might surmise that grandfathering is implemented in practice because of the political influence of rent-seeking firms despite its comparative inefficiency. Woerdman, however, sidesteps this issue, which points to the essential complementarity between efficiency and distribution as policy objectives.

Finally, Woerdman has little to say about the wide-ranging evidence that market institutions characteristically fail to promote the full adoption of cost-effective energy-efficient technologies. This empirical generalization by no means provides an argument against using incentive-based policies to reduce carbon dioxide emissions. It does, however, suggest that well-designed regulatory standards can provide Pareto-improving outcomes that are unattainable through reliance on emissions taxes and/or tradable permit schemes alone, at least if the transaction costs associated with those standards are sufficiently small. Institutional economics has much to contribute to this area of research, in which the core problem is to design policy regimes that both send the right price signals and that help market participants achieve optimal outcomes at prevailing market prices.

At base, Woerdman's analysis focuses on the role of institutional constraints in the policy process while characterizing economic behavior and decisions in largely neoclassical terms. A related task is to explore how institutional economics can contribute to our understanding of the complexities of business and household behavior that are not captured by the neoclassical model. Integrating these perspectives would likely yield important insights regarding both the descriptive task of understanding the policy process and the normative challenge of designing mechanisms that optimally address the multiple objectives of environmental policy.

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Donella Meadows, Jørgen Randers, Dennis Meadows, Limits to Growth: The 30-Year Update, Chelsea Green, White River Junction, Vermont. ISBN: 1-931498-51-2, 338 pp.

Jared Diamond, Collapse: How Societies Choose to Fail or Succeed, Viking Press, New York. ISBN: 0-670033-37-5, 310 pp.

It is an interesting coincidence that these two books appeared at approximately the same time. The human-dominated subsystems on earth are facing increasingly crucial decisions. Both books are about how we got to this point and what we can do about it. Diamond's book does this with a highly readable and engaging narrative that uses the comparative method and "natural experiments" to analyze a series of case study human societies that have either collapsed or succeeded across the broad span of human history. Meadows et al. use the now familiar World3 computer model in this 30-year update of their groundbreaking first use of the model in 1972. While each of these approaches has their benefits and deficiencies, together they present a compelling picture of the choices facing modern society.

Diamond's synthesis and comparative historical analysis is a stunning transdisciplinary integration of the natural and social sciences and the humanities. Diamond does this better than anyone alive today and the book is a real tour de force. Disciplinary critics will argue that Diamond's treatment is "shallow" or merely lifted from other sources. But that is the nature of synthesis. One must sift through and integrate a huge amount of diverse information, looking for common threads and building testable hypotheses. Diamond not only read the original research; he also visited the primary researchers and discussed his syntheses with them for accuracy before going forward. In this process, Diamond more often than not is able to pose coherent theories about the reasons for the collapse or sustainability of specific historical societies. But more importantly, he is able to pose broad theories that could only have been gleaned from a broad and comprehensive comparative analysis of many societies. He then applies these theories to the current human condition and lays out their implications for our common future. For example, he identifies the 12 most serious environmental problems facing past and future societies—problems that more often than not have led to the well documented collapse of these historical societies:

1. Loss of habitat and ecosystem services;
2. Overfishing;
3. Loss of biodiversity;
4. Soil erosion and degradation;
5. Energy limits;
6. Freshwater limits;
7. Photosynthetic capacity limits;
8. Toxic chemicals;
9. Alien species introductions;
10. Climate change;
11. Population growth; and
12. Human consumption levels.

More importantly, Diamond, and several others before him (Tainter, 1988; Yoffee and Cowgill, 1988; Ponting, 1991), have emphasized that the interplay of multiple factors is almost always more critical than any single factor. Societies on the edge become brittle and lose resilience, making them more susceptible to the impacts of potential perturbations of several kinds, including climate change, political corruption, war, terrorism, or the inability to adapt social values to new circumstances.

The analysis is enriched because some historical examples exclude some of these factors while others include them all. For example, Easter Island is probably the clearest historical example of a society that collapsed due to overuse of their environment in isolation from other factors and other societies. Easter Island was the last island to be settled by

Polynesian colonists in their wave of eastward expansion. But by completely deforesting their small island home, they cut off any chance of building large canoes to return. They also ultimately destroyed their island's ability to support humans. Diamond compares the experience of Easter with the large number of other Polynesian Islands that formed arguably our best historical "natural experiment" with the factors that influence sustainability or collapse of societies. The islands varied in terms of their natural resource base, their proximity to and trade with nearby islands, and their internal social structure and governance. The effects of these factors are highly interdependent, and Diamond clearly makes the point that decisions made by societies are critical in determining their success or failure.

Diamond goes on to analyze a range of historical and present societies, including the Anasazi, the Maya, the Greenland Norse, Tokugawa Japan, Haiti, the Dominican Republic, Iceland, China, Australia, Rwanda, and Montana. He clearly identifies the multitude of factors at work in each case and his masterful and comprehensive synthesis provides lessons for modern society about the dangers of collapse, but also the opportunities to change course and achieve sustainability.

Meadows et al. take a different (but complementary) approach, using an integrated global computer simulation model—World3. The World3 model has been the subject of three influential books, beginning with the Limits to Growth (Meadows et al., 1972), continuing with Beyond the Limits (Meadows et al., 1992) and ending with this 30-year update (Meadows et al., 2004). World3 is a globally aggregated systems dynamics model, containing approximately 16 state variables (things like population, capital stocks, pollution levels, arable land), 100 variables total and 80 fixed parameters. The latest versions are written in STELLA and can be run on any PC.

Because of the influence of the original book (several million copies were sold), this model has been the topic of intense scrutiny, debate, misunderstanding, and, one could argue, willful misinformation over the years. One interesting bit of misinformation that has been persistently circulating is the idea that the model's "predictions" have been proven totally wrong by subsequent events (Economist, 1997). In fact, the model's forecasts made in 1972 have been pretty much on target so far. The model's forecasts of collapse under certain scenarios did not start to occur until well past the year 2000. In fact, the true tests of this model's forecasts will arrive in the coming decades.

World3 has been criticized mainly on methodological grounds (e.g. Cole et al., 1973). The most often cited difficulties are that it does not include prices explicitly, that it *assumes* resources are ultimately limited, and that it does not present estimates of the statistical uncertainty on its parameters. If fact, World3 is a viable and effective method to reveal the implications of the primary assumptions about the nature of the world that went into it. That is all that can be claimed for *any* model. These assumptions or "pre-analytic visions" need to be made clear and placed in direct comparison with the corresponding assumptions of the alternatives, in this case the "unlimited growth model." As Meadows et al. (1992, 2004) have repeatedly pointed out, the essential difference in pre-analytic visions centers around the existence and role of limits: thermodynamic limits, natural resource limits, pollution absorption limits, population carrying capacity limits, and most importantly, the limits of our understanding about where these limits are and how they influence the system. The alternative unlimited growth model (see, for example, Nordhaus, 1994) *assumes there are no limits* that cannot be overcome by continued technological progress, while the limited growth model *assumes that there are limits*, based on thermodynamic first principles and observations of natural ecosystems. Ultimately, we do not know which pre-analytic vision is correct (they are, after all, assumptions), so we have to consider the relative costs of being wrong in each case (Costanza, 2000; Costanza et al., 2000). This is at the crux of the problem raised by both books, a point taken up again below.

At the time of its initial release in 1972, World3 was at the cutting edge of computer simulation. Since then, simulation capabilities have increased dramatically, as has the availability of data to calibrate and test global models. One should mention some of the things that could have been done, especially in the recently released 30-year update, but have not been. The most important of these has to do with calibration and testing. In all the books on World3, calibration of the model with historical data is downplayed. This is strange, since the model runs always start in 1900 and run for 200 years to 2100. Why not show historical data for the variables in the model for which historical data is available in order to demonstrate the model's "skill" at reproducing the past? The reason given for this is that since the model is only an approximation, one should not put too much emphasis on "precise" calibrations. This is ultimately a mistake, since it misses the opportunity to present quantitative tests of the model's performance—tests against which World3 would fare quite well and which would address at least some of the objections of its critics. World3 is also probably the only integrated global model for which a true "validation" test could be run. One could take the original forecasts made in 1972 of the period from 1972 to 2002 and compare them with the actual data from the 1972–2002 period. This has, unfortunately, not yet been done.

Finally, while the discussions of World3 often point to the limited vs. unlimited growth assumptions as a key difference with conventional economic models, they do not take the opportunity to look at the relative costs and benefits of being right or wrong in those assumptions. If one does this, one can easily see that the cost of assuming no limits and being wrong is the collapse scenarios shown by World3 and the numerous examples of historical collapses documented by Diamond. On the other hand, the cost of assuming limits and being wrong is only mildly constrained growth (Costanza et al., 2000). It should be obvious that in the face of the huge uncertainties involved, if we hope to avoid collapse and achieve sustainability, we should make more cautious assumptions about limits. Both Diamond and Meadows et al. agree that the world is now one big interconnected system and (unlike past civilizations) it will succeed or fail as a unit. Diamond uses the metaphor of the Dutch polder to drive home this point. The recent experience of New Orleans is a vivid manifestation of this metaphor. If the levees collapse, we all are sunk. Perhaps

the experience of New Orleans will be enough of a "wake up call" to cause people to think differently about our common future. One can only hope that books like the two reviewed here will ultimately have enough influence to begin to turn the tide.

REFERENCES

Cole, H.S.D., Freeman, C., Jahoda, M., Pavitt, K.L.R. (Eds.), 1973. Models of Doom: A Critique of the Limits to Growth. Universe Books, New York. 244 pp.

Costanza, R., 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. Conservation Ecology 4 (1), 5 (online) URL: http://www.consecol.org/vol4/iss1/art5.

Costanza, R., Daly, H., Folke, C., Hawken, P., Holling, C.S., McMichael, A.J., Pimentel, D., Rapport, D., 2000. Managing our environmental portfolio. BioScience 50, 149–155.

Economist, 1997. Plenty of Gloom. 20 Dec.

Meadows, D.H., Meadows, D.L., Randers, J., Behrens, W.W., 1972. The Limits to Growth. Universe, New York.

Meadows, D.H., Meadows, D.L., Randers, J., 1992. Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future. Chelsea Green, Post Mills, Vermont.

Meadows, D.H., Randers, J., Meadows, D.L., 2004. Limits to Growth: The 30-Year Update. Chelsea Green, Post Mills, Vermont.

Nordhaus, W.D., 1994. Managing the Global Commons: The Economics of Climate Change. The MIT Press, Cambridge, MA. 213 pp.

Ponting, C., 1991. A Green History of the World: The Environment and the Collapse of Great Civilizations. Sinclair-Stevenson, London. 432 pp.

Tainter, J.A., 1988. The Collapse of Complex Societies. Cambridge University Press, Cambridge. 250 pp.

Yoffee, N., Cowgill, G.L. (Eds.), 1988. The Collapse of Ancient States and Civilizations. University of Arizona Press, Tuscon. 333 pp.

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