Comments on "Lethal Model 2: The Limits to Growth Revisited" by William D. Nordhaus

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Since we are concerned with indicators of changing relative scarcity, it may be of interest to note that I purchased my copy of *Beyond the Limits*[1] about one month after Nordhaus purchased his, but I was charged not $20 as was he, but $10. In keeping with this observation, my comments on Nordhaus's effective critique of *Beyond the Limits* are from a microeconomic perspective.

The Nordhaus paper[2] provides better guidance to the questions of concern than does either *Beyond the Limits* or its best seller predecessor, *The Limits to Growth*,[3] and it does so with less than five percent as many words. Having noted this, what is there left for me to add? Since I agree with the criticisms that Bill Nordhaus makes of the *Limits I* and *II* models, I asked myself if any exceptions, any special cases, existed in which the broad claim of the Limits analysis -- "overshoot and collapse" -- might actually make sense.

One of the central predictions of the Limits studies is increasing scarcity of natural resources, both nonrenewable and renewable. Indeed, the Limits authors originally predicted exhaustion of numerous mineral and fossil fuel resources, resulting in a precipitous collapse of the economic system. In venturing this

1. Meadows, Meadows, and Randers (1992).
2. Nordhaus (1992).
3. Meadows, Meadows, Randers, and Behrens (1972).

prediction, the Limits authors gave little attention, as Nordhaus notes, to the crucial roles played by exploration and discovery, technological progress, and substitution. For the authors of the Limits studies, there is no smooth transition, no gradual slowing down of activity associated with shifting from one resource base to another. Of course, this flies in the face of the economic theory of natural resources; but, more important, it flies in the face of experience.

What, then, is the source of the Limits modelers predictions of increasing scarcity, of approaching exhaustion? First, it is well known that the "static reserve index" -- simply dividing current reserves of some nonrenewable natural resource by current annual use rates -- is quite useless as a measure of scarcity. It ignores the responsiveness of both the reserve stock and the use rate to price changes. Hence, the static reserve index underestimates by a dramatic margin the "time until exhaustion." In fact, these indexes have been relatively *constant* or *increasing* over time.

If we check today to see how the *Limits I* predictions have turned out, we learn that (according to their estimates) gold, silver, mercury, zinc, and lead should be thoroughly exhausted, with natural gas running out within the next eight years. Of course, this has not happened. Reserves have increased, demand has changed, substitution has occurred, and recycling has been stimulated.

There is abundant evidence, as the Nordhaus paper illustrates, that the "economic scarcity" of natural resources has been -- to a large degree -- declining, *not* increasing. We have evidence of this going back to the pioneering study by Harold Barnett and Chandler Morse, which found declining real unit costs of extraction over time for *nonrenewable* resources.[4] On the other hand, more recent evidence indicates that the time trend is *not* monotonic, particularly in terms of relative prices. Indeed, some of the more recent analyses have detected evidence of increasing scarcity.[5]

It is interesting to recall, in this regard, Robert Pindyck's work, which demonstrated in theoretical terms why resource prices

4. Barnett and Morse (1963).

5. See, in particular, Smith (1980).

were likely to decline during an initial period but increase later, as the marginal product of exploration begins to decline and as technologies of recovery begin to exhibit diminishing returns.[6] Margaret Slade later examined the temporal price paths of numerous resource categories and verified for many resources the U-shaped pattern predicted implicitly by Pindyck's analysis.[7]

Research with other scarcity indicators -- including marginal discovery cost[8] and marginal extraction cost[9] -- has confirmed these patterns. Of course, as Richard Norgaard has argued, economic scarcity measures are accurate indicators of scarcity only if the information upon which the market is exercising its judgement is itself reasonably accurate.[10] In any event, what is most striking with all of this research is that it is the renewables, not the nonrenwables, that seem most prominently to exhibit increasing scarcity (including forestry, agriculture, and fisheries).

This brings me to a case in which the Limits prophecy of "overshoot and collapse" *can* make sense. It is with a subset of renewable resources: biological ones, such as species. The natural growth functions of a substantial number of species exhibit what has come to be known as "critical depensation."[11] This refers to a growth path (plotting the time rate of change of the stock, or population, against the stock level) in which below some critical level of the stock of the species, the natural rate of growth is negative. The result is a set of three equilibria. Two are stable: extinction (the origin) and the "carrying capacity" -- the maximum stock that habitat can support. The third equilibrium is the critical one: the minimum viable population. It reflects the reality that the large ranges of habitat that exist for some species, such as whales, means that relatively small numbers are insufficient for mating pairs to yield

6. Pindyck (1978).
7. Slade (1982).
8. Devarajan and Fisher (1982).
9. Barnett and Morse (1963); Johnson, Bell, and Bennett (1980).
10. Norgaard (1990).
11. Clark (1990).

birth rates that exceed the natural rate of loss to predators and disease. This is an unstable equilibrium.

In the nineteenth century, hunters did not shoot down each and every passenger pigeon, but nevertheless, the species was driven to extinction. A similar pattern has doomed other species. A contemporary case in point is the blue whale. Harvesting has been prohibited under international agreements since 1965, but the stocks continue to decline toward extinction. Thus the case in which some kind of "overshoot and collapse" might actually occur is the case of renewable -- in particular, biological -- resources.[12]

The irony is that the so-called "exhaustible" resources are nothing of the kind. They are really quite inexhaustible, for the host of reasons economists have noted for at least a half century. That is why they are better labeled "nonrenewable resources." It is the renewable resources that in some cases are very much exhaustible -- not because of their finiteness, but because of the way they are managed. The problem typically is not physical limits on resource availability; on the contrary, improper incentives and inadequate information are more often the source of the declining stocks.[13] Thus the reason why some resources -- water, forests, fisheries, and some species of wildlife -- are threatened while others -- principally minerals and fossil fuels -- are *not* is that the scarcity of nonrenewable resources is well reflected in market prices. This is much less the case for the renewable resources, which, in fact, are characterized by being open access or common property resources.

This conclusion prompts at least two responses. First, it can be said that this is not really what the Limits authors had in mind when they predicted "overshoot and collapse." This is certainly true. Second, it could be said that the necessity to identify such a special case in order to validate -- in a sense -- the Limits conclusions is itself evidence of the overall legitimacy of the Nordhaus critique. This is also correct.

12. A broader class of biological growth functions, exhibiting "generalized depensation," can result in oscillation, another of the Limits modelers' scenarios.
13. Tietenberg (1992).

Having said that, I wish to turn to an area that is best categorized as not even an exception to the Nordhaus critique, but as an extension of it. Something that differentiates both the times of publication and the contents of *Limits II* from *Limits I* is an expanded concern beyond nonrenewable and renewable resources to environmental resources, such as clean air and water. Here the empirical evidence is growing that -- contrary to the assumptions of the Limits modelers -- economic growth does *not necessarily* produce greater pollution.

For some environmental problems, such as inadequate sanitation and unsafe drinking water, there is a monotonic and *inverse* relationship between the level of the environmental threat and per capita income.[14] This relationship holds both cross-sectionally (across nations) and for single nations over time. For other environmental problems, the relationship with income level is not monotonic at all, but a "hill." At low levels of income, pollution increases with per capita income. Then at some point, pollution begins to decline with further increases in income. This is true of most forms of air[15] and water pollution, some types of deforestation, and habitat loss.

Pollution increases from the least developed agricultural countries to those beginning to industrialize fully, such as Mexico and the emerging market economies of Eastern Europe and parts of the former Soviet Union. After peaking in such nations, pollution is found to decline in the wealthier, industrialized nations that have both the demand for cleaner air and water and the means to provide it. Finally, for another set of environmental pollutants, including carbon dioxide emissions, the relationship between per capita income and emission levels *increases* monotonically, at least within the realm of experience.

In any event, for each of these cases, the respective curves are shifted downward by technological changes, as we have experienced dramatically in the U.S. for controlling point-source

14. World Bank (1992).
15. Grossman and Krueger (1992).

water pollutants. At the very least, we must conclude that the environmental picture is far less simple than the Limits modelers would have us believe; indeed, for most environmental pollutants, they are simply wrong.

The Limits analysis is particularly disappointing because the general area of inquiry -- global resource and environmental issues -- *would* benefit from more analysis. It is obviously not enough to say that markets will automatically respond appropriately to scarcity. Imperfections in markets and imperfections in public policies clearly reduce the effectiveness of these responses. Common property resources, externalities, the tax treatment of resources, and price controls are more than just rare exceptions. Unfortunately, none of the required analysis is provided by the Limits modelers.

Furthermore, the current debate surrounding the notion of "sustainability" is *not* advanced by the analyses of *Limits I* or *II*. This is unfortunate because that debate has recently moved beyond an economic critique of what is, at best, a poorly defined concept, to some attention to a set of underlying and better-defined issues.[16] The result may eventually be some common ground for discussion between economists and ecologists -- who typically hold such different perspectives -- on key issues such as the composition of social capital, intergenerational equity, and the scale of human activity.[17]

Finally, it is worthwhile to reflect briefly on the U.S. experience with pollution control policies because doing so offers the reminder that more than once -- in the environmental area, as perhaps in others -- society, in choosing public policies, has tended to "do the right thing," although for the "wrong reasons." A recent example of this is the planned cutback under the Clean Air Act amendments of 1990 of emissions of sulfur dioxide as a means of limiting acid rain. The original motivation was to protect Adirondack lakes and Eastern forests, but the evidence has pointed toward very small benefits, relative to the costs of control. More recently, however, we have

16. Solow (1991).
17. Toman and Crosson (1991).

learned that the human health impacts of sulfate particles can be significant, and may indeed provide some economic rationale, after all.[18]

This leads me to ask what the actual policy prescriptions of the Limits analysis *are*. It is not perfectly clear. The book lays out a set of "steps to avoid collapse," but some of these are impossible to translate into terms of public policy. Of those that can be translated into public policy, the first is one that is hard to disagree with, in general, anyway: "improving the signals." The Limits authors call for internalizing environmental costs in prices, presumably through taxes or tradeable permit systems. In addition, and somewhat more controversially, they call for recasting economic indicators like GNP to account for uninternalized externalities and the depreciation of natural capital.

Second, the Limits authors recommend minimizing the use of nonrenewable resources. This recommendation does not, as a general rule, make sense. The authors urge society to "recycle whenever possible," which also, of course, would be flawed public policy. Recycling has a role to play, but a limited one in extending the resource base. In terms of waste management strategies, safe landfilling and incineration should certainly be part of the overall portfolio.

Third, the Limits authors call for the prevention of "the erosion of renewable resources," urging society to maintain stocks at their current levels. Again, as a general rule, this makes no sense economically, whether for soils, water supplies, or biological species.

In a sense, I may have given the Limits modelers too much credit for these policy prescriptions because they also maintain that such "piecemeal approaches," as they call them, are doomed to failure and that only the cessation of economic growth can avoid "overshoot and collapse." Thus as Nordhaus notes, the modelers do indeed call for a cessation of economic growth. In so doing, they demonstrate a common misunderstanding among noneconomists about the nature of economic growth. They seem to think of it in terms of more and

18. Portney (1990).

more cars or refrigerators for those who already have one, *not* more efficient refrigerators, more CD's instead of record players, or more and better vaccines to prevent disease.

In conclusion, I would like to acknowledge that the first Limits study did have one positive social impact. It provided the stimulus for some leading economists to carry out work in the area of natural resource depletion. I will close my commentary on Nordhaus's excellent paper by noting that the second study is following in that tradition.

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