for limited natural resources, output could rise as fast as, or faster than, population. And, of course, Malthus' "fixed land" is one case which satisfies the requirement of "limited natural resources."

D. Only when the rate of technological and organizational advance is too slow to offset the declining marginal returns to population increase would output per capita be forced down to the subsistence level. And, of course, "fixed technology and institutions" satisfies this condition.

E. Except for the assumption of diminishing marginal returns to labor and capital in the social production function, social output could increase as fast as, or faster than, labor and capital additions.

It is also apparent, however, that while each of these classes of conditions is necessary, the particular conditions are not. The specifications of particular conditions we have given (exponential population growth, fixed land, and the like) are more stringent than absolutely necessary for Malthus' conclusions.

Strategic variables and sensitivity. That the five types of conditions are necessary for the Malthusian scarcity model is an important truth, frequently overlooked. The dynamic forces which tend to drive economic evolution toward Malthus' conclusion are sometimes viewed as a population problem, or a natural resource problem, or a race between technology and population, or in still other simplified ways. Such simplifications do not, of course, deny the existence of the other relations characterized here as necessary, but frequently these relations are admitted only implicitly or not recognized at all. Further, incomplete specification of the entire model permits implicit introduction of other assumptions and views. These latter are sometimes dangerous to sensible analysis, and are partly responsible for a fraction of nonsense in resources literature.

The conditions required for the Malthusian scarcity effect—known as the "Malthusian dilemma"—constitute a multi-variable, dynamic model, containing the variables and kinds of relations described. Every one of them is potentially important. Yet it is true that if one makes certain assumptions, certain of the variables and conditions become unimportant, while others become dominant or strategic.

Time horizon. The assumption concerning time horizon is extremely prejudicial to the question of which variables are strategic. Let an extremely "long term" be assumed as the setting for the analysis. Then the entire outcome of the Malthus model hangs on whether or not the

annual rate of population increase exceeds zero—depends, that is, on whether or not population more than reproduces itself, however minutely. Population is the strategic variable, and, given a finite world, the population equation is virtually the only important relation. Assume, for example, a net reproduction rate of 0.016, very roughly the present world rate, a considerable part of which is due to improved longevity. This involves a birth rate less than half that which Malthus' empirical work led him to use. Then the world population would increase *one hundred-fold* in 290 years, and *one thousand-fold* in 435 years. Let the annual net reproduction rate be still lower—set it at 0.001, about 1/30 of Malthus' finding. Then the long term doom from scarcity is only deferred. The 2½ billion living bodies of 1950 generate: 25 billion in A.D. 4300, a ten-fold increase; 250 billion in A.D. 6600, a hundred-fold increase; 2,500 billion in A.D. 8900, a thousand-fold increase. And this numbers game may be played without end, with an unspecified long-term horizon. Consequently, if the time horizon is a very long or an endless one, the crucial question is whether net rate of reproduction is positive, for this makes ultimate population boundless. No other question is very relevant: technological change, capital formation, utilization of the depths of the earth or its atmosphere and solar energy, and so on, are submerged in people and endless time. If time is infinite, so is population; if time is extremely long, then population is extremely large.

Now let the time horizon be a closer one—25, 50, even 100 years. The following world populations result at decade intervals from continuation of the present annual net reproduction rate of about 0.016:

Year	*World Population* (in billions)
A.D. 1950	2.5
1960	2.9
1970	3.4
1980	4.0
1990	4.7
2000	5.5
2010	6.5
2020	7.6
2030	8.9
2040	10.4
2050	12.2

For these shorter periods, the population variable no longer nullifies the other terms in the model. For the earlier part of the 100 years, population level may be less significant than availability of advanced technology and

capital for the lower income areas of the world; employment of new lands, intensity of land use, and availability of chemical fertilizers; institutional arrangements for domestic and international trade and exchange; and other conditions. Even for the final 50 years, population level would not appear to be obviously dominant. It is no longer enough to define scarcity as a finite world, as Malthus did. It becomes necessary to ask how great or how little a volume of resources constitutes economic scarcity.

Rate of population increase. As to the second necessary condition of the Malthus model—annual rate of population increase (r)—this is important for economic growth over moderately distant time periods. This is demonstrated in the following table:

	World population (in billions)		
Year	$r = .03$ (Malthus)	$r = .016$ (present)	$r = .001$
1950	2.5	2.5	2.50
1975	5.2	3.7	2.57
2000	11.0	5.5	2.63
2025	22.9	8.2	2.69
2050	48.0	12.2	2.77

If explicitly or implicitly one uses the Malthus rate, then Malthus was surely right. Population *is* the strategic variable for periods longer than 50 years or so. On the other hand, one might be inclined to project the present rate of world population increase, a far lower rate than Malthus', and partly reflecting increased life-span. Then population must be considered, but other elements may not be neglected, as they were by Malthus. If one posits $r = 0.001$, then population is not a significant variable, and may be neglected.

For Malthus, the population function is independent of level of consumption (or output), except that consumption per capita may not be less than subsistence levels. This was central and explicit to Malthus' analysis and conclusions, and is necessary to them. For if in consequence of an increase in income per capita the birth rate should fall, scarcity and its effect could conceivably be avoided. The Malthus model absolutely requires that population *not* vary inversely with income.

It may now be seen why Malthus emphasized the population level. For unchecked $r = 0.03$ is a monstrous force. Population multiplies by almost 20 in the first century, by about 2½ million in the fifth, and by the year A.D. 3000 the population mass would exceed the earth's and if

closely packed would be five times as bulky.[14] If Malthus did believe $r = 0.03$, then the relative neglect of other variables is understandable. For in this case and given a finite world, none of the other variables is important.

Natural resource availability. The third condition for the Malthus formulation is limited economic availability of natural resources. So far as I can tell, this assumption derived directly from the fact that the world's agricultural lands were of limited physical extent.

Several questions may be asked. Was Malthus unaware that agricultural land varied in economic quality? Malthus *was* aware that agricultural land was not homogeneous. But this was not important to his theory. His thesis was the basic and ultimate inconsistency between a natural birth rate tending to double population each twenty-five years and the food availability from a limited agricultural territory, the earth. For him, there was no question but that the unhomogeneity of land could be ignored. The fixed agricultural land of the globe meant natural resource scarcity. In his own words, ". . . what is true . . . in reference to a single farm, must necessarily be true of the whole earth, from which the necessaries of life for the actual population are derived."[15]

Was Malthus unaware that there were natural resources other than land? His *Essay* hardly mentions them, but we may be sure he was aware of them. But, again, they could be ignored. One reason is that just given for ignoring variations in economic qualities of agricultural land. The other is that his society was primarily an agricultural one, whose major problem was food for subsistence (fish, game, and forests did not figure importantly in his scheme).

These oversimplifications do not disturb me. The mark of good theory is not that it describes reality completely, in all respects faithfully, but that it captures the essence of that part of reality which is under consideration. Good theory, like art, simplifies, abstracts, and highlights. It is therefore, in a sense, inappropriate to ask whether Malthus believed his conditions to be complete and detailed descriptions of reality. Of course he did not. A really good theorist is a hair-splitter only when necessary, or when engaged as a critic. The proper question is whether Malthus believed his theory and conditions to be essentially accurate. And to this, the answer is that certainly he did.

[14] *Any* positive rate of population increase will do these things if one's time horizon is distant enough. Henry Villard, *Review of Economics and Statistics*, May, 1955, observed that the *present* world net reproduction rate would yield a population size equal to the weight of the earth in only a couple thousand years or so.

[15] *Introduction to Malthus*, D. V. Glass, ed., Wiley, p. 145.

Technology and institutions. Malthus assumed that technology and economic organization were, if not fixed, at least not subject to radical change. But the beginnings of the industrial revolution were observable about Malthus even when he wrote the first *Essay*, and there was significant industrial advance as he went through successive editions. In the *Essay* he comments, for example, on the remarkable advances in productivity in textiles. Was it solely because of his estimate of r that technological change was given so little attention? There is no way of knowing for certain, of course. An $r = 0.03$ is sufficient reason for ignoring technological change. But, in addition, it would have required prophetic genius, rather than analytical brilliance, for Malthus to appreciate the significance of such phenomena as technological change. The phenomena which entirely transform the equations of the Malthus model are advances which did not take place until after the study was completed and his conclusions had congealed. The important ones are the increase in biological and chemical knowledge, development of the earth sciences, the industrial applications of such knowledge, and the recent atomic energy advances. Such events as Wohler's synthesis of urea, the discovery of cell composition of living things, Liebig's advances in organic chemistry, Mendeleev's periodic table, Mendel's laws, Pasteur's bacteriological discoveries, and the great biological, chemical, and nuclear advances which followed did not take place until much later. Without these advances, there was no reason for Malthus to doubt man's dependence upon naturally fertile soil; to doubt the applicability of a principle of diminishing returns to increments of population; or to place much confidence in man's ability to limit procreation, since in Malthus' view this required sexual continence. It is only with access to the above and other technological changes that, concurrent with striking increases in output per capita and food availability, r begins to decline, land perhaps ceases to be economically fixed, dependence on natural agricultural fertility diminishes sharply, and the single industry principle of diminishing returns, while a truism in a static model, may become anachronistic with respect to changing social output and economic growth.

Law of diminishing returns. The five individual conditions necessary for the Malthusian dynamic model and its unhappy results are being systematically discussed. In each case the interest is briefly to characterize the strategic importance of the condition, the sensitivity of the model results to the individual variables, and the validity of the conditions in contemporary society. The last of the conditions that so concerns us is "the law of diminishing returns." What is necessary at this point is that

some of the confusion as to what the "law" is be cleared away. Certainly the diminishing returns principle which is required by the Malthusian formulation is not the one which modern economists view as a natural (although abstract) law; that is, the Malthusian condition is not our familiar, well accepted, necessarily-true "law" at all. There are a considerable number of quite different propositions of diminishing returns extant.[16] I discuss here four which are seemingly or actually embodied in the Malthusian dynamic model.

One of the diminishing returns propositions is the *end result* of the Malthusian economic growth model. Any simple statement of output behavior in the Malthusian theory seems to be itself a statement of the diminishing returns principle. For example, thus: during economic growth, output increases less than in proportion to the increase of population. But it is really inappropriate to use the diminishing returns term so, despite historical sanction. As already described, the Malthusian economic growth model, in the simplest form it could be stated, is a complex of five quite separate types of conditions, all necessary, so that it is misleading to imply that it is a singular principle, and to cloak it with the validity today credited to the "law of diminishing returns." If our entire discussion is viewed as a footnote to the allegation that the Malthusian dilemma is a "law of diminishing returns," then no harm would result. But neither would much good—it is really too lengthy a footnote. In short, it propagates misunderstanding to call the Malthusian results a "law of diminishing returns"—this is not what modern convention and accepted terminology mean by the term. And in any case, it is clear that the proposition so used is not "law." I labor the point not for professional economists, who are no longer much given to the practice, but for non-economists.

A second "diminishing returns" proposition, which is *not* required in my Malthusian formulation, is *static model diminishing returns to social scale.* This proposition, according to modern usage, is that if all factor input quantities are increased proportionately, output will increase by lesser degree. Thus, the social production function is such that if factor inputs are doubled, output will less than double. This is unnecessary to the Malthus model I have constructed. He did not need this condition because in his *dynamic* model he built in the severe limitation of no increase in the factor *land.* With this model, one cannot ask whether outputs will double if all inputs are doubled, since his land input is fixed.

A third principle of diminishing returns, the true "law" of economics,

[16] See, for example, T. Schultz, *Journal of Farm Economics,* October, 1932.

is the static law of variable proportions applied to a homogeneous (or invariant composition) output and individually homogeneous (or invariant composition) inputs. This states, for the production of individual commodities, under invariant socio-technical conditions, that after some point additions of a single factor will yield diminishing marginal returns. Formulated rigorously, this is a provable proposition; it is law.

However, the Malthusian model doesn't use this universally acceptable assumption, but rather a fourth proposition which is a dubious modification of it. Malthus requires that the principle be applicable to a whole economy, that is, to a social production function. The condition for the Malthus model is that in a static social production function the marginal productivity of each factor is monotonically declining, and the second partial derivates are negative. The point, briefly, is that the social production function, as distinct from a commodity one, involves unhomogeneous outputs, technologies, and inputs. Recourse to the homely case of limits of ability to raise wheat with men and horses on an acre must be viewed as an analogy, not proof, unless the social production function produces only wheat with acres, men, and horses. This is not the place to elaborate on the difference between a commodity production function and a social one. But its importance is illustrated by the fact that the difference is major in accounting for so-called "external economies."

This discussion of diminishing returns was intended to establish these four points: there are a good many views of diminishing returns; only one of them (the third, above) is the accepted law of diminishing returns; this one is not the Malthusian condition; the Malthusian condition is of uncertain validity.

4. *The First Conservation Movement*[17]

"Conservation," a coined term, was a part of the "Progressive" political reform platform of the Theodore Roosevelt presidential period. It was also a social movement underlying that reform effort. In terms of ideas, conservation was a wide-ranging melange of views, concerning all the individual natural sciences, economics, political science, public administration, sociology, engineering, art, and public health.

To see it as a political program makes clear features of conservation which are otherwise difficult to understand. How does it happen that the conservation movement moved from natural resources to policies on

[17] S. Hays, *The First American Conservation Movement, 1890–1920*, pp. 84f. This recent unpublished Harvard doctoral dissertation is an outstanding *political history* of the movement.

immigration, anti-industrialization, trust-busting, pure food laws, child-labor, Anglo-Saxon supremacy, and so on? One clue here is that it was a successful political movement; these and their architects are rarely consistent in thought or action. Was the conservation movement dominated by its leaders and flavored by their personalities, rather than intellectually led and constructed with scholarly rigor? To ask is to answer: was there ever a successful political movement which was not? Were there manipulation, power alliances, scare propaganda, and other behavior different from the high personal-life ethics of conservation leaders? Again, of course there were—this was American politics. As a successful political movement, conservation was opportunistic, expedient, and compromising in high degree.

As it was a successful political and social movement in American national life, so conservation could not be truly revolutionary in its immediate impact. However, conservation could be, and was, revolutionary in part of its doctrine, and in its *eventual* influence upon American society. The doctrine of "conservation of nature" was an American part of a major revolution in thought in the Western world against the then dominant social philosophy of the self-regulating market economy. Marxism was one European part of that revolution in ideas. In the same period began the now successful revolution against the idea that labor is merely a factor input to the production function in a purely competitive market, and that wages are, according to natural law, merely a factor return from a laissez faire distribution system. And as with labor, so with the "land" factor of classical economics. Conservation views rejected the idea of nature as purely the classical market-place phenomenon "land."

With the vantage of hindsight, Karl Polanyi writing 50 years later, describing the larger revolution of Western society against the self regulating economy, never even mentioning conservation or any of its adherents, has phrased the essence of the conservationists' revolutionary rejection of land laissez-faire with wonderful succinctness and accuracy:

> 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.
>
> Traditionally, land and labor are not separated; labor forms part of life, land remains part of nature, life and nature form an articulate whole. Land is thus tied up with organizations of kinship, neighborhood, craft, and creed—with tribe and temple, village, guild, and church. . . .
>
> . . . The economic function is but one of the many vital functions of land. It invests man's life with stability; it is the site of his habitation; it is a condition of

his physical safety; it is the landscape and the seasons. We might as well imagine his being born without hands and feet as carrying on his life without land. And yet to separate land from man and organize society in such a way as to satisfy the requirements of a real-estate market was a vital part of the utopian concept of a market economy. (Karl Polanyi, *The Great Transformation: The Political and Economic Origins of Our Time*, Boston: Beacon Press, 1957, p. 178. First published in 1944.)

As might be expected from the features of the conservation movement described above, there is not, in the vast conservation literature of the period 1890–1920, a definitive and rigorous economic analysis of what natural resource economic scarcity is. Rather, scarcity doctrine arises in a variety of ways out of more practical, less academic writings.

Limits. The conservation literature of the period 1890–1920 abounds with quantitative estimates and descriptions of the nation's endowment of natural resources, and exhortations to improve these estimates. One of the important practical contributions of the conservation movement, according to its leaders, was the inception of a program to inventory the nation's natural resource wealth. The historic Governor's Conference and Inland Waterways Conference were responsible for literally thousands of estimates of the physical quantities and characteristics of natural resources within the nation's boundaries. And the non-quantitative discussions continually emphasized that these estimates, and the ones proposed to be made, represented the nation's natural resource wealth. It is quite clear from the record that economic natural resource scarcity was equated with these estimates of finite physical resources within the nation. As with Malthus, finite natural resource physical limits constitute economic scarcity. But the definition of resources differs:

> We have a limited supply of coal, and only a limited supply. Whether it is to last for a hundred or a hundred and fifty or a thousand years, the coal is limited in amount. . . . (Pinchot, *The Fight for Conservation*, New York, Doubleday Page, 1910, p. 43)
>
> We have timber for less than thirty years at the present rate of cutting. The figures indicate that our demands upon the forest have increased twice as fast as our population.
>
> Our supplies of iron ore, mineral oil, and natural gas are being rapidly depleted, and many of the great fields are already exhausted." (*ibid.*, pp. 123f.)

The conservationist concepts of limits and thereby economic scarcity are, unlike Malthus', multi-dimensional. Natural resources are specific in type, location, qualities, and relationships, one to another; and economic scarcity (limit) characterizes all the dimensions. Thus one type of natural resource may be more scarce than another, one quality more scarce than another, and so forth.

Ecological balance. As we have learned in the past few generations (in considerable degree from the stimulus of the conservation movement and its educational efforts), there are small and large systems of interdependency among nature's biological organisms and its geological and atmospheric features. Forest watersheds, for example, play an important role in moderating and equalizing water flow from uneven rainfall by initial retention and slow release. In the absence of forest (or other plant) cover, soil is washed into the rivers, rivers flood and cave their banks, and so on. The conception of ecological balance has been widely presented in scholarly and popular literature.[18]

Additional meaning is thereby given to the doctrine of economic scarcity by the conservation view of nature as a system in ecological balance. The analogy of a chain as strong as its weakest link is relevant. Quantities and qualities of individual natural resources are dependent one upon another. In a dynamic world, constraints additional to the over-all limits described above are imposed by the requirement of "balance." This "scarcity" in no way depends upon man. It derives from interdependencies. It would be true in a dynamic world even if man did not in a substantial way modify nature.

Ecological damage and destructive utilization by man. In the conservationist view, stated in an extreme way, nature sans man was a world optimally balanced ecologically. Thus it follows that modern man's activities, however prudent, are necessarily damaging to natural ecological balance, and the ecological system is a weakened one. This, then, constitutes an additional component of the economic scarcity doctrine. The scarcity of limits (above) is initially tighter because of the constraint of balance (above), and is further aggravated by upset of ecological balance from civilized man's presence.

A few examples will be helpful. Civilized man eliminates forests and puts the Great Plains under the plow, and thereby changes nature's balance. Buffalo and other wild-life disappear, soil is lost, and rivers silt. The point here is *not* poor management. It is that nature's ecological system once supported only several million nomadic inhabitants in the United States area, and today it has almost 200 million industrial ones.

The economic scarcities arising from the limits of nature and the constraint of ecological balance are further inevitably subject to aggravation by modern man's destructive utilization of mineral resources. Fossil fuels once burned are forever lost. Metallic minerals can furnish repeated

[18] E. P. Odum, *Fundamentals of Ecology*, Saunders, 1954; J. H. Storer, *The Web of Life*, Signet Books, 1956.

use by secondary recovery; nevertheless they are eventually dissipated by corrosion, wear, and other loss. This generation of additional economic scarcity is thus a necessary consequence in a society which utilizes non-renewable mineral resources. The rate of such deterioration in resource availability can be moderated only as society chooses to consume less of these natural resources.

Waste and wise use. All of the foregoing economic scarcities occur even under conditions of wise use of resources. In conservation doctrine, the above scarcities are in practice inescapable. The limits of the world are physical bounds. The facts of ecological interdependencies are physical. Man's weakening of the natural ecological system occurs because of the physical drains occasioned by his large numbers and industrialized society.

But these scarcity forces are greatly aggravated by waste. In conservation literature, waste is given much attention as a source of economic scarcity of natural resources. This is not to say that there is attributed to waste more importance than "limits" or "ecological balance" or "upset of balance" as the origins of scarcity. Rather, waste is emphasized because the other origins of scarcity tend to be a non-active, constraining type, whereas waste is an active input to the generation of scarcity. In this sense, waste is similar to the pressure of large modern societies in weakening ecological balance and exploiting irreplaceable mineral resources. Like these scarcity forces, waste depends upon man's activities. But unlike them waste is easily avoidable by "wise use." Waste is man's foolishness in aggravating an already existing and ineluctable situation of natural resource scarcity.

What constitutes waste? The conservationist slogan answer of "unwise" or "inefficient" use does not carry us very far. I have therefore distilled four types of "waste" from the enormous conservation literature of the period to illustrate the meaning of the term in conservation doctrine.

Destructive use of natural resource. One type of waste is destructive utilization of a natural resource where it would be possible to procure *approximately the same kind* of product or service by non-destructive use of that resource, of a renewable resource, or of another, more plentiful resource. If arid grazing land is turned to crop production, with subsequent erosion, this is waste. If hydropower dams are permitted to silt with eventual reduction or total loss of their output, this is waste. If coal, oil, or gas, irreplaceable in nature, are used to generate electric power while undeveloped water power sites remain unexploited, this is waste.

The list of examples can be greatly multiplied, by means of the following simple rules I have concocted of what conservationists meant by "waste avoidance" and "wise use":

A. renewable resources, such as forests, grazing land, crop land, water, should not be physically damaged or destroyed;

B. renewable resources should be used in place of nonrenewable ones, insofar as *physically* possible;

C. plentiful mineral resources should be used before less plentiful ones, insofar as *physically* possible.

These rules are not the ones of a laissez-faire economy. Such an economy is guided by revenue maximization and cost minimization in the producing sphere, and utility maximization and freedom of choice in the consumer one. In conservation doctrines, such a society is wasteful and generates natural resource scarcity.

Physical mismanagement of renewable resources. The second type of waste is failure to procure the maximum sustained *physical* yield of useful extractive products from nature's renewable resources. Whereas the first type of waste includes over-exploitation of renewable resources to the point where their capacities are reduced, this type of waste is under-exploitation. Production of crops, fish, livestock, timber, and hydropower should be maximized to the limits of sustained physical yield from the respective resources. In two ways, it is wasteful not to partake fully from nature's ecological bounty. If nature's perennial yield is not used, then this is viewed as waste in an elemental sense, as leaving fruit to rot on the tree or vine is waste. And if the renewable resources are not used to the maximum of their sustained physical yield potential, then non-renewable resources will tend to be drawn upon.

Physical mismanagement of non-renewable resources. As the second type of waste characterized mismanagement of renewable resources, so the third type of waste which generates resource scarcity relates to mismanagement of non-renewable ones. Waste occurs with respect to mineral resources from failure to maximize the physical yield of extractive product from the physical resources which are destroyed. As noted earlier, there is serious doubt whether the pools of oil in the earth should be tapped so rapidly. But to the extent that a pool is tapped and drawn upon, then it is wasteful, and productive of scarcity, not to maximize the volume of petroleum eventually withdrawn from the pool. Again, this is quite a simple and straightforward notion. If a resource is to be used, then let it be used, not spoiled. To conduct oil production in such way as to make only 20 per cent of the pool recoverable, or coal mining so as to leave 50 per cent of the deposit underground and unrecoverable—these are waste and generate scarcity.

Unwise use of the products of resources. The first type of waste, above, resulted from not using resources in proper order of priority, and the second and third from exploiting resources unwisely. The fourth type of waste in conservation doctrine results from unwise use *not* of the natural resource itself, but of the extractive products yielded by it. Gas should be withdrawn for use only, and not flared. Mineral fuels were withdrawn from nature to furnish useful heat; to burn them in furnaces of low thermal efficiency is wasteful. Metals were mined and timber cut to provide useful services; since they are physically recoverable as secondary materials and scrap, they must be so recovered or there is waste. This is further extension to the utilization sphere of the principle of maximizing *physical* yield and minimizing *physical* destruction of natural resources.

Unlike the other scarcity forces enumerated earlier, waste is remediable. Waste results from ignorance or apathy of man in his individual behavior; from physical inefficiency in use of natural resources because of improper criteria built into the laissez-faire system; from inefficient government activity and inadequate government intervention in the economic sphere; and other causes.

Social effects of scarcity. What, according to conservation doctrine are the consequences of natural resource scarcity, from the facts: that nature is limited; that nature is an ecological balance; that modern society is damaging to that ecology and necessarily destructive of mineral resources; and that wasteful behavior aggravates scarcity?

As the result of scarcity, major portions of the population are unnecessarily separated from livelihood on the land and association with the land, with resultant evil social consequences. There is a reduction in the relative numbers of the most valuable group of citizenry, the independent farmer, and a weakening of agrarianism—the core of national life. Ethical values are perverted by crass materialism and urban pleasures. There is increased industrialism and urbanism, an undesirable development, and a poor trade for the former agricultural society. The beauty and wonder of Nature are increasingly lost, to ourselves and our descendants. There is psychic damage, to the individual, the family, the community, and the nation.

Effects of scarcity on economic structure. The economic effects of scarcity, in conservation literature, are of two kinds: those involving economic structure and organization of the nation, and those involving productivity, cost, and price.

The conservationists found that, unless remedial steps were taken by government and the citizenry, the forces of resource scarcity, coupled with the high efficiency of the trust form of industrial organization, would produce monopoly, and maldistributions of income among the populace so severe as to be inconsistent with a democratic society. From scarcity and monopoly control there would increasingly develop larger and larger profits—unearned increment. The eventual outcome would be severe maldistribution of land and property ownership, and of income.

Cost and productivity effects of scarcity. In conservation literature, resource scarcity was a powerful force working to reduce labor productivity and to increase the real cost of all products. The growing economy would increasingly press upon already scarce resources. Destructive utilization of minerals would make them more scarce. Encroachment of cities and highways would further reduce available resources. And waste would be

the final turn of the screw to grind the American society to poverty and misery. Output per worker would decline steadily. The real cost of commodities would rise steadily. Real income per capita would steadily fall, to subsistence levels.

Interpreting conservation economic doctrine. My purpose in probing into the First Conservation Movement was to improve understanding of this important source of the doctrine of natural resource scarcity, both because the movement was an important development in the nation's history and because much contemporary view derives from that movement. I wanted to unearth the assumptions of this doctrine and observe the logic of the analysis. I was interested in the elements and details from which the crucial scarcity generalizations were compounded And I was interested in the conservation movement's own antecedents and major sources of ideas. The quest, I think, has been at least partly successful. I have dug out premises, ascertained the structure of the analysis, and detailed the conservation theses in various ways. I have learned the important fact that quantitative economic analysis of antecedent nineteenth century economic evidence did not in any rigorous way enter the analysis of economic scarcity and economic effect.

But a word of warning is appropriate. For a variety of reasons, it is extremely difficult to ascertain and interpret the economic doctrine of scarcity of the First Conservation Movement. The leading figures of the movement were not economists, and there is no evidence in their writings that they had any substantial training in economic analysis. This means that there is little or no recourse to rigorous economic formulation and statement, and therefore that the meanings of terms are sometimes uncertain to an economist-reviewer of the literature.

Despite the difficulties and uncertainties, I believe that I have accurately characterized the essential elements in the conservation doctrine of natural resource scarcity. The movement was enormously successful in its own time. And its influence reaches to the present. As in President Taft's time, so today "A great many people are in favor of conservation, no matter what it means."[19] To the extent to which I have been successful, then, the discussion should be not only a useful contribution in its own terms, but also speak, in some degree, to conservation beliefs which most of us hold as revealed doctrine.

The views of most other economists on the conservation movement differ from the interpretive summary I have presented above. So far as

[19] *Outlook*, May 14, 1910, p. 57, quoted in J. Ise, *The U.S. Forest Policy*, Yale University Press, 1920, p. 373.

I know, most professional economists who have made important contributions in the economics of natural resources tend to consider conservation as concerned with the economic problem of *time rate of use* of natural resources. I find this interpretation of the conservation movement to be incomplete, and possibly misleading.

Part of conservation doctrine was indeed this familiar proposition: it can be constructed from the Malthusian case by simply assuming that some resources can be, and others necessarily are, destroyed by use. In Chart 1, for example, let it merely be assumed that the resource axis gradually is "eaten away"; or in Chart 2, that resources are used up, and the economy is forced onto lower level resource isoquants. In both cases the expansion paths fall to lower levels. This, essentially, is the time rate of use problem—that there is a fixed stock whose exhaustion and changing availability depend on the time distribution of use.

But part of conservation doctrine, and the *gestalt* in which time rate of use appeared, go quite far beyond the time rate problem. To characterize conservation in this way has two defects. It credits conservation with contributions made earlier and more systematically by Malthus, Ricardo, and Jevons, among others. And it fails to credit conservation with an important and partly successful revolution in social ideas and applied political economy.

The concept of "ecological balance" is importantly different from time rate of use of a stock, and moreover is not even a very familiar idea in academic work on economics of natural resources. The additional idea of ecological damage was also a novel, or at least an undeveloped one, for economic thought. The conservationists even modified the classical notion of "limits": the resource "limits" conceived by the conservation movement as relevant were those within national boundaries, and the economic objective was national self-sufficiency—hardly consistent with the trade assumptions of classical economics. Of the hundreds of papers in the *Proceedings* of the 1908 Conference of Governors in the White House and the three-volume 1909 *Report of the National Conservation Commission to the President*, only four (by count of titles) looked outside the United States, and these did so primarily from the point of view of United States interest.

With respect to "waste" and "wise use," the characteristic economist view is that this conservation doctrine has little meaning and is of no value for economic analysis. With respect to meaning, I continue to differ. The codification I have given to waste has meaning—government administrators could follow these rules (and some do, with results that in my view are frequently unfortunate). Of course, the rules are at variance

with economic common sense and understanding if these are based on laissez-faire premises. But this is the essence of the matter—conservation doctrine did, in significant degree, reject laissez-faire, consumer sovereignty principles; it questions the quality, even more than the mechanics, of modern civilization. This is why the intelligent men among them could plead for their view of "wise use" and avoidance of waste, to the mystification of later economists.[20]

5. *Two Concluding Observations*

In Malthus' time, and to a lesser extent during the period of the conservation furor, a considerable part of "final" or virtually final output was natural, mainly agricultural, goods—foodstuffs, natural fibers, timber, game, and so on. To this extent, increase in these outputs could be, and was, viewed as identical with economic growth. Now as to how these goods would be further processed, again there was a simple answer. They would be *mechanically* shaped from the gifts of nature—the wheat grain would be taken out; the hide separated from the meat; the timber sawed to size; the fibers combed, twisted, and woven; and so forth. Turning to the derivation of the basic substances from nature, man's role here also was a *mechanical* one. Thus, if a man stood on a square mile of land, or a nation on 3,000,000, the natural resources relevant for economic activity could be easily identified and measured. They were acres of crop land or pasture, board feet of standing timber, and the like.

A great deal has happened in advanced Western nations since these times to the meaning of final goods, the methods by which they are produced, and the definition of natural resources. With respect to the meaning of goods, more than 90 per cent of the increase in real GNP in the United States since 1870 has been of nonagricultural origin. With respect to the method of transforming materials into final goods, this has

[20] Where the economist defines the term "conservation" narrowly, with explicit warning of its delimitation, there can be no confusion. I agree, for example, with E. S. Mason, who has recently written, "If . . . conservation is defined as 'a shift in the time distribution of use of a resource in the direction of the future,' we have a set of issues that can be analyzed, but one which represents only a small part of the traditional concern of conservationists." But note that the subject thus defined omits the principal concerns which have rallied the major groups in the historical and contemporary conservation movements, and which have made conservation a major public policy issue. I am arguing that the larger questions can also be defined and merit analysis by economists. I thus think Professor Mason is too strong in his comment that, "If conservation is defined as a 'wise use of resources' nothing escapes its ken, but the invitation to subjective value judgements is so sweeping as to leave little room for rational analysis." Both quotations from "The Political Economy of Resource Use," in *Perspectives on Conservation*, The Johns Hopkins Press, 1958, pp. 157f.

become far less a purely mechanical one, and to a considerable degree a controlled heat or electro-chemical process. Finally, the natural resource building blocks have changed radically—they are atoms and molecules. That is, the natural resource input is to a far less degree acres, and to far greater degree particular chemical compounds.

This has changed the meaning of "natural resources" for societies which have modern technologies and access to capital. We now look more at contained molecules of iron, magnesium, aluminum, coal, nitrogen, and so on, and at their naturally existing chemical combinations, than at acres or board feet. While in a sense, the same ultimate world limits still exist, in a more significant sense they do not. How many taconite iron atoms or sea water magnesium atoms and bromine molecules constitute plenitude, and how many scarcity? In significant degree, further, even the ultimate limits are different from Malthus'. His natural resources were conceived for a two-dimensional world. Ours is a three-dimensional one, sustained by subsurface resources. His society could reach natural resources to only insignificant distances above and below his acres. We have multiplied our "reach" by many thousands.

I am greatly impressed by a "new" form of resource scarcity—the problem of space, privacy, and nature preservation. Actually it is not new, as the following quotation from Mill indicates.

> There is room in the world, no doubt, and even in old countries, for a great increase of population, supposing the arts of life to go on improving, and capital to increase. But even if innocuous, I confess I see very little reason for desiring it. . . . A population may be too crowded, though all be amply supplied with food and raiment. It is not good for man to be kept perforce at all times in the presence of his species. A world from which solitude is extirpated, is a very poor ideal. Solitude, in the sense of being often alone, is essential to any depth of meditation or of character; and solitude in the presence of natural beauty and grandeur, is the cradle of thoughts and aspirations which are not only good for the individual, but which society could ill do without. Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture ploughed up, all quadrupeds or birds which are not domesticated for man's use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture. (J. S. Mill, *Principles*, London, 1871, Bk. IV, ch. 6)

It may surprise this audience to learn that by far the largest fraction of contemporary conservationists are concerned with this form of resource scarcity, and not with minerals or agricultural land shortages.

This category of doctrine already includes a "quality scarcity" concern over fouling streams, disfiguring land, and air pollution. And I guess it should also include concern over atmospheric and land contamination by radioactivity.

As to whether this is a proper area for economic analysis, this is obviously a decision for the individual economist. It has been sanctioned as a problem in political economy from Mill to Pigou at least. It is part of the problem of social investment and communal resource use which is increasingly concerning economists. Finally, it is a problem of sizable economic dimensions.

COMMENT

EDGAR M. HOOVER, Harvard University

Barnett's paper has a rare combination of qualities—it is both careful and provocative. I had hoped I might find in it some occasion to pick a quarrel with him, but shall have to leave that to others. I propose to accept his findings about the origin of the scarcity doctrine, and to go on to ask, "What can we now conclude about whether there is, or is not, a 'population problem' or a 'resources problem' to worry about?"

In a commendably rigorous way, Barnett has deflated the Malthusian bogey of population growth eventually reducing the world to a state in which the bulk of the population everywhere is on the edge of starvation. He has shown that no less than five conditions would have to prevail in order to make the bogey operate according to specifications, and that each of the five may be questioned. In essence, there is one loophole on the demographic side, and at least two on the economic side.

Does this dispose of the "population problem" and the "resources problem"? I thought it might be fruitful to try to set up a model, as Barnett has done—but in this case a model defined by the absence of any population or resources problem. More specifically, what are the basic conditions that would give us an economy in which no case could be made for any kind of policy designed to restrict either population growth or resources exploitation? How realistic are these conditions? In just a few minutes I cannot do the sort of model-building job he did, but can merely heave out a few pieces of rough building material.

First of all, we shall not find the necessary basic conditions for complacency in the densely populated backward economies, where population pressure and the resource limitations are all too evident and Malthus would feel right at home. So we have to restrict our inquiry to the range of conditions that might apply in advanced countries.

Now, a conceivably sufficient condition for absence of a resources problem would be that resources were not scarce—that is, that they were free goods and exercised no constraint upon output. This can be ruled out as both trivial and incompatible with the conditions of an advanced industrialized economy. (I interpret Barnett's contention about resources scarcity to mean not that no scarcity exists, but that resources are not getting *more* scarce as time goes on.)

On the demographic side, a possibly sufficient condition would be that population growth would automatically slow down to a halt while income was still high. Until about 15 years ago many people might have thought this a realistic assumption or "law" of population growth in advanced countries. In view of subsequent demographic experience, however, it seems exceedingly improbable.

What about the technological escape from Malthus? (Technological progress includes here, of course, the creation of new resources.) Is it enough if we can count on technology advancing indefinitely? No. In order to make population growth a matter of no concern, we should have to assume much more—namely, that the rate of technological advance is positively geared to the rate of population growth. Is this a realistic assumption? I know of no basis for concluding that technical progress responds in this way.

What, then, about the scale economies (internal and external) of larger population? If we could assume that these scale effects operated (apart from technological advance) so as to produce at least constant returns to labor in the social production function, then we should not have to worry about any economic burden from overpopulation. This seems in fact to be a necessary condition for our "no-problem" model, in view of the fact that none of the alternative conditions we have so far considered seems at all likely to apply in the real world.

This question of the form of the social production function is a complex one. We might ask first, what about the growth of capital? If the rate of capital accumulation could be assumed to vary in close response to the rate of population growth, then we could (as Barnett does) simply consider labor and capital together as one input. But this does not seem to be the case, judging from experience. The observed association is slight, if any. Faster population growth can not be counted on to produce correspondingly faster capital accumulation.

So perhaps everything hinges on the scale economies of a larger population per se. What are those based on? Adam Smith had a pretty good answer: the more complex division of labor, which in turn depends on

widening the range of contacts among individual units of production and consumption.

But does the "extent of the market," to use Smith's term, depend really on the ratio of population to natural resources? If it did, then we might have here a population-growth effect that would transform diminishing returns into constant or even increasing returns to population.

Actually the range of contacts and division of labor depend on a somewhat different sort of ratio: population relative to area and to the costs of transport and communication. Natural resources, as Barnett points out, have less and less direct association with area. The really crucial factor is the cost of contact. Is it affected by population density?

It is very significantly affected, because most means of transport are themselves subject to economies of scale (that is, traffic density). For example, in the nineteenth century the actual and anticipated growth of population in the United States warranted the building of railroads, which greatly widened the spatial range of division of labor and contributed to an over-all rise in productivity. With a very sparse and static population, this would not have occurred.

I suggest, however, that this experience may not be a very good basis for generalization. Subsequently developed means of contact like motor transport, air transport, and radio do not seem to be anywhere near so dependent on high traffic density to achieve economy. Moreover, it is possible to run into *increasing* costs from traffic density when the amount of space required for transport itself becomes a large factor. Road and also air traffic in our larger urban areas would seem already to be in this stage, and population densities in such areas are in process of thinning out rather than increasing. It would seem, then, that we cannot assume that population growth in technologically advanced countries will continue to produce scale economies to offset against diminishing returns.

Here it is useful to remind ourselves that that peculiarly natural resource, space, plays a unique and dual economic role. On the one hand, space is a "negative resource" or natural handicap—it embodies distance to be bridged in order to effect economically useful contacts. When space in viewed in that aspect, its intensive occupancy by people appears as a source of increasing returns (to population). But at the same time, space has value as elbow room (entirely apart from any useful materials it may contain), and in this aspect increased density of occupancy leads to diminishing returns. In closing, I should like to second and underline Barnett's reference to the steadily increasing importance of this second aspect, especially from the consumer welfare standpoint.

Space-scarcity is in the last analysis inexorable, and is being accentuated in every advanced society by rising standards of income, leisure, and personal mobility.

To sum up: Barnett has shown that, despite the warnings of extreme Malthusians and conservationists, we are not necessarily damned—(at least, not if we can confine our concern to the more advanced countries). I have shown, less adequately, that we are not necessarily saved either. I expect we would both agree that complacency with regard either to population growth or resources use is unwarranted.

THEODORE W. SCHULTZ, University of Chicago

This paper reminds one how indebted we are to talent from the exact sciences for revealing to us the ominous scarcity of natural resources. Barnett's paper opens with a selection of statements of the relationships between population and food (natural resources) drawn from distinguished physical and biological scientists. We expect these to be models of the best in scientific analysis; axioms explicit and exact, concepts clear and identifiable, and the connections rigorous and precise. The thinking of this elite should, therefore, be sobering for such as us. In model one, the growth of the human population in the earth's ecological economy is represented as a cancer. Model two informs us that if we breed like rabbits, in the long run we have to live and die like rabbits. Model three reveals to us that humanity behaves as if it would not rest content until the earth is covered completely and to a considerable depth with a writhing mass of human beings, much as a dead cow is covered with a pulsating mass of maggots. No doubt, the exact mode of thought of scientists gives them bold and compelling imagery. This remarkable talent should not be lost for poetry. Population and food, however, might better be spared.

A major part of Barnett's paper is devoted to an examination of the first American conservation movement. Three things emerge: he finds that this movement made many useful contributions; it did much to shape and advance the doctrine of economic scarcity of natural resources; and economists generally have failed to see the real contributions that this movement made. I shall contend that in reaching these conclusions Barnett may have sold economics short in those areas of analysis where it has some relevant things to say about the ideas attributed to this movement. I am asking for economic criticism.

Economic criticism is important. It is based on a fairly well-defined and established set of standards. There are, of course, other important

standards of criticism. However, in the case of the doctrine under review and in examining and evaluating the role that the conservation movement played in it, economic standards are among the appropriate ones and as economists we should have some special competence in this form of criticism. The approach that Barnett uses in this paper does not examine critically the ideas that he attributes to the conservation movement and that presumably support the doctrine under review.

The conservation movement was, as Barnett points out, an assemblage of many ideas. These ideas presumably had some connections with the doctrine of economic scarcity of natural resources. I have no doubt that they did, but I am puzzled because it is not at all clear to me from this paper how these ideas are connected with this particular doctrine.

Any growth in population increases the ratio of the number of people to the area (surface) of the earth, and, of course, also, to the cubic content of the earth. Surely, the doctrine under review was not based on any notion as crude as that, although the poetic images of those scientists to whom I referred at the outset would appear to qualify on this score. What, then, was the substance of this doctrine of economic scarcity of natural resources? Did it pertain to free versus scarce (not free) natural resources, or to natural resources becoming scarcer relative to other resources, or did it encompass both of these relationships? These questions, however, go unanswered, and it is, therefore, not clear what is meant by this doctrine.

For my purposes I shall define this doctrine as representing views based on the belief that natural resources become scarcer relative to other resources as population increases and economic growth proceeds. Resources, whatever their form, natural or otherwise, are here viewed not as free but as scarce components that render valuable services in production.

Barnett observes that the first conservation movement was in opposition to the "then dominant social philosophy of the self-regulating market economy." But they looked upon this malfunctioning of the market economy as affecting adversely all resources and not exclusively or especially that of natural resources. The view that there are absolute limits to the quantity of coal, iron, water, and presumably also to that of agricultural products and wood implies a set of loose connections that may or may not support the doctrine. It is, therefore, the task of economic criticism to make clear that these particular connections in themselves do not necessarily result in, say, coal becoming scarcer relative to labor as population increases and economic growth proceeds. The idea of

ecological balance would appear to represent a form of external economies but it does not necessarily support the doctrine. Then, too, the idea of waste and wise use, when it is given economic content, is applicable to each and every resource; it is in no way specific to natural resources. The list of bad social effects of scarcity and of monopoly are not restricted to scarcity or monopoly in the area of natural resources. What this says is: (1) The doctrine means that natural resources become scarcer relative to other resources, and (2) The particular ideas attributed to this movement pertain almost entirely to other issues.

The principal difficulty in classifying and evaluating the ideas of this movement is conceptual in nature. What is needed at the outset is a clear and identifiable concept of economic scarcity applicable to particular natural resources. This concept must specify scarcity in terms of values, that is, in relative prices, and the type of scarcity that is relevant pertains to the changes in values that are associated with increases in real national income (a measure of economic growth) and increases in population. Can one use a classification of products, that is, of raw materials, semi-processed, and finished products? As a very rough approximation, changes in the relative prices of these classes of products may be of some help. But these prices can mislead one seriously. We must specify the prices of the services rendered by a particular natural resource relative to the prices of the services rendered by other resources (of labor and of reproducible durable capital, for example).

Once we see clearly that it is the change in the relative price of the service of a natural resource that is the key to the concept, it follows that it is possible for the evidence (economic growth data) to reveal rising, or constant, or falling relative prices for the services of a natural resource. Presumably, ideas in support of the doctrine of economic scarcity of natural resources would attempt to show that the relative price of the services of natural resources had been rising and would continue to rise. But this is not the burden of the ideas that Barnett attributes to the conservation movement; on the contrary, these particular ideas are not inconsistent either with constant or falling relative prices of the services of the resources under discussion. Accordingly, these ideas do not argue either for or against the doctrine.