DRAFT
February 3, 1994

MAKING SENSE OF SUSTAINABILITY*

Alan Randall**
The Ohio State University

Abstract: The literature on sustainability offers something for all tastes. Prognoses range from cornucopia to catastrophe; diagnoses extend from simple market failures to modern lifestyles incompatible with the carrying capacity of the planet; and policy prescriptions run the gamut from minor mid-course corrections to radical restructuring of economy and society. However, this literature acquires more coherence when one observes that most of the discord stems from different assumptions about substitution possibilities and from differences between single-agent and structural models. I argue that discounting and missing intergenerational markets are over-rated as problems, and Hartwick-type investment rules are over-rated as solutions. On the other hand, safe minimum standard concepts deserve more attention than economists typically give them. I conclude with commentary on some specific policy instruments.

---

*Invited paper, 1994 annual conference of the Australian Agricultural Economics Society, Wellington, New Zealand, February 8-10.

**I have benefitted greatly from a dialogue with Mike Farmer that continues beyond the research for his dissertation (1993).

Contrary, perhaps, to the impressions of non-specialists, there already exists a substantial economic literature on sustainability. There is a considerable economic-theoretic literature and a considerable prescriptive literature. The intersection, even, is non-empty; that is, some of the theoretical literature takes seriously the task of prescription, and some of the prescriptive literature is sensitive to what can be learned from economic theory. It is true there is little empirical literature; but I find it hard to be critical about that: it is not easy to imagine what a meaningful economic-empirical literature about sustainability would look like.

The diagnostic and prescriptive literature appears at first glace noisy and discordant. Diagnoses range from simple market failures to modern lifestyles incompatible with the carrying capacity of the planet. Policy prescriptions run the gamut from correction of market failures to elimination of discounting, intergenerational reassignment of entitlements, optimal re-investment rules for natural resource rents, and a safe minimum standard of conservation; and that is just from relatively mainstream resource economists. Some of our ecological economist colleagues would extend the range of prescriptions to include "robust strategies" emphasizing resiliency, and radical restructuring of the modern consumer economy and society.

In trying to make some sense of all this disagreement about diagnosis and prescription, perhaps the place to start is with the theoretical literature.

Economic Theory and Sustainability

What, exactly, are the theorists concerned about sustaining? The literature suggests at least five different sustainability goals.

Sustainability Goals

1. *Maintaining Welfare, or Aggregate Output.* A reasonable goal is to sustain welfare across the generations. The Bruntland Commission's definition--meet(ing) the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987)--would surely be satisfied by any arrangement that succeeds in maintaining welfare for the indefinite future.

Solow's famous (1974) formulation addresses aggregate output:

$$\frac{Y}{L} = e^{t}\left(\frac{D}{L}\right)^{g}\left(\frac{K}{1}\right)^{1-g-h}$$

where Y is aggregate output, L is labor (i.e., population, such that dividing by L puts things in per capita terms), D is natural resources, K is reproducible capital, technology is Cobb-Douglas, and t is the rate of technological progress. However, output is aggregated in such a way that maintaining Y/L is, in effect, maintaining welfare.

2. *Maintaining the Stock of Capital.* This goal which addresses D plus K, (i.e., societal wealth properly indexed and aggregated) arises from the Solow view of the world; especially, from his favorable assumptions about the substitutability of D and K. To meet this goal, some type of Hartwick (1977, 1978) rule is followed: the scarcity rents from natural resources exhaustion must be re-invested in reproducible capita. The purpose of such a rule is to maintain the productive capacity of society which, if accomplished, would maintain welfare.

Notice immediately that the Hartwick rule is either tautological or wrong. If D and K are excellent substitutes (e.g., as would be the case with CES aggregate production technology and substitution elasticity ≥ 1), if K and Y are aggregated and indexed according to optimal pricing rules, and if resource rents reflect correctly the value of incremented scarcity due at extraction, then that rule is correct by definition. Otherwise, satisfying the Hartwick rule is insufficient to sustain welfare.

3. *Maintaining Natural Resources.* If natural resources really are different, i.e., D and K are not very good substitutes, then sustainability policy has to be targeted at D itself. Daly (1990), and Pearce and Turner (1990) are among the economists who have tried to delineate policies addressed specifically to D. El Serafy (1989) has proposed a rule requiring that habitats and biotic resources not be used beyond their long-run regenerative capacity, and exhaustible resources be depleted no more rapidly than they can be replaced by sustainable harvest of renewables. Barbier, et al. (1990) propose a policy of compensatory projects, such that non-sustainable harvest of a particular resource is compensated by some particular D-enhancing project in order to sustain aggregate D.

While the standard growth model characterizes D as natural resources for production, it is well to remember the importance of nature for assimilation wastes. Some of the major sustainability issues currently on the public mind--e.g., global warming, and depletion of the ozone layer--concern the waste assimilation capacity of D. The maintenance of natural resources may requre constraints on release of wastes.

4. *Ecological Sustainability.* If biotic resources really are importantly different from K and from, say, mineral deposits, then sustainability policy should be targeted toward biotic, or ecological sustainability (e.g. Common and Perrings 1992). Such an approach may well require radical re-thinking of how economists model sustainability issues; and it may well suggest radical restructuring of modern consumer society. Arguments to support these kinds of approaches are likely to involve not just the modeling assumptions but also the ethical stance of biocentrism or "deep ecology" (see e.g., Taylor 1981, 1983).

5. *Preservation of Particular Natural Resources.* Regardless of one's position concerning aggregate Y, D, and K, there may be particular natural phenomena--geological formations, habitats, ecological associations, or species--that one wants to see preserved for the future. Preservation arguments of this kind seldom hinge on urgent concerns about human survival (or, if they do, they logically collapse into one of the above four categories). Preservation motives range from the utilitarian (these things provide pleasure indirectly or directly), to claims of intrinsic value (they have a good of their own), to claims that they have rights that we are obligated to respect. One commonality, however, is the premise of uniqueness, i.e., that the thing to be preserved has little in the way of acceptable substitutes.

Since preserving certain particular natural resources is acceptable (although likely for different reasons) to proponents of the first four kinds of sustainability goals, I will first concentrate on goals one through four. I will, however, eventually return to issues concerning preservation of natural resources.

Modeling Assumptions

The choice of sustainability goals, and the modeling results concerning attainability of any particular goal, depend on modeling assumptions.

Cake or Corn: Is Production Modeled Explicitly? Cake-eating models deal with the optimal depletion of a given endowment, and generate only one robust result: a society that discounts the value of future consumption will choose a consumption path declining with time. Within one's own life, such a choice might be termed myopic. In a multi-generational context, such selfish behavior can be supported only by a positional dictatorship of the present generation (Ferejohn and Page 1977). From the perspective of sustainability, however, none of this is very interesting: a cake-eating universe is inherently unsustainable, and the kinds of discussions one can base upon such models have an unrelievedly pessimistic tone.

At the opposite end of the optimism-pessimism scale, Solow (1974) provides a model in which society could conceivably maintain its welfare across indefinitely many generations even though it uses exhaustible resources. Solow's model explicitly considers production, but to Solow (1974), production is greatly facilitated by Cobb-Douglas technology and perfectly-divisible D.

An intermediate position considers a natural resource that is capable of regeneration, within the bounds set by biological possibilities. Future prospects are influenced by the regenerative capacity of the natural resource, as well as the degree to which reproducible K can substitute for it.

Substitutability. In comparing the first four sustainability goals, perhaps the first thing that strikes one is the importance of assumptions about substitutability. Models addressed to the first two goals typically assume generous substitution between particular resources and between aggregate D and K. Maintaining welfare clearly permits a broad range of substitution in consumption, as does the concept of aggregate output. Generous substitutability is assumed in production, such that output can be maintained even as the composition of aggregate capital shifts markedly. While seldom modeled explicitly, it is clear from the discussion in this literature that technology is assumed to progress over time and to respond to relative scarcity so that its progress is tilted toward increasing the substitutability of plentiful resources for those that are scarce. In some treatments, K is clearly intended to include human capital and to embody progressing technology.

Analysts who are more impressed with the limits of substitutability, gravitate to sustainability objectives (3) and (4). They see the need to focus sustainability policy specifically on maintaining natural resources and/or biotic resources.

Substitutability can, of course, be a matter of more than tastes and technology. Some of the literature in environmental ethics and most of the "deep ecology" literature suggests ethical limits on substitution: to substitute the artificial for the natural and be just as happy may be, *ipso facto*, an indication of depravity.

Regeneration of Biotic Resources. It is common for economists to model regeneration of biotic resources as a function, often sigmoid in shape. I will do some of that, later in this paper. To conceptualize uncertainty, I assume that the regeneration function is not deterministic but can be represented as a confidence band. The more risk-averse among us can focus mainly on the lower boundary of that band.

While for economists that is a considerable concession to existential uncertainty, many ecologists believe that in reality much less is known about the regeneration of natural populations. While economists seek point solutions identified by familiar tangents to regeneration curves, ecologists are more likely to examine the resiliency of the populations and to seek robust policy solutions that perform reasonably well over a broad range of conditions.

Single-agent or Structural Models? Models in the Ramsey-Solow tradition are single-agent models. There is no division in roles, e.g. producer, consumer, government; and no populations of folk in different circumstances who might be motivated to trade, so that prices may emerge.

Recently, Howarth and Norgaard (1990) and Farmer (1993) have developed conceptual analyses in which the structure of succeeding generations is explicitly modeled. These models produce insights about resource prices, discount rates, and endogenous incentives for rationing and resource conservation that are unattainable with singe-agent models.

Lessons From an Over-lapping Generations Model

Farmer (1993) constructed an overlapping generations model along the following lines. At any time, there are three generations living (young, y; middle-aged, m; and retired, r) For any individual, an optimal life-plan maximizes

$$U(C_y) + U(C_m) + U(C_r)$$

(where C is aggregate consumption), subject to production technology, the regeneration function for D, and various accounting restrictions: the young borrow K and buy D; the middle-aged lend K and sell D; the retired just consume; production combines D and K to produce (more) K; all consumption is taken from K; all budgets balance; and materials balance.

The model starts with initial endowments of D and K, and determines resource allocation, consumption, and prices endogenously, as the generations trade with each other and succeed each other. In the model, all agents have perfect foresight. This is not stacking the deck: much of the previous literature worries that selfish agents, even with perfect foresight, may choose an unsustainable consumption path. Farmer's agents are selfish, rather than altruistic; intergenerational altruism is much to be encouraged and can only help in the quest for sustainability, but it would be stacking the deck to assume it.

This model enables us to critique four rather standard prescriptions for sustainability.

Discounting Is Not the Problem, and Discount Rate Repression Is Not the Solution. It is perhaps the most enduring of myths that a society which discounts future production and costs *ipso facto* sacrifices future welfare, and therefore violates reasonable requirements for intergenerational equity (Young 1992). Note that the individuals in Farmer's model maximize welfare summed, undiscounted, across the three life-stages. The individuals are neutral with respect to time preferences about consumption. Nevertheless, positive interest rates emerge endogenously. Why? Because capital is scarce and productive, and the young have to buy (borrow) it.

In Farmer's model, future prospects depend on what is assumed about initial endowments, the substitutability of D and K, and the regeneration of D. A considerable range of outcomes is possible: welfare may be increasing or decreasing over time; resource crises may occur, even with perfect foresight. In cases where future prospects are for declining welfare, it may be tempting to blame the positive interest rates that emerge endogenously, and to prescribe discount rate repression in order to raise future consumption. But that would be the wrong diagnosis and the wrong prescription:

regardless of whether the consumption path is increasing or decreasing, a policy of interest rate repression would only make things worse for the future. Furthermore, this result has nothing to do with any positional dictatorship of the present generations. Unborn future generations would prefer that those living now face incentives to save, and to select only those investments that pass a net present value test.

Entitling Future Generations Will Help Them Less Than One Might Think. Recently, Bromley (1989) proposed that the problem of sustainability could be solved by an appealingly simple yet effective instrument: a reassignment of property rights to future generations. This approach would be effective: a future generation protected by property rights would have veto power over earlier-generation actions that might threaten its welfare. It would be simple: the property rights reassignment to the future would be once-and-for-all (although it would require a momentous public decision to actually make such a change); and enforcement of the reassigned property rights would proceed routinely, as does current enforcement of currently-assigned property rights.

Howarth and Norgaard (1990) endorse this proposal, based on their analysis with a two-generation, overlapping generations model, in which prices are given exogenously. They start by examining trade between adjacent generations, given that property rights are first reassigned from the older to the younger. Then, by induction, they consider entitlement of distant future generations.

Both Bromley (1989) and Howarth and Norgaard (1990) are alert to the Coase theorem, which would suggest that reassignment of property rights (even across generations) would have less impact on resource allocation than one might think. Nevertheless, they conclude that Coasian concerns do not undermine the validity of their proposal.

In Farmer's model, intergenerational trading opportunities are much more complete than in the Howarth-Norgaard model. With three generations, asset and capital markets are completely characterized, and prices are endogenized. Production responds to prices, and prices respond to demands. The Coase theorem, properly interpreted, says something like: the fewer are the impediments to trade, the more nearly are resource allocation outcomes insensitive to the initial assignment of rights. Farmer's results conform to the Coasian insight. The assignment of property rights to each successive young generation at birth provides only modest protection for the immediate unborn generation; the effect on more distant generations is indeterminant. In cases where the model predicts that current consumption levels are unsustainable, the reassignment of property rights is typically insufficient to reverse that outcome. To express it more formally, the Howarth-Norgaard finding -- that reassignment of property rights to future generations is sufficient to secure future welfare -- is not attainable as a general equilibrium result.

Hartwick Rules Are Not Policy Prescriptions. Hartwick rules require that Hotelling (i.e., scarcity) rents from exhaustible resource extraction be re-invested. I have argued, above, that the claim that Hartwick rules assure sustainability is either tautological or wrong. Here, I address their serviceability in prescription.

There's no assurance that a Solow single-agent economy will generate the prices that validate the Hartwick tautology (Krautkraemer et. al. 1994). There are enormous obstacles to, first, measuring the rents from resource depletion and, then, overcoming the incentive problems in controlling capital investment to ensure that the ex ante and ex post value of national wealth is unchanged. Further, the problem of price formation, in the structural sense, is ignored. To borrow an example from Mike Farmer, Hartwick rules assume we can chop down an entire rainforest and reinvest the rents in some reproducible asset of equal value, all without affecting the prices of either asset. It is a policy without an implementation prescription.

Safe Minimum Standard Policies Have Some Promise. Randall (1991) and Randall and Farmer (1994) have argued that a policy rule to allocate natural resources on the basis of efficiency criteria, but always subject to a safe minimum standard (SMS) of conservation (Ciriacy-Wantrup 1968) would be taken seriously by ethicists operating from a broad range of philosophical perspectives. The SMS is a constraint adopted for good reason, and the constraint itself can be abandoned if the cost of enforcing it becomes intolerably high (Bishop 1978). Here, I plan to address three related issues: the role of a SMS constraint in policy for sustainability, principles for setting the SMS, and the problem of implementation.

To address these questions, consider a simple two-period diagram. Assume *D* is renewable, that is, *D* withheld from production in one period regenerates by the next period. If S_t is the stock of *D* withheld from production in period *t*, the regeneration function traces the relationship between S_t and S^a_{t+1}, the amount of *D* available in the next period. In a two-period diagram, the line of slope=1 starting from the origin is diagnostic: at points above that line, S^a_{t+1} exceeds S_t so that the natural resource is at least potentially sustainable; but at points below the line, the natural resource will eventually be exhausted even if none of it is used in production (Figure).

Assume perfect foresight and efficient markets in *Y*, *D*, and *K*. An interesting question is whether natural resource "crises" (i.e., situations where scarcity of natural resources threatens the sustainability of adequate consumption levels for the human population) are possible. Assume that *D* and *K* are not perfect substitutes and that factor-specialization is penalized in production.

If the regeneration function is always concave and lies above the line of slope = 1 for a range of values of S_t, it will have a steep positive slope near the origin. In this case, the market economy provides very strong defenses against resource crises: the price of D will grow very large as the resource nears exhaustion, and any S_t conserved as a result of this incentive will regenerate generously $(S^{a}_{t+1} \gg S_t)$.

The sustainability question becomes more interesting if the natural resource regeneration function is sigmoid (Figure). If less than S_{min} is withheld from production in each period, natural resource exhaustion is inevitable. The optimal stock to carry forward is S^{*}_{t}, at which point the steady-state efficiency condition, 1+r = 1+h, holds (where r is the marginal efficiency of capital, and h is the marginal regeneration rate of the natural resource) and D^{*}_{t} may be used in production in each period.

Interpreting S_{min} as the minimum standard (i.e., the minimum carry-over stock to assure resource regeneration), the idea of a *safe* minimum standard invokes uncertainty. Assume that the regeneration function is stochastic and that its lower bound is traced by the dashed curve (Figure). Then, if $\widetilde{SMS}$ is withheld from production in each period, resource exhaustion will be avoided, even in the worst case with respect to resource regeneration. We take $\widetilde{SMS}$ as what is meant by the term safe minimum standard in the literature; we would call it safe minimum standard of *preservation*.

$\widetilde{SMS}$ sustains the resource (and that may satisfy some preservationists). But we have cast the issue as one of sustaining adequate consumption levels for the human population. Assume that D_{min} is the minimum allocation of natural resources to production that is required to sustain adequate consumption. Let each time period, t, represent a generation of people. Then, any generation that uses less than D_{min} suffers extreme deprivation (however that is defined). We identify $\widehat{SMS}$ (Figure) as the minimum stock withheld from production that will provide D_{min} for each succeeding generation. Draws of D_{min} and regeneration of the stock are guaranteed. $\widehat{SMS}$ is the safe minimum standard of *conservation*. While conservation of $\widehat{SMS}$ is *required* to *assure* sustainability, the odds of doing better than that are working in favor of a society that abides by an $\widehat{SMS}$ constraint: if regeneration turns out to be better than lower-bound, as it probably will, subsequent generations will be able to use more than D_{min} and/or conserve more than $\widehat{SMS}$.

Let us pause at this point, to observe that some progress has been made in addressing the first two issues. Why might a SMS constraint be needed? The story that emerges from Farmer's model is generally favorable to the prospects of sustainability given fully functioning intergenerational markets. Nevertheless, there are no general-form guarantees. If initial endowments at too low, D-K substitutability and the regeneration of D are ungenerous, and/or the system is subject to uncertainty and experiences a run of bad luck, sustainability may be jeopardized. With sigmoid regeneration and required minimum draws of D, the system could find itself on a slippery slope. Some kind of SMS constraint could be invoked, in order to protect society against such outcomes.

How should the SMS be set? Randall and Farmer (1994) argue that the safe minimum standard should be set at $\widehat{SMS}$, a more conservative level than one might expect. $\widehat{SMS}$ allows for continuing harvest of D_{min}, to meet the minimal consumption requirements of present generations.

The remaining question concerns implementation. At the outset, observe that all pro-active sustainability policies raise implementation issues: I have not addressed implementation of discount-rate repression, entitling the future, or Hartwick rules, only because I have dismissed these policies for other reasons. An $\widehat{SMS}$ rule requiring present society to conserve resources to avoid exhaustion in some (perhaps distant) future generation is not a sustainable equilibrium outcome; in other words there is no Lockean contract that would bind present society to abide by $\widehat{SMS}$ for the benefit of distant future societies. Rather, $\widehat{SMS}$ is a commitment that a society might undertake for ethical reasons.

D_{min} is defined as the natural resource draw necessary to avoid extreme deprivation for the current human society. One would expect a generation that inherited a natural resource stock less than $\widehat{SMS}$ to nevertheless use at least D_{min}, risking resource exhaustion for some subsequent generation. To do otherwise would be to voluntarily accept self-sacrifice (to drink from the poisoned cup, as it were) for the benefit of future societies. In practical terms, that seems too much to ask.

Ethical theories offer only limited help, here. While many ethical systems would require individual self-sacrifice for the sake of principle or for the good of others, there seems little basis in ethical theory for obliging a society to sacrifice itself for the good of future societies.

An implementable safe minimum standard policy must seek to conserve not $\widetilde{SMS}$ but SMS. That is, it must seek to avoid placing any present or future society in a position where it must choose between sacrificing itself and dooming subsequent societies. In practical terms, a $\widehat{SMS}$ policy would emphasize early warning, and early implementation of conservation policies that require only modest sacrifice on the part of each society. Since unilateral withdrawal from any intertemporal contract or obligation is always a possibility, conservationists have a strong interest in keeping the costs of conservation tolerably low. In addition, as Barbier and Markandya (1990) have suggested, some societies may have already passed the point of no return: sustainability could not be achieved with internal resources regardless of willingness to sacrifice for the future. It may be possible, however, for more asset-rich societies to subsidize these "basket cases" back to a sustainable path.

Practical Policies to Remote Sustainability

To this point, I have been concerned mostly to provide some guidance to the economic-theoretic considerations that help rationalize and systematize a sometimes discordant literature; to debunk some popular panaceas; and to explore the potential of policies incorporating a safe minimum standard of conservation. Now, I offer some commentary on practical policies to promote sustainability.

Population and Technology. Population and technology, and what might be expected concerning their growth, figure prominently in most discussions of sustainability. I have not ignored these issues, but one might need to look hard in order to find where I have treated them. Population was acknowledged, but then submerged immediately when I presented the Solow (1974) model in per capita terms. Solow's (1974) observation--that output per capita could be maintained so long as technological progress kept pace with population growth--serves merely to state the problem. Policies to control the growth of the human population and to encourage continuing technological progress are essential to any meaningful sustainability policy.

The analysis of a safe minimum standard of conservation made much of D_{min}, the minimum natural resource draw to protect present generations from deprivation, and rightly so. Nevertheless, the magnitude of D_{min}, is itself an issue of technology: D_{min} would be reduced by a technology that increased the substitutability of K for D. If the resource crisis concerned not D, generic natural resources, but particular natural resources, the range of possible substitutions is expanded to include other, less scarce, natural resources.

Mainstream economists are fairly optimistic that market forces tend to encourage technological progress and direct it toward increasing the substitutability of more available resources for those that are increasingly scarce. Nevertheless, a pro-active technology policy would provide some additional insurance.

Accounting for Resource Depletion. I have argued that intertemporal/intergenerational markets are more complete and more effective in assuring sustainability than is widely suspected. Furthermore (I have argued), Hartwick rules--invest rents from natural resource depletion in reproducible capital assets--have problems with respect to theoretical coherence and implementability.

Nevertheless, the general idea of systematic accounting for natural resource depletion has much to recommend it. National accounts do not substitute for the incentives that actually allocate resources, but they may serve to motivate the political will essential for redirecting incentives. Natural-resource-exporting countries, such as Australia and New Zealand, are naturally torn between consuming and investing the proceeds from resource extraction; and exhortations to invest more and consume less cannot hurt.

Getting the Prices Right. Whatever optimism we gain from economic-theoretic models of sustainability must be sobered by the realization that such models assume that the standard market failures are (already) resolved, the prices are (already) right, and government stands ready always to implement public policy proposals that pass a benefit-cost test.

Policies for sustaintability *must build upon* the common sense recommendations of resource economics:

• Correct market failures, by implementing efficient institutions (see, e.g., Johnson 1992). Many of the most egregiously unsustainable policies and practices would fail tests for efficiency, as well as sustainability. Many of the most obvious market failures concern the generation and release of wastes that threaten sustainability as surely as does resource scarcity.

• Provide those conservation policies that pass a standard modern benefit cost test, i.e., one that measures willingness to pay for preference satisfaction without undue regard to observable market prices. Remember, the Randall-Farmer argument for an SMS rule addresses such a rule imposed as a constraint upon (*not substituted for)* policies that pass an efficiency test.

Getting Ahead of the Game. Our development of SMS concepts leads to a clear policy recommendation. Get ahead of the game. Implement conservation policy while it is still cheap, i.e., before the crises are upon us, before the train wrecks are imminent, while the sacrifices inherent in a serious conservation policy are still modest. That way, we can be averse to environmental risk, without paying an excessive price for our risk aversion. Furthermore, given that moral arguments can at best persuade others to adopt obligations, it is best that the obligations upon succeeding generations to conserve for the benefit of more distant generations involve only limited sacrifice.

This recommendation springs logically from our development of the case for a safe minimum standard of conservation. While our arguments for the SMS deviate only modestly from the path of mainstream economics, I believe the policy conclusion is fairly consistent with the "robust strategies" concepts that are emerging from ecology and ecological economics.

Preservation of Particular Natural Resources. Optimists and pessimists with respect to future welfare, capital accumulation and/or conservation of generic natural resources (D) agree that there are some particular natural resources that should be preserved, even as they may disagree as to exactly which ones fall into this category (Solow 1992). It seems that I have spent most of the last 25 years worrying about this problem. Not surprisingly, I could discuss this question in more detail than most audiences could bear. Mercifully, I will leave you with just one observation.

Development, it has often been observed, is the process of converting particular natural resources into reproducible capital. It is natural and healthy to worry about the risk that we might stumble into giving up too much that is rare and irreplaceable to gain that which is generic and reproducible. Arrayed against that risk is an opposite risk: we might reduce present and future welfare by restraining excessively the process we call "development". While this dilemma often seems insoluble, a strong economy not only allows the luxury of preserving environmental particulars, but also generates increasing demands for such preservation. It is easier when we afford it and when the citizenry is demanding that we do it. If the optimists are right, and welfare follows an increasing path, the demands for preserving particular natural treasures will only increase.

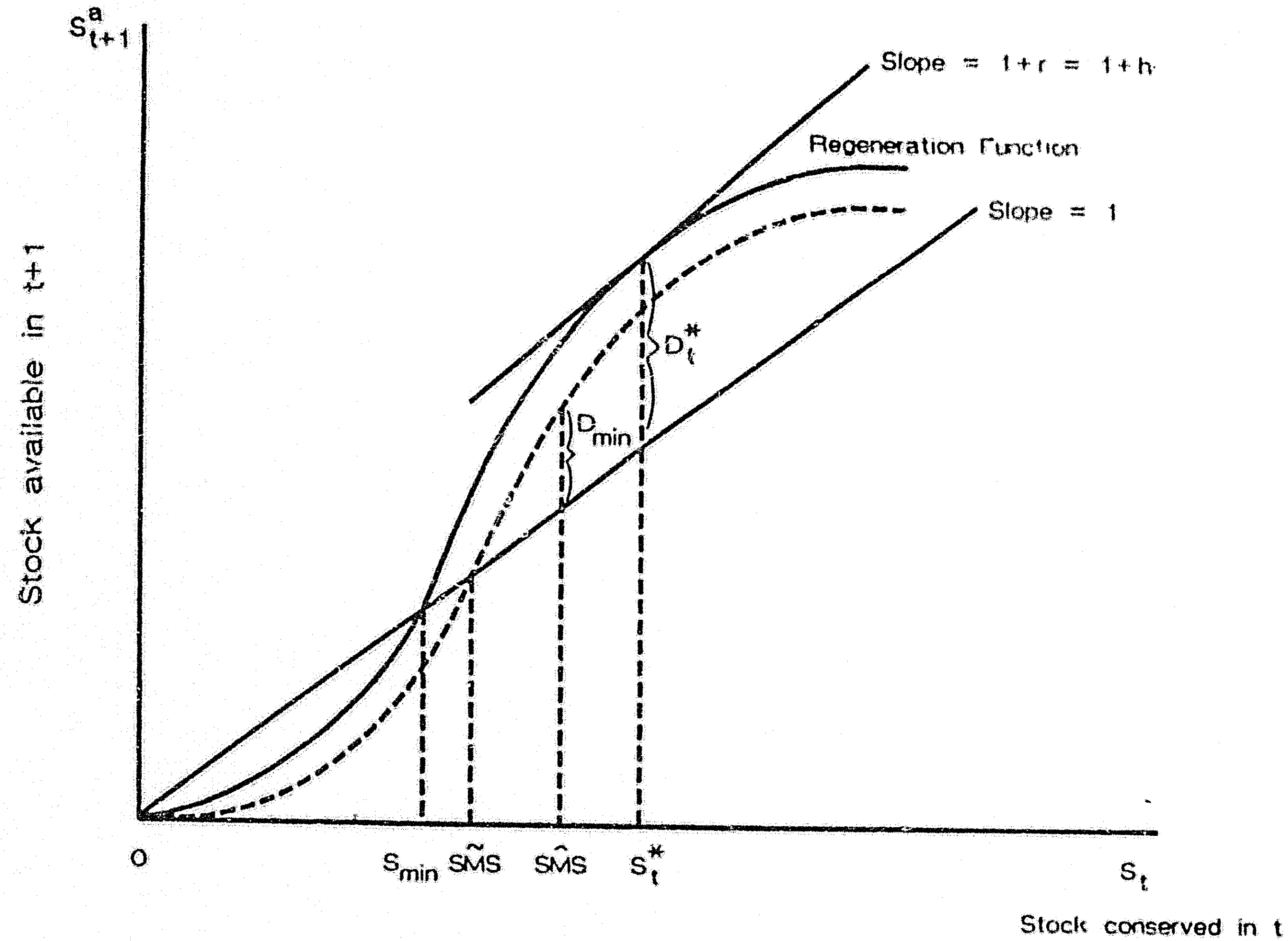

Figure. Setting the SMS.

References

Barbier, E. B. and A. Markandya. 1990. "The Conditions for Achieving Environmentally Sustainable Development," *European Economic Review* 34: 659-669.

Barbier, E. B., A. Markandya, and D. W. Pearce. 1990. "Environmental Sustainability and Cost-Benefit Analysis," *Environment and Planning* 22: 1259-1266.

Bishop, R. C. 1978. "Economics of Endangered Species." *American Journal of Agricultural Economics* 60: 10-18.

Bromley, Daniel W. 1989. "Entitlements, Missing Markets and Environmental Uncertainty," *Journal of Environmental Economics and Management* 17: 181-194.

Ciriacy-Wantrup, S. von. 1968. *Resource Conservation: Economics and Policies*, (3rd ed.) University of California Division of Agricultural Sciences, Berkely.

Common, M.and C. Perrings, 192. "Towards an Ecological Economics of Sustainability," *Ecological Economics* 6: 7-34.

Daly, H. 1990. "Some Operationed Principles of Sustainable Development," *Ecological Economics* 2: 1-6.

El Serafy, S. 1989. "The Proper Calculation of Income from Depletable Natural Resources," in Y. J. Ahmad, S. el Serafy, and E. Lutz, eds., *Environmental Accounting for Sustainable Development* (Washingon, D.C., The World Bank).

Farmer, M. C. 1993. "Can Markets Provide for Future Generations?" Ph.D. dissertation, The Ohio State University, Columbus.

Ferejohn, and Talbot R. Page. 1978. "On the Foundations of Intertemporal Choice," *American Journal of Agricultural Economics* 60: 269-275

Hartwick, J.M. 1977. "Intergenerational Equity and the Investing of Rents from Exhaustible Resources," *American Economic Review* 67: 972-974.

Hartwick, J. M. 1978. "Exploitation of Many Deposits of an Exhaustible Resource," *Econometrica* 46: 201-217.

Howarth, Richard B., and Richard B. Norgaard 1991. "Intergenerational Resource Rights," *Land Economics* 66: 1-11.

Johnson, R. W. M., 1992. "Resource Management, Sustainability, and Property Rights in New Zealand" *Australian Journal of Agricultural Economics* 36: 167-186.

Krautkraemer, J., J. Pezzey, and M. A. Toman. 1994. "Economic Theory and Sustainability," in D. W. Browley (ed.) *Handbook of Environmental Economics*, Blackwell (in press).

Pearce, D. W., and K. Turner. 1990. *Economics of Natural Resources and the Environment*. London, Harvester Wheatsheaf.

Randall, A. 1991. "The Economic Value of Biodiversity." *Ambio: A Journal of the Human Environment* 20(2): 64-68.

Randall, A., and M. C. Farmer. 1994. "Benefits, Costs, and a Safe Minimum Standard of Conservation," in D. W. Bromley (ed.) *Handbook of Environmental Economics*. Blackwell (in press).

Solow, Robert M. 1974. "Intergenerational Equity and Exhaustible Resources," *Review of Economic Studies: Symposium on the Economics of Exhaustible Resources* 41: 29-45.

Solow, R. 1992. "An Almost Practical Step Toward Sustainability," Washington, *Resources for the Future, Inc.*

Taylor, P. 1981. "The Ethics of Respect for Nature," *Environmental Ethics* 3: 197-218.

Taylor, P. 1983. "In Defense of Biocentrism," *Environmental Ethics* 5: 237-243.

World Commission on Environment and Development (WCED). 1987. "Our Common Future," New York, *Oxford University Press*.

Young, R., 1992. "Evaluating Long-Lived Projects: The Issue of Intergenerational Equity," *Australian Journal of Agricultural Economics* 36: 207-232.