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The Environment and Emerging Development Issues

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Development economics for the most part has failed to recognize renewable environmental resources as economic goods. Yet the lives of the poor in developing countries are intimately tied to the fate of their local common-property resources—soil, fuelwood, water, and so on. Ignoring the loss of common-property renewable resources (via degradation, centralization, or privatization) in calculations of net national product can mask the destruction of resources available to a country's poor behind the false appearance of a growing national economy. This paper describes the difference between the problem of managing local common-property resources in developing countries and the problem of protecting the global commons such as the atmosphere and oceans. It outlines the calculations that would include the local commons in the national income accounting of capital assets and argues that the interests of those most dependent on the increasingly scarce local commons will be best served by placing control in their hands, while the central government provides infrastructure and educational support. To control the pollution of the global commons, on the other hand, the paper sketches a plan in which most countries would have a high incentive to participate—a global allocation of limited, tradable permits to discharge defined pollutants.

Environmental resources are of minor importance to poor countries. . . . They play an insignificant role in the process of economic development. . . . Such resources are luxury goods, and they loom large in public consciousness only when incomes are high. . . . Environmental resources are only a rich country's preoccupations. . . . They are a mere diversion created by economists not sensitive to the true needs of the poor in poor countries. . . .

These sentences will seem at once strange and recognizable. They will seem

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strange because today we all like to believe that the ideas they express are not true. At the same time, they will be recognizable to anyone who has delved into the literature on development economics and looked for environmental issues in it. Even were we to search through the vast body of writings on development planning, not to mention the literature on investment criteria, we would be hard put to discover any sign of environmental resources. Academic development economics does not yet acknowledge their existence, in that one will not find them in any recognized survey article, text, or treatise on the subject.

To cite only a few instances, Drèze and Stern (1987) and Stern (1989) are surveys of cost-benefit analysis and development economics, respectively. The former, a ninety-page article, contains precisely one sentence on the subject of nonrenewable and renewable resources (and it is to tell readers where to go if they wish to learn about such matters); the latter, an eighty-eight-page article, also contains a single sentence (and this also tells readers where to go should they wish to learn about such matters). A third example is provided by the two-volume *Handbook of Development Economics* (Chenery and Srinivasan, eds., 1988), which simply has no discussion of environmental resources and their possible bearing on development processes. The disconnection of academic development economics from a central aspect of the lives of people about whom development economics revolves would appear to be pretty much complete. Environmental resources appear in this literature about as frequently as rain falls on the Sahara.[1]

Despite this neglect, something like a literature on the environment and economic development is now emerging.[2] In this paper we therefore try to place this small literature in perspective and develop what appears to us to be some of the themes with the greatest research potential—that is, those which also have implications for policy in poor countries. This will enable us also to apply economic theory to obtain new insights into the allocation and management of environmental resources. We want to do this by providing a framework of thought which will encourage the reader to view environmental resources as *economic goods*. This will no doubt seem a banal intention, but it is remarkable how much of current writing on the environment displays an innocence of this point of view. Our approach is based on the conjecture that until environmental

1. Yet, environmental economics as an autonomous subject has developed rapidly in recent years. Much work has been done both at the analytical and empirical levels on the valuation of environmental resources (see, for example, Johansson 1987, 1990) and on the identification of appropriate environmental policy instruments (see, for example, Tietenberg 1990). However (and this is the point we are making in the text), both these sets of questions have been discussed in the context of western industrial democracies. We will confirm later in this article that the context matters very much in the field of environmental economics.

2. The incorporation of environmental resources into social cost-benefit analysis for development planning was attempted in Dasgupta (1982). Earlier treatises on social cost-benefit analysis in poor countries, such as Little and Mirrlees (1969, 1974) and Dasgupta, Marglin, and Sen (1972), contain no discussion of these issues. Readers wishing to study environmental economics should consult Ulph (1989) for a review of a number of texts and treatises written over the past fifteen years or so.

resources become a commonplace furniture of economic thinking and modeling, they will continue to be neglected in the design of policy and in the implementation of policy. Periodic "affirmative actions" on the environment is not the right way of going about things.

Now there are several routes we can follow for the purpose of introducing our subject. Here, we pursue one which is perhaps less popular today than it used to be: it is to seek a unifying principle concerning the "technology of production" of environmental goods and services. In other words, we start by viewing the matter from the purely *ecological* side of things. Later, we view the subject from the *institutional* end. These are complementary avenues of inquiry. Both need to be covered, but it is pretty much a matter of indifference with which one we begin.

I. Environmental Resources and Their Physical Characteristics

Environmental problems are almost always associated with resources that are regenerative or renewable but that nonetheless are in danger of exhaustion from excessive use.[3] The earth's atmosphere is a paradigm of such resources. That is, under normal courses of events the atmosphere's composition regenerates itself. But the speed of regeneration depends upon the rate at which pollutants are deposited into it, and it depends upon the nature of the pollutants (smoke discharge is clearly different from the release of radioactive material). Now, in talking of a resource we need, first of all, a way of measuring it. For the case in hand we have to think of an atmospheric quality index. The net rate of regeneration of the stock is the rate at which this quality index changes over time. This will depend upon the nature and extent of the pollutants which are discharged, and it will also depend upon the current index of quality; that is, the current level of the stock. These are immensely complex, ill-understood matters. There is a great deal of synergism associated with the interaction of different types of pollutants in the atmospheric sink (see Ehrlich, Ehrlich, and Holdren 1977). But the analytical point we are making here remains valid.

Animal, bird, plant, and fish populations are also typical examples of renewable natural resources, and there are now a number of studies which address the reproductive behavior of different species under a wide variety of environmental conditions, including the presence of parasitic and symbiotic neighbors. Land is also such a commodity, for the quality of arable and grazing land can be maintained by careful use. Overuse, however, impoverishes the soil and eventually produces a wasteland. (The symbiotic relation between soil quality and vegetation cover is, of course, at the heart of the current anxiety over Sub-Saharan erosion.)

3. Except for some remarks in section II, we are ignoring nonrenewable resources here for reasons of space. For an account of what resource allocation theory looks like when we include exhaustible resources in the production process, see Dasgupta and Heal (1979).

Underground basins of water often have a similar characteristic. The required analysis, however, is a bit more problematic in that we are concerned both about its quality *and* quantity. Under normal circumstances an aquifer undergoes a self-cleansing process as pollutants are deposited into it. (Here, the symbiotic role of different forms of bacteria, as in the case of soil and the atmosphere, is important.) But the effectiveness of the process depends, as always, on the nature of pollutants (for example, the type of chemicals) and the rate at which they are discharged. Furthermore, many aquifers are recharged over the annual cycle. But if the rate of extraction exceeds the rate of recharge, the water table drops, thereby raising extraction costs. In fact, for coastal aquifers the issue is not only one of depositing pollutants; excessive extraction alone may cause the groundwater table to drop too far, and saltwater intrusion can then destroy the basin. (For instances of these occurrences, see Dasgupta 1982 and Center for Science and Environment 1982, 1985.)

These examples suggest that a number of issues in environmental economics are within the subject matter of capital theory (this is very much the spirit of the exposition in Clark 1976). But there are added complications, among them the fact that the impact on the rate of regeneration of environmental resources of a wide variety of investment decisions is not fully reversible, and in some cases quite irreversible. (As always, one should not be literal. A very slow rate of regeneration produces a strong flavor of irreversibility.) In this limited sense, issues concerning what is usually labeled "pollution" can be studied in the same general sort of way as those concerning animal, bird, plant, and fish populations, aquifers, forests, and soil quality. This provides us with a unified way of thinking about matters. It allows us to use insights we draw from a study of one class of environmental resources when studying another. It forces us to pay attention to the intertemporal structure of economic policies.

If this were all, life would be relatively simple. But it is not all. We argue presently that admitting environmental resources into economic modeling ushers in a number of additional, potent complications for development policy. They arise out of the fact that for poor people in poor countries, such resources are often *complementary* to other goods and services. So an erosion of the environmental resource base can make certain categories of people destitute even while an economy on average is seen to be growing.

There is thus an intellectual tension between aggregate concerns (for example, the greenhouse effect, or the appropriate mix of natural resources and manufactured capital in aggregate production) that sweep across regions, nations, and continents, and concerns (for example, the decline in firewood or water availability) that are specific to the needs and concerns of poor people from as small a group as a village community. This tension should be borne in mind. Environmental problems present themselves in the form of different images to different people. At this stage of our understanding it would be a wrong research strategy to try to put them all together into one large basket. In the following section we ignore the detailed, institutional features which surround the use of *local* environmental resources in favor of studying the intertemporal nature of environmental policy in terms of aggregate considerations. This allows us to discuss in a simple manner the link between measures of net national product (NNP) and rules for social cost-benefit analysis of investment activity. As a by-product, it enables us to talk briefly about a matter much discussed today—sustainable development—that a decade and a half ago was shown to be the implication of a wider, richer inquiry going under a different name—optimal development. We will pick up the institutional trail in section III.

II. Determinants and Constituents of Well-Being and Net National Product

It is useful to remember that the kinds of resources we are thinking of here are, on occasion, of direct use in consumption (as with fisheries), on occasion in production (as with plankton, which serves as food for fish species), and sometimes in both (as with drinking and irrigation water). Their stocks, as we noted earlier, are measured in different ways, depending on the resource: in mass units (such as biomass units for forests, cow dung, and crop residues); in quality indexes (such as water and air quality indexes); in volume units (such as acre-feet for aquifers); and so on. When we express concern about environmental matters we in effect point to a decline in their stock. But a decline in their stock *on its own* is not a reason for concern. This is seen most clearly in the context of exhaustible resources, such as fossil fuels. To not reduce their stocks is to not use them at all, and this is unlikely to be the right thing to do.

To be sure, this is not the case with renewable natural resources, since we could in principle limit their extraction and use to their natural regeneration rate and thus not allow their stocks to decline. But this too may well be the wrong thing to do, in that there is nothing sacrosanct about the stock *levels* we have inherited from the past. Whether or not policy should be directed at expanding environmental resource bases is something we should try to *deduce* from considerations of population change, intergenerational well-being, technological possibilities, environmental regeneration rates, and the existing resource base. The answer cannot be pulled from the air.

That it can is a common misconception. Here is a recent example of this: "We can summarize the necessary conditions for sustainable development as constancy of the natural capital stock; more strictly, the requirement for nonnegative changes in the stock of natural resources, such as soil and soil quality, ground and surface water and their quality, land biomass, water biomass, and the waste-assimilation capacity of the receiving environments" (Pearce, Barbier, and Markandya 1988, p. 6).

The passage involves a "category mistake," the mistake being to confuse the *determinants* of well-being (for example, the means of production) with the *constituents* of well-being (for example, health, welfare, and freedoms). But leaving that aside, the point is not that sustainable development, even as it is defined by these authors, is an undesirable goal. It is that thus defined it has negligible information content. (We are not told, for example, what stock levels we ought to aim at.) This is the price that has to be paid for talking in terms of grand strategies. The hard work comes when one is forced to do the ecology and the economics of the matter.

So then, information about stocks on their own is not a sufficient statistic for well-being. What we are after are present and future well-being and methods of determining how well-being is affected by policy. And it is not an accident that the index which, when properly computed, can be used toward this end is net national product.[4]

Defining Net National Product

Net national product is held in ill repute today. (In what follows, we will be concerned only with the real value of NNP.) It is often thought that it is even in principle incapable of reflecting aggregate intergenerational well-being. This belief is not correct. Subject to certain technical restrictions, for any conception of the social good, and for any set of technological, transactional, informational, and ecological constraints, there exists a set of shadow (or accounting) prices of goods and services. These prices, when used in the estimation of NNP, ensure that small projects relative to the size of the economy that increase this index are at once also those that increase the social good.[5] A great many of these shadow prices will be person- or household-specific. Put more generally, they will be agent-relative, to reflect the fact that needs and incomes differ along gender, age, caste, or ethnic lines, and that many of the exchanges which take place in poor agrarian and pastoral societies are not anonymous; that is, such exchanges take place in personalized, or named markets.[6]

These considerations bring out the intellectual tension we spoke of earlier. The point is that in practice it is impossible to take all this into account in one

4. The theory of optimal development in economies with environmental resources was developed over fifteen years ago, and it produced a series of sharp prescriptions, much sharper than the recent literature on sustainable development. Implied in the theory of optimal development were rules for social cost-benefit analysis of investment projects and for estimating net national product. See, for example, Mäler (1974), Solow (1974), Dasgupta and Heal (1979), Dasgupta (1982), and Lind (1982).

5. The technical restrictions amount to the requirement that both the set of feasible allocations and the social ordering reflecting the social good are convex. The assumption of convexity is dubious for pollution problems, as was illustrated in Starrett's classic article (see Starrett 1972). Nevertheless, in a wide range of circumstances it is possible to separate out the "nonconvex" sector, estimate net product for the "convex" sector, and present an estimate of the desired index as a combination of the net product of the convex sector and estimates of stocks and their changes in the nonconvex sectors. This is a simple inference from the work of Weitzman (1970) and Portes (1971).

6. We are borrowing the latter terminology from Hahn (1971). As an example of a named market, consider the Hindu *jajmani* system, which supports a set of mutual economic obligations between landowners (peasant masters) and low-caste families. (See, for example, Wiser 1936, Epstein 1967, and Bowes 1978.) We are not suggesting that such personalized markets are efficient, even when we take account of existing transaction and informational costs. Nor are we suggesting that they lead to equitable allocations. The outcomes are often the result of implicit bargaining among people with vastly different bargaining strengths. See below in the text. See also Dasgupta (1990b) for further discussion.

grand measure of real NNP. The thing to do is to improve on our current ways of doing things and capture these concerns in a piecemeal fashion. This is the approach we will take here.

Current estimates of NNP are based on biased sets of prices. They are biased in that the prices that are imputed to environmental resources in situ are usually zero, even though we know that their accounting prices are positive. Thus the social profits of projects which degrade the environment are lower than the profits that are actually imputed to them. This means, in turn, that wrong sets of projects are chosen. In particular, resource-intensive projects look better than they in fact are.

One can go further. The bias would be expected to extend itself to the prior stage of research and development. When environmental resources are underpriced, there is little incentive for agencies to develop technologies which economize on their use. The extent of the distortion created by this underpricing will vary from country to country. Quite obviously, poor countries cannot compete with rich ones in the field of basic research. They have to rely on the flow of new knowledge produced in advanced industrial economies. Despite this, poor countries need to have the capability for basic research. This is because the structure of their shadow prices is likely to be quite different, most especially for non-traded goods and services. Even when it is publicly available, basic knowledge is not necessarily *usable* by scientists and technicians unless they themselves have a feel for basic research. Basic knowledge should not simply be taken off the shelf. Ideas developed in foreign lands ought not merely be transplanted to the local economy. They need to be adapted to suit local ecological conditions.

This is where estimating shadow prices (and more generally, creating incentives which correspond to these shadow prices) can be of considerable help. Adaptation is itself a creative exercise. Unhappily, it is often bypassed. The foreign technology is simply purchased and installed with little modification. There is great loss in this.

This leads to the question of how we should value environmental resources in situ; or in other words, what their shadow prices are in situ. It also leads to the question of how we should measure NNP once we have estimated shadow prices. As it happens, this latter question has a precise answer. How we should define NNP is therefore not a matter of opinion; it is a matter of fact.

The theory of intertemporal planning tells us to choose current controls (for example, current consumptions and the mix of current investments) in such a way as to maximize the current value Hamiltonian of the planning problem. As is now well-known, the current value Hamiltonian is the sum of the flow of current well-being and the shadow value of all the net investments currently being undertaken.[7] (Thus, the planning exercise generates the entire set of intertemporal shadow prices.) It is possible to show that the current value Hamilto-

7. The current value Hamiltonian will in general also contain terms reflecting the social cost of breaking any additional constraint that happens to characterize the optimization model. But we are avoiding such technicalities in the text.

nian measures the return on the *wealth* of an economy, measured in terms of well-being (see the appendix). The theory also tells us that if the objective of planning (that is, the intergenerational index of well-being) is stationary, then along the optimal program the Hamiltonian remains constant through time. (In saying this we are suitably normalizing the relevant variables. The best economic treatment of all this is still Arrow and Kurz 1970.)

This provides us with the necessary connection between the current value Hamiltonian and NNP. NNP is merely a linearized version of the current value Hamiltonian, the linearization amounting to representing the current flow of well-being by the shadow value of all the determinants of current well-being. In the simplest of cases, where current well-being depends solely on current consumption, NNP is reduced to the sum of the social (or shadow) value of an economy's consumption and the social (or shadow) value of the changes in its stocks of real capital assets.

The Hamiltonian calculus in fact implies something more. It implies also that along an optimal program NNP at any date is the maximum consumption the economy can enjoy at that date, were it made a condition that consumption be never allowed to fall. In short, NNP at any date along an optimal program is the maximum sustainable consumption at that date. This was not seen immediately as an implication of the mathematical theory of programming, although it should have been transparent from the work of Arrow and Kurz (1970) and Solow (1974). So a proof was provided by Weitzman (1976) in the context of economies which are capable of sustaining a steady economic state, and it was extended to the context of economies with exhaustible resources in Dasgupta and Heal (1979, pp. 244–46; see also Solow 1986).

Now "changes in capital stocks" means changes in *all* capital stocks—manufactured capital as well as natural resources. As of now, we know of no country which tries to account for environmental resource changes in its national income accounting. As we noted earlier, the effect on estimated growth rates could be significant were countries to do this, since it is entirely possible that growth in per capita GNP is currently being achieved in a number of poor countries via a deterioration of the environmental resource base. Growth in NNP over the recent past may well have been negative in a number of countries which are judged to have enjoyed positive growth.[8]

To understand how this can be, consider as an extreme hypothetical case a

8. See the calculations in Repetto and others (1989). Suggestions that conventional measures of NNP should be augmented by measures of *net nature product* (see the interesting work of Agarwal and Narain 1989) are prompted by this concern and are perfectly consistent with what we are saying in the text. By net nature product, Agarwal and Narain mean a measure of net changes in the environmental resource base. The correct measure of NNP is, of course, the sum of conventional NNP and net nature product. It is this aggregate which we are elaborating upon in the text. For tactical reasons it may well be desirable to present valuations of changes in the environmental resource base separately from conventional NNP figures. But we are concerned in the text with analytical issues. For this reason we are discussing an overall measure of NNP.

country which lives ("optimally") simply by exporting its exhaustible resources and importing consumption goods with the export revenue. Assume, too, that resources are costless to extract and that other than extraction there is no domestic production. NNP in this country, when correctly measured, would be nil. No matter that its current consumption may be high, the social value of the rate of disinvestment would exactly match the shadow value of its consumption rate. Furthermore, being exhaustible, exports must eventually go to zero, and so consumption must eventually go to zero. Such an economy cannot manage a positive, sustainable consumption path. It is this fact which is reflected in NNP, when correctly measured. We would not, however, know any of this from conventional national income accounts. NNP in this economy, as conventionally measured, could be large, and it would even be seen to be rising if the rate of disinvestment were stepped up (see Dasgupta and Heal 1979, pp. 244–46).

An important practical question (much discussed in the recent literature; see El Serafy and Lutz 1989) concerns the appropriate treatment in NNP of expenditure for protecting the environment. The answer is that it all depends upon whether such expenditures are for the purposes of redressing a flow of environmental damage or for enhancing stocks of environmental resources. To take an example, expenditures for liming lakes to counter the flow of acid rains maintain environmental quality. Were this not to be included in final demand, increased liming (which increases well-being) would be recorded as a decline in NNP. Similarly, capital expenditures (for example, the construction of stack-gas scrubbers, sewage treatment plants, and solar energy equipment) should also not be deducted from estimates of NNP, for they go to augment the durable-capital base. On the other hand, those expenditures which go to enhance resource bases, such as forests, get reflected in the value of changes in resource stocks. In order to avoid double-counting, such expenditures therefore should be excluded from NNP computations.

The general moral is that before writing down an expression for NNP it is best to express in a formal model the characteristics of the activities being undertaken in the economy under study. What passes for intermediate expenditure and what does not will be reflected in the Hamiltonian, and one can then readily construct the formula for the country's NNP, and one can simultaneously obtain the system of shadow prices. The procedure is a shade pedantic. But it provides a safeguard against mistakes. In the appendix we provide a formal account of this, and for completeness we sketch the manner in which future uncertainty can be taken into account.

Difficulties associated with the estimation of shadow prices and real NNP are compounded by the fact that unlike computers and tractors, environmental resources often affect current well-being directly as stocks, and not merely as service flows (an exception is noise pollution). Fisheries and aquifers are useful not only for the harvest they provide (this is the flow) but also as stocks, because harvesting and extraction costs are low if stocks are large. Tropical forests are beneficial not only because they may supply timber (this is the flow of service);

they are beneficial also as stocks, because they prevent soil erosion and, in the case of large tropical forests, help maintain a varied genetic pool, and contribute substantially to the recycling of carbon dioxide.

To take another example, transportation costs (in particular caloric costs) for women and children would be less were the sources of firewood not far away and receding. Likewise, air and water quality have direct effects on well-being; it is, let us remember, the concentration of pollutants which is relevant here. This has an implication for the current value Hamiltonian, and therefore for real NNP (see the appendix).

Estimating Shadow Prices

The prior question, of how we should estimate shadow prices for environmental resources, is a complex one. But it is not uniformly complex. For commodities such as irrigation water, fisheries, and agricultural soil, there are now standard techniques of evaluation. These techniques rely on the fact that such resources are inputs in the production of tradable goods (see, for example, Brown and McGuire 1967 for irrigation water; Cooper 1975, Clark 1976, and Dasgupta 1982 for fisheries; and Repetto and others 1989 for soil fertility). For others, such as firewood, and drinking and cooking water, the matter is more complex. The fact remains, though, that even these are inputs in production; specifically, inputs in household production. And this provides us with a method for estimating their shadow prices. To obtain them we will need to have an estimate of household production functions. In some cases (as with fuelwood) the resource input is a substitute for a tradable input (for example, kerosene); in others (as with cooking water) it is a complement (sometimes a weak complement) to tradable inputs (for example, food grain). Such information is in principle obtainable. It allows the analyst to estimate shadow prices. (See Schecter and others 1989 and Mäler 1990c. We should note, however, that applied work in this area has shied away from analyzing production in poor households in poor countries. There is an urgent need for research in this field. See section IV below.)

The approach we have outlined above (the "production function approach") allows one to capture only the "use value" of a resource, and its shadow price may well exceed this. Why? The reason is that there are additional values embodied in a resource stock. One additional value, applicable to living resources, is their "intrinsic worth" as living resources. (We plainly do not think that the value of a blue whale is embodied entirely in its flesh and oil, or that the value of the game in Kenyan game parks is simply the present value of tourists' willingness to pay!) It is pretty much impossible to get a quantitative handle on intrinsic worth, and so the right thing to do is to take note of it, keep an eye on it, and call attention to it whenever the stock is threatened.

Another source of value is more amenable to quantification. It arises from a combination of two things common to environmental resources: uncertainty in their future use values and irreversibility in their use. (Genetic materials in tropical forests provide a prime example.) The twin presence of uncertainty and irreversibility implies that even were the aggregate well-being function neutral to risk, it would not do to estimate the shadow price of an environmental resource solely on the basis of the expected benefit from its future use. Irreversibility in its use implies that preservation of the stock has an additional value—the value of extending one's set of future options. Future options have an additional worth precisely because with the passage of time more information is expected to be forthcoming about the resource's use value. (This additional worth is often called an *option value.*) The shadow price of a resource is the sum of its use value and its option value (see Arrow and Fisher 1974; Henry 1974; Dasgupta 1982; Fisher and Hanemann 1986; and Mäler 1989).

As we noted earlier, environmental resources in situ are mostly regarded as free in current economic exercises even while their shadow prices are positive. As we have also noted above, this leads to biases in policy and to biases in the design and installation of new technology. Recall also that even at the prior level of research and development they lead to biases, for there is little incentive for agencies to develop technologies which economize on the use of environmental resources. Indeed, an entire debate on whether economic and environmental considerations are in contraposition is a misplaced one; they are when economic calculations are biased. They would be consonant with each other if environmental resources were put on par with the kinds of goods and services which occupy the attention of economists most of the time.

III. Markets and Their Failure

All this has been from what one might call the operations-research side of things. It is an essential viewpoint, but it is a limited viewpoint. Its complement is the institutional side, with all its attendant difficulties. Indeed, it is the institutional side which has most often been the starting gate for environmental economics. Particular emphasis is placed upon the fact that markets for these goods either do not exist or are prone to malfunctioning when they do exist (see Mäler 1974; Baumol and Oates 1975; and Dasgupta 1982). By "markets" we do not necessarily mean price-guided institutions. Rather, we mean institutions which make available to interested parties the opportunity to negotiate courses of actions. And by "malfunctioning markets" we mean circumstances in which such opportunities are not present (because, say, property rights are unspecified); in which they are exploited at best partially (because, say, the bargainers do not know each other well; see Farrell 1987); or in which they are somewhat one-sided. (This often-one-sidedness of opportunities means that we are thinking of distributional issues as well and not merely those bearing on efficiency.)

Nowhere is this generalized form of market failure more common than in those hidden interactions which are *unidirectional*—for example, deforestation in the uplands, which often inflicts damages on the lowlands. As always, it pays to concentrate first on the assignment of property rights before seeking remedies. The common law, if one is permitted to use this expression in a universal context, usually recognizes the rights of polluters, not those of pollutees. Translated into our present example, this means that the timber merchant who has obtained a concession in the upland forests is under no obligation to compensate farmers in the lowlands. If the farmers wish to reduce the risk of heightened floods, it is they who have to compensate the timber merchant for reducing the rate of deforestation. Stated this way, the matter does look morally bizarre, but it is how things are. Had property rights been the other way around—recognizing pollutees' rights—the boots would have been on the other set of feet, and it would have been the timber merchant who would have had to pay compensation to farmers for the right to inflict the damages which go with deforestation. When the cause of damages is hundreds of miles away, however, and when the victims are thousands of impoverished farmers, the issue of a bargained outcome usually does not arise.[9] Thus, judged even from the viewpoint of efficiency, a system of polluters' rights in such an example would be disastrous.[10] We would expect excessive deforestation. Stated in another way, the private cost of logging would in this case be lower than its social cost.

Now when the social costs of production of environmental goods are higher than their private costs, resource-based goods may be presumed to be underpriced in the market. Quite obviously, the less roundabout, or less distant, is the production of the final good from its resource base, the greater is this underpricing, in percentage terms. Put another way, the lower is the value added to the resource, the larger is the extent of this underpricing of the final product. We may then conclude that countries which export primary products do so by subsidizing them, possibly on a massive scale. Moreover, the subsidy is paid not by the general public via taxation but by some of the most disadvantaged members of society: the sharecropper, small landholder, or tenant farmer; the forest dweller; and so on. The subsidy is hidden from public scrutiny; that is why nobody talks of it. But it is there. It is real. We should be in a position to estimate it. As of now, we have no such estimates.

Matters are usually quite different for economic and ecological interactions which are *reciprocal,* such as the use by several parties of a piece of grazing land. Many of the production and exchange contracts we see in poor agrarian and pastoral societies over the use of such resources are explicit ones, and compli-

9. Even under such conditions, bargained outcomes do arise sometimes, since community leaders, nongovernment organizations, and a free press have been known to galvanize activity on behalf of the relatively powerless. In recent years this has happened on a number of occasions in India in different sets of contexts. The most publicized one has been the Chipko movement, which involved the threatened disenfranchisement of historical users of forest products. This was occasioned by the state claiming its rights over what was stated to be "public property" and then embarking on a logging program. The connection between environmental protection and civil rights is a close one. There is absolutely no question that political and civil liberties are instrumentally useful for environmental protection.

10. The classic on this subject (Coase 1960) had an argument proving the neutrality of the assignment of property rights on allocative efficiency. Coase's theorem requires stringent assumptions, including the little-noticed one that there are only two parties involved. With more than two parties matters are different, for Shapley and Shubik (1969) and Starrett (1973) have shown that an economy can fail to possess a core allocation if there are polluters' rights over private "bads," such as household garbage. In their examples a core allocation, however, does exist with pollutees' rights.

ance with them is enforced by means of elaborate rules, regulations, and fines. (In the current literature, see in particular Feder and Noronha 1987; Wade 1987, 1988; Hecht, Anderson, and May 1988; Agarwal and Narain 1989; Chopra, Kadekodi, and Murty 1989; and Ensminger, forthcoming.) However, many contracts are merely implicit, the obligations they entail having often been codified over the years in the form of social norms. In such cases, associated social sanctions sometimes are imposed on violators of such norms, occasionally on those who fail to impose sanctions on violators, even more rarely on those who fail to impose sanctions on those who fail to impose sanctions on violators, and so on.[11] Thus, the fact that a piece of environmental property is not in private (or government) hands does not mean at all that there is institutional failure. The anthropological literature is replete with studies of communities that have developed elaborate patterns of monitoring and control over the use of what are today called common property resources.

Economic analysis is thought by some to have implied that common property resources can only be managed through centralized coordination and control (by "centralized" we mean the government or some agency external to the community of users). Referring to the problem of the commons in the theoretical literature, Wade (1987, p. 220), in a much-cited article, writes that "the prevailing answer runs as follows: when people are in a situation where they could mutually benefit if all of them restrained their use of a common-pool resource, they will not do so unless an external agency enforces a suitable rule." And he proceeds to describe enforcement mechanisms in his sample of villages which do not rely on external agencies.

But the literature has not implied the necessity of centralized or external control. The theory of games has unraveled the variety of institutional mechanisms (ranging from taxes to quantity controls) which can in principle support desirable allocations of common property resources. The theory makes clear, and has made clear for quite some time, that enforcement of the agreed-upon allocation can be carried out by the users themselves. In many cases this may well be the most desirable option. As always, monitoring, enforcement, information, and transaction costs play a critical role in the relative efficacy of these mechanisms, and we will have something to say about this in what follows. (For a formal, mathematical account, and an informal discussion of the possibilities implied by the formal analysis, see Dasgupta and Heal 1979, chap. 3, sections

11. By a social norm we mean a generally accepted injunction to follow a specified behavioral strategy. Social norms are internalized by people up to a point, so that the infinite chain of meta-norms we have just mentioned in the text is not required for sustaining reciprocity and cooperation. See in particular Wiser (1936), Polanyi (1944, 1977), Goody (1973), Scott (1976), Chambers, Longhurst, and Pacey (1981), Cashdan (1989), and a fine analytical discussion by Elster (1989). We are not suggesting that social norms are efficient, nor that they are necessarily equitable. In fact, inefficiencies and inequities abound. (See, for example, Popkin 1979, Beteille 1983, Iliffe 1987, and Elster 1989.) We are merely asserting that they exist, and that they support outcomes which would not prevail in their absence. Aumann (1981), Fudenberg and Maskin (1986), and Abreu (1988) provide a formal basis for seeing how norms can be sustained even when people have not internalized them, and how they can be both inefficient and inequitable. The required analysis makes use of the theory of repeated games. See Dasgupta (1990, forthcoming) for an elementary exposition.

4–5.) The confirmation of theory by evidence on the fate of different categories of common property resources is a pleasing success of modern economic analysis.[12]

IV. Public Failure and the Erosion of Local Commons

There is a vast difference between global and local commons. The open seas are common property resources, as are usually village ponds. As economic analysis makes clear, what are problems for the former are by no means problems for the latter. However, it is the global commons, and popular writings on them (for example, the influential article by Hardin 1968), which have shaped popular images of all common property resources. This has been most unfortunate because, unlike global commons, the source of the problems associated with the management of local commons is often not the users but other agencies. The images invoked by "the tragedy of the commons" are mostly not the right ones when applied to local commons. The point is that local commons (village ponds and tanks; pastures and threshing grounds; watershed drainage and river beds; and sources of fuelwood, medicinal herbs, bamboo, palm products, resin, gum, and so on) are in no society open for use to all. They are open only to those having historical rights, through kinship ties, community membership, and so on. Those having historical rights of use tend, not surprisingly, to be very protective of these resources. Local commons are easy enough to monitor, and so their use is often regulated in great detail by the community, as we noted earlier, either through the practice and enforcement of norms or through deliberate allocation of use (see, for example, Wade 1987).

The extent of common property resources as a proportion of total assets in a community varies greatly across ecological zones. In India they appear to be most prominent in arid regions, mountain regions, and unirrigated areas. They are least prominent in humid regions and the river valleys (see Agarwal and Narain 1989; and Chopra, Kadekodi, and Murty 1989). An almost immediate empirical corollary of this is that income *inequalities* are less where common property resources are more prominent. Aggregate income, however, is a different matter altogether, and it is the arid and mountain regions and unirrigated areas which are the poorest.[13] This needs very much to be borne in mind when policy is devised.

In an important and interesting article, Jodha (1986) used data from eighty villages in twenty-one dry districts from seven states in India to estimate that among poor families the proportion of income based directly on common prop-

12. Game-theoretic analyses of common property resources have almost invariably concentrated on the case of large numbers of users, where each user contributes a tiny amount to environmental degradation, but where the total effect, by virtue of the large numbers involved, is substantial. Repetto (1988) confirms that it is this class of cases, and *not* instances of large investment projects, which provides most of the bases of environmental degradation in poor countries.

13. As might be expected, even within dry regions dependence on common property resources falls with rising wealth across households. The interrelationship between destitution and the erosion of the rural environmental resource base is developed in a wider analytical context in Dasgupta (1989).

erty resources is for the most part in the range of 15 to 25 percent. This is a nontrivial proportion. Moreover, these resources are very much complementary to the sources of income from private property resources, which are mainly labor; milch and draft animals; land for cultivation and crops, but often not the stubble in the postharvest period; common agricultural tools, such as ploughs, harrows, levelers, and hoes; fodder-cutting and ropemaking machines; and seeds. Common property resources also provide the rural poor with partial protection in times of unusual economic stress. For landless people they may be the only nonhuman asset at their disposal. As it also happens, a number of such resources—such as fuelwood and water for home use, medicinal herbs, resin, and gum—are the responsibility of women and children.

A similar picture emerges from Hecht, Anderson, and May (1988), which describes in rich detail the importance of the extraction of babassu (a Brazilian palm tree) products among the landless in the Brazilian state of Maranhao. The complementarity between this extraction activity and agricultural work is striking, most especially for women. These extractive products are, as it happens, a particularly important source of cash income in the period between agricultural food crop harvests.

It is not difficult to see why common property resources matter greatly to the poorest of the rural poor in a society, nor, therefore, is it difficult to understand the mechanisms through which such people may well get disenfranchised from the economy even while in the aggregate it enjoys economic growth (a formal account of the processes through which this can occur is developed in Dasgupta 1989). If one is steeped in social norms of behavior and understands community contractual obligations, one does not calculate every five minutes how one should behave. One follows the norms. This saves on costs all around, not only for the individual as an "actor," but also as a policeman and judge. It is also the natural thing for one to do if one has internalized the norms. But this is sustainable so long as the background environment remains pretty much constant. It will not be sustainable if the social environment changes suddenly. One might even be destroyed. It is this heightened vulnerability, often more real than perceived, which is the cause of some of the greatest tragedies in contemporary society. For they descend upon people who are, in the best of circumstances, acutely vulnerable.

The sources which trigger destitution by this general means vary. The erosion of common property resource bases can come about in the wake of shifting populations (accompanying the growth process itself), rising populations, technological progress, unreflective public policies, predatory governments, and thieving aristocracies. There is now an accumulation of evidence on this range of questions, and in what follows we present an outline of the findings in three sets of studies.

In his work on the drylands of India, Jodha (1986) noted a decline in the geographical area covering common property resources ranging from 26 percent to 63 percent over a twenty-year period. This was in part due to the privatization of land, well over half of which in his sample had been awarded to the rural nonpoor. He also noted a decline in the productivity of common property resources on account of population growth among the using community. In an earlier work, Jodha (1980) identified an increase in subsistence requirements of the farming community and a rise in the profitability of land exploitation from cropping and grazing as a central reason for increased desertification in the state of Rajasthan in India. Jodha argued that, ironically, it was government land reform programs in this area, unaccompanied by investment in improving the productive base, which had triggered the process (for a formalization of the dynamics of such a process, see Dasgupta 1982, chap. 6).

Ensminger (forthcoming), in a study of the privatization of common grazing lands among the Orma in northeastern Kenya, indicates that the transformation took place with the consent of the elders of the tribe, and she attributes this willingness to changing transaction costs brought about by cheaper transportation and widening markets. The elders were, quite naturally, from the stronger families, and it does not go unnoted by Ensminger that privatization has accentuated inequalities. However, she provides no data to tell whether the process has increased the prevalence of destitution among the economically weak.

In an earlier, much-neglected work on the Amazon basin, E. Feder (1977, 1979) described how massive private investment in the expansion of beef-cattle production in fragile ecological conditions has been supported by domestic governments in the form of tax concessions and provision of infrastructure, and by loans from international agencies such as the World Bank. The degradation of vast tracts of valuable environmental resources was, not surprisingly, accompanied by the disenfranchisement of large numbers of small farmers and agricultural laborers from the economy, and it made traditional forest dwellers destitute, at best, and simply eliminated them, at worst.[14]

The sources of the transformation of common property resources into private resources described in these three sets of studies are, of course, quite different. Consequently, the ways in which they affected those with historical rights have been quite different. But each is understandable and believable. Because they are confirmed by economic theory, the findings of these case studies are almost certainly not unrepresentative. They suggest that privatization of village commons and forest lands, although hallowed at the altar of efficiency, can have disastrous distributional consequences, disenfranchising entire classes of people from economic citizenship (for alternative demonstrations of this theorem, see Cohen and Weitzman 1975 and Dasgupta and Heal 1979, chap. 3). They also

14. See also Dasgupta (1982, chap. 2) and Hecht (1985). The data suggest that during the decades of the 1960s and 1970s protein intake by the rural poor *declined* even while the production of beef protein increased dramatically. Much of the beef was destined for exports, for use by fast-food chains. These matters, which are an instance of the intricate link between economic, social, and financial institutions, have been taken up anew by Repetto (1988), Mahar (1988), and Binswanger (1989). The latter in particular has shown how in Brazil the exemption from taxation of virtually all agricultural income (allied to the fact that logging is regarded as proof of land occupancy) has provided strong incentives for the acquisition of agricultural lands by the higher-income groups and a general incentive for the acquisition of forest lands for the purposes of deforesting them.

show that public ownership of such resources as forest lands is by no means necessarily a good basis for a resource allocation mechanism. Decisionmakers are in these cases usually far removed from the site (living as they do in imperial capitals); they have little knowledge of the ecology of such matters; their time horizons are often short; and they are in many instances overly influenced by interest groups far removed from the resource in question.

All this is not at all to suggest that rural development is to be avoided. It is to say that resource allocation mechanisms which do not take advantage of dispersed information; which are insensitive to hidden (and often not so hidden) economic and ecological interactions (that is, general equilibrium effects); which do not take the long view; and which do not give a sufficiently large weight to the claims of the poorest within rural populations (particularly the women and children in these populations) are going to prove environmentally disastrous. It appears, then, that during the process of economic development there is a close link between environmental preservation and the well-being of the poor, most especially the most vulnerable among the poor. Elaboration of this link has been one of the most compelling achievements at the interface of anthropology, economics, and nutrition science.

The links between environmental degradation and an accentuation of deprivation and hardship can take forms which are even today not always appreciated. The responsibilities for gathering fuelwood and fetching water for domestic use in most rural communities fall upon women and children. When allied to household chores and their farming obligations, the workload of women in South Asia in terms of time is often one-and-a-half to two times that of men (see, for example, Fernandes and Menon 1987; Kumar and Hotchkiss 1988; B. Agarwal 1989). This workload has over the years increased directly as a consequence of receding resources. It is very much worth reminding ourselves that we are speaking of a category of people of whom more than 50 percent suffer from iron deficiency, of whom only a little below 50 percent suffer from wastage, and who in some parts of the world work fifteen to sixteen hours a day during the busy agricultural season. Thus, communities in the drylands of the Indian subcontinent and in Sub-Saharan Africa today often live miles away from fuel and fodder sources and permanent water sources. Surveys in East Africa have shown, for example, that women and children spend up to five hours a day collecting water during the dry season (see Food and Agricultural Organization 1987). The consequence is that anything between 10 and 25 percent of daily daytime energy expenditure is required for collecting water.[15]

15. See Chen (1983) for a review of the link between improved water supply and health benefits among the rural poor. We should note that a similar problem is associated with fuelwood collection. In northern India, for example, it is thought that some 75 percent of firewood for domestic use comes from twigs and fallen branches. From data that are now available from the drylands of India on time allocation on the part of women in fuelwood collection, the energy costs in this activity would seem to be also in the range of 10 percent to 25 percent. It should be noted that estimates of the energy-cost of collection are essential ingredients in the calculation of the shadow prices of fuelwood and water.

All this cannot but be related to the fact of high fertility and low literacy in rural areas of most poor countries. Poverty and the thinness of markets make it essential for households to engage in a number of complementary production activities: cultivation, cattle grazing, fetching water, collecting fuelwood, cooking food, and producing simple marketable products. Each is time-consuming. (Labor productivity is low not only because capital is scarce but also because, as we have just noted, environmental resources are scarce, too.) If it is to survive, a household simply has to accomplish these tasks each day, and a small household cannot do them all. Each household needs many hands. Children are needed as workers by their parents, even when parents are in their prime. Children are not merely a consumption good (as in Nerlove, Razin, and Sadka 1987), nor are they only a means to old-age security (as in Cain 1983). They are also of current use to parents. But a high rate of fertility and population growth further damages the environmental resource base, which in turn can provide further (private) incentives for large families, which in turn further damages the resource base, and so on—until some countervailing factors (whether public policy or some form of Malthusian check) stop the spiraling process. But by the time this happens millions of lives have suffered (for further development of these issues, see Dasgupta, forthcoming, and Nerlove and Meyer 1990).

Information concerning the ecology of local commons is often dispersed, and is usually in the hands of the historical users. There are exceptions, of course, but as a general rule this makes it desirable that the local commons be protected as commons and that decisions regarding local commons be left in the hands of the users themselves. This is because the local commons will almost certainly remain the single source of essential complementary goods for poor people for a long while yet. To be sure, it is essential not only that governments provide infrastructural and credit and insurance facilities, but that they make new information concerning technology, ecology, and widening markets available to the users. But there is little case for centralized control. Quite the contrary, there is a case for facilitating the growth of local, community decisionmaking—in particular, decisionmaking by women, who are for the most part the main users of such resources. The large, often fragmented literature on local common property resources is beginning to offer us an unequivocal picture that during the process of economic development the protection and promotion of environmental resources would be best served were a constant public eye kept on the conditions of the poorest of the poor in society. Environmental economics and the economics of destitution are tied to each other in an intricate web. We should not have expected it otherwise.

V. International Failure and the Erosion of Global Commons

Global commons pose a different type of problem. The impossibility of establishing adequate property rights to the atmosphere, to watersheds, and to large bodies of water, such as the oceans, are a cause of inefficiencies in the allocation of resources. In the case of the atmosphere (for example, over the matter of global warming), there is not even the option of "voting with one's feet." Furthermore, future generations are not directly represented in today's forum for decisionmaking. Their interests are included only indirectly through transactions between different coexisting generations. Thus the inefficiencies and inequities involved are not merely static ones but are intergenerational ones as well (see Mäler 1990b for a more detailed discussion of these issues). From this it follows that the international community needs consciously to design systems which improve upon existing resource allocation mechanisms.

The most complicated international environmental problems are, like the local commons, characterized by reciprocal externalities; that is, most countries that contribute to environmental damages also suffer from them. Emissions of greenhouse gases are an instance of this. A central problem is that "reciprocal" countries do not contribute to the damages in equal amounts. Thus, for a cooperative outcome to be achievable, some financial transfers will be necessary, if only in an implicit manner. Several such systems suggest themselves—debt relief for the preservation of the Amazon being among the most frequently talked about.

This is not to say that agreements cannot be reached without side payments; it is only to say that they will tend to be less efficient. Barrett (1990) has argued, for example, that one should not expect all countries to sign the Montreal protocol on emissions of chlorofluorocarbons (CFCs). (The protocol involves no side payments.) If an equilibrium exists, it can only involve *some* countries signing the protocol. The reason is that were only a few countries to sign the protocol, national benefits from further reduction in CFC emission would be high. This would induce more countries to sign. However, were many countries to sign the protocol, national benefits from further reduction would be small, and it would then not be worth a country's while to sign the agreement.

Direct (side) payments among countries for solving environmental problems have not been so common. When made, side payments have tended to be nonpecuniary; for example, trade and military concessions (see Krutilla 1966; Kneese 1988). Very recently, an agreement has been reached on reducing the production and use of CFCs in developing countries. This has involved the creation of an international fund for technological transfers to these countries. It is a most promising development, and it needs to be studied carefully for the purposes of further development.

One broad category of allocation mechanisms well worth exploring in the international context involves making the global commons quasi-private. The basic idea, which originated in Dales (1968), is similar to the principle currently being experimented with in the United States. The idea, if extended to the international sphere, would have the community of nations set bounds on the total annual use of the global commons, such as the atmosphere, have it allocate an initial distribution of transferable national rights which add up to the aggregate bound, and allow the final allocation among different users to be determined by competitive markets.[16]

For example, consider greenhouse gases. Suppose the community of nations desires to reduce emissions to a prescribed global level. Units of the various gases would then be chosen so that all gases have the same (expected) effect on global climate. In other words, at the margin the emission of one unit of any one gas would have the same (expected) climatic effect as the emission of one unit of any other gas. The scheme would allow countries to exchange permits for one gas for permits for any other. Countries would receive an initial assignment of marketable permits. As is well known, this scheme has informational advantages over both taxes and quantity controls on individual emissions. (See Dasgupta, Hammond, and Maskin 1981 for a formal analysis of optimal incentive schemes for pollution control.) Furthermore, were the permits to refer to *net* emissions (that is, net of absorption of carbon dioxide by green plants), the scheme would provide an incentive for countries with fast-growing tropical rain forests to earn export revenue by encouraging forest growth and then selling permits to other countries. The scheme also has the advantage that the necessary side payments required to induce all (or most) countries to participate in the agreement can be made through the initial distribution of emission permits. Countries which do not expect severe damages from global warming would also wish to participate were they to be provided initially with a sufficient number of permits (or rights).

The sticking point will clearly be over reaching an agreement on the initial distribution of permits among nations. (How a national government allocates the nation's rights among agencies within the country is a different matter.) But the point here is that if the bound set on annual aggregate greenhouse emissions is approximately optimal, it is always possible to distribute the initial set of rights in such a way that all countries have an incentive to join the scheme. For this reason one cannot overemphasize the fact that there are large potential gains to be enjoyed from international cooperation; a scheme involving the issue of marketable permits in principle offers a way in which all nations can enjoy these gains. The argument that "national sovereignty" would be endangered is in fact no argument, for the point about global commons is precisely that they are beyond the realm of national sovereignty.

VI. Summary

In this article we have tried to present a perspective on what we take to be the central emerging issues at the interface of environmental and development con-

16. See Tietenberg (1980, 1990) for reviews of the experience that has been accumulated with such schemes in the United States. See also Dasgupta (1982) and Mäler (1990a) for mathematical formalizations of these schemes under varying environmental circumstances. The motivation behind these formalizations is that they enable us to calculate the efficiency gains realizable by such resource allocation mechanisms.

cerns. The fact that for such a long while environmental and development economics have had little to say to each other is a reflection only of these academic disciplines; it does not at all reflect the world as we should know it. Poor countries are for the most part agrarian and pastoral, and it is but natural that the bulk of society in these lands depends crucially on renewable natural resources. One of the sobering lessons of the international development experience has been that the magnitudes of poverty and destitution have proved singularly resistant to reduction in many parts of the globe. It is beyond our competence to try to explain this, but there is growing evidence that acute poverty and environmental degradation are closely linked in most poor countries. We have argued that the poor in resource-exporting countries are very likely subsidizing these exports. A reasonable rule of thumb for the "environmentalist" would therefore be to keep a constant eye on the poorest of the poor. Their activities (for example, migration patterns of communities or time-use patterns of poor women) are often a good signal of the state of the environment. By the same token, it is fatuous to talk and write about poverty and development unless we simultaneously study the fate of environmental resources under alternative resource allocation mechanisms. The separation of environmental and development economics has proved to be enormously costly in terms of lost hopes and wasted lives.

We have argued that local and global commons pose quite different problems and that environmental damages at the local level have often been inflicted upon such communities (possibly unwittingly) by outside agencies—very often by their own governments. There are countries where information about the environmental resource base is almost wholly absent. If environmental resources are to be brought into line with other capital assets, they must as a minimum enter national income accounting. In this paper we have presented an outline of how to go about doing this in a meaningful way. We would imagine that it is the global commons which will occupy the international stage in the immediate future, as evidence accumulates on the mechanisms underlying their degradation. We have presented the bare bones of a resource allocation mechanism in which countries receive marketable permits for the use of the global commons and in which all nations have an incentive to participate.

Appendix

Consumption and Accumulation with Environmental Effects: A Definition of NNP

In this part of the appendix we present what we hope is a canonical model involving consumption and accumulation with environmental effects. Our aim is to display the connection between shadow prices, rules for project evaluation, and national income accounting in a context which is simple but which has at the same time sufficient structure to allow us to obtain a number of the prescriptions we alluded to in the text, especially in section II. Keeping to essential matters here, we ignore the kinds of "second-best" constraints (including disequilibrium phenomena) which have been the center of attention in the literature on project evaluation, as in Dasgupta, Marglin, and Sen (1972) and Little and Mirrlees (1974).

We consider an economy with a multipurpose, manmade capital good whose stock is denoted by K_1. If L_1 is the labor effort combined with this, the flow of output is taken to be $Y = F(K_1, L_1)$, where $F(.)$ is an aggregate production function. (In what follows we assume that all functions satisfy conditions which ensure that the planning problem defined below is a concave program. For example, we assume that $F(.)$ is concave.) The economy enjoys in addition two sorts of environmental resource stocks: clean air, K_2, and forests, K_3. Clean air is valued directly, whereas forests have two derived values: they help keep the atmosphere clean, and they provide fuelwood, which, too, is valued directly. Finally, we take it that there is a flow of environmental amenities, Z, which directly affects aggregate well-being.

Forests enjoy a natural regeneration rate, but labor effort can increase it. Thus we denote by $H(L_2)$ the rate of regeneration of forests, where L_2 is labor input for this task, and where $H(.)$ is, for low values of L_2 at least, an increasing function. Let X denote the rate of consumption of fuelwood. Collecting this involves labor effort; let this be L_3. Presumably, the larger the forest stock the less is the effort required (in calorie requirements, say). We thus assume that $X = N(K_3, L_3)$, where $N(.)$ is an increasing, concave function of its two arguments.

Output Y is a basic consumption good, and this consumption is also valued directly. However, we take it that the production of Y involves pollution as a by-product. This reduces the quality of the atmosphere both as a stock and as a flow of amenities. We assume, however, that it is possible to take defensive measure against both these ill effects. First, society can invest in technologies that reduce the emission of pollutants, and we denote the stock of this defensive capital by K_4. If P denotes the emission of pollutants, we have $P = A(K_4, Y)$, where A is a convex function, decreasing in K_4 and increasing in Y. Second, society can mitigate damages to the flow of amenities by expending a portion of final output, at a rate R. We assume that the resulting flow of amenities has the functional form, $Z = J(R, P)$, where J is increasing in R and decreasing in P.

There are thus four things that can be done with output Y: it can be consumed (we denote the rate of consumption by C); it can be reinvested to increase the stock of K_1; it can be invested in the accumulation of K_4; and it can be used, at rate R, to counter the damages to the flow of environmental amenities. Let Q denote the expenditure on the accumulation of K_4.

Now, the environment as a stock tries to regenerate itself at a rate which is an increasing function of the stock of forests, $G(K_3)$. The net rate of regeneration is the difference between this and the emission of pollutants from production of Y.

We can therefore express the dynamics of the economy in terms of the following equations:

(1) $$dK_1/dt = F(K_1, L_1) - C - Q - R$$

(2) $$dK_2/dt = G(K_3) - A[K_4, F(K_1, L_1)]$$

(3) $$dK_3/dt = H(L_2) - X$$

(4) $$dK_4/dt = Q$$

(5) $$X = N(K_3, L_3)$$

(6) $$Z = J\{R, A[K_4, F(K_1, L_1)]\}.$$

The current flow of aggregate well-being, W, depends positively upon aggregate consumption, C; the output of fuelwood, X; the flow of environmental amenities, Z; and the quality of the atmospheric stock, K_2. However, it depends negatively upon total labor effort, $L = L_1 + L_2 + L_3$. (As noted above, labor effort could be measured in caloric terms.) We thus have $W(C, X, Z, K_2, L_1 + L_2 + L_3)$.

Stocks of the four types of assets are given at the initial date; the instantaneous control variables are C, Q, R, X, L_1, L_2, and L_3; and the objective is to maximize the (discounted) sum of the flow of aggregate well-being over the indefinite future. We take well-being to be the numeraire. Letting p, q, r, and s denote the (spot) shadow prices of the four capital goods, K_1, K_2, K_3, and K_4 respectively, and letting v be the imputed marginal value of the flow of environmental amenities, we can use equations 1 through 6 to express the current value Hamiltonian, V, of the optimization problem as

(7) $$\begin{aligned} V = {} & W[C, N(K_3, L_3), Z, K_2, L_1 + L_2 + L_3] \\ & + p[F(K_1, L_1) - C - Q - R] + q\{[G(K_3) - A[K_4, F(K_1, L_1)]\} \\ & + r[H(L_2) - N(K_3, L_3)] + sQ + v[J\{R, A[K_4, F(K_1, L_1)]\} - Z]. \end{aligned}$$

Recall that the theory of optimum control instructs us to choose the control variables at each date so as to maximize expression 7. (Notice that we have used equations 5 and 6, and so the controls are now C, Z, Q, R, L_1, L_2, and L_3.) Writing by W_C the partial derivative of W with respect to C, and so forth, it is then immediate that along an optimal program the control variables and the shadow prices must satisfy the conditions:

$$\text{(i) } W_C = p; \quad \text{(ii) } W_X N_2 + W_L = rN_2; \quad \text{(iii) } W_Z = v;$$
$$\text{(iv) } W_L = [(q - vJ_2)A_2 - p]F_2; \quad \text{(v) } W_L = -r dH(L_2)/dL_2;$$
$$\text{(vi) } p = vJ_1; \quad \text{and (vii) } p = s.$$

F_2 stands for the partial derivative of F with respect to its second argument,

L_1; and as mentioned earlier, $L = L_1 + L_2 + L_3$. We have used this same notation for the derivatives of $N(.)$, $J(.)$, and $A(.)$. Interpreting these conditions is instructive, for they tell us what kinds of information we need to estimate shadow prices. (We do not write down the intertemporal "arbitrage conditions" which these shadow prices must also satisfy, since we do not use them.) But for our purposes, the point to note is that we can immediately derive the correct expression for NNP from equation 7. It is the linear support of the Hamiltonian along the optimal program. In order to keep the expression for NNP from becoming overly cumbersome, let us denote by O^* the *vector* of all the nonprice arguments in the Hamiltonian function along the *optimal* program at any given date. Thus, $O^* = (C^*, Z^*, Q^*, R^*, K_1^*, K_2^*, K_3^*, K_4^*, L_1^*, L_2^*, L_3^*)$. It follows from taking the Taylor expansion around O^* that the linear support of the Hamiltonian is

$$\begin{aligned}(8)\qquad & V(O^*) + W_C C^* + W_X X^* + W_Z Z^* + W_{K_2} K_2^* + W_L(L_1^* + L_2^* + L_3^*) \\ & + p\mathrm{d}K_1^*/\mathrm{d}t + q\mathrm{d}K_2^*/\mathrm{d}t + r\mathrm{d}K_3^*/\mathrm{d}t + s\mathrm{d}K_4^*/\mathrm{d}t\end{aligned}$$

where Z^* is equal to $J\{R^*, A[K_4^*, F(K_1^*, L_1^*)]\}$.

We may divide the whole expression by W_C to express NNP in aggregate consumption numeraire. It should also be recalled that by assumption W_L is *negative*. Now, for evaluating a marginal project $V(O^*)$ is irrelevant, as it is a constant term. We may as well then drop it. In this case, NNP in the optimizing economy, measured in well-being numeraire, is the remaining term of equation 8, namely:

$$\begin{aligned}(9)\qquad \mathrm{NNP} = {} & W_C C + W_X X + W_Z J\{R, A[K_4, F(K_1, L_1)]\} + W_{K_2} K_2 \\ & + W_L(L_1 + L_2 + L_3) + p\mathrm{d}K_1/\mathrm{d}t + q\mathrm{d}K_2/\mathrm{d}t + r\mathrm{d}K_3/\mathrm{d}t + s\mathrm{d}K_4/\mathrm{d}t.\end{aligned}$$

However, for international comparisons $V(O^*)$ is of interest, since countries differ in the stocks of capital they hold. In this case NNP should be measured on the basis of equation 8 (see Weale 1990). It is possible to show that there is a permissible representation of the well-being function for which

$$(10)\qquad V(O^*) = \delta(pK_1^* + qK_2^* + rK_3^* + sK_4^*)$$

where $\delta\ (> 0)$ is the rate at which the flow of aggregate well-being is discounted. This means that the Hamiltonian measures the sum of the social returns on all of society's capital assets. In short, it is a measure of society's wealth (see Solow 1986).

Notice that all resources and outputs are valued at the prices which sustain the optimum program.[17] To highlight the points we want to make here, we have

17. One could alternatively think of a sequence of policy reforms and use shadow prices defined at the existing structure of production. Given that the planning program is by hypothesis concave, a sequence of such moves would take the economy ultimately to the optimum. For a simplified exposition of the connection between these two modes of analysis (reforms and optimization), see Dasgupta (1982, chap. 5).

chosen to work with a most aggregate model. Ideally (income) distributional issues will find reflection in the aggregate well-being function. These considerations can readily be translated into the estimates of shadow prices (see Dasgupta, Marglin, and Sen 1972).

Let us suppose that we are involved in the choice of projects. A marginal project is a perturbation of the optimal program. It can be expressed as a ten-vector (dC, dX, dR, dL_1, dL_2, dL_3, dI_1, dI_2, dI_3, dI_4), where $I_i = dK_i/dt$, ($i = 1$, 2, 3, 4); and dC, and so on, are small changes in C, and so on. A marginal project has no effect on the fourth term on the right-hand side of equation 9. (For the purposes of social cost-benefit analysis we could, therefore, simply ignore this term when estimating NNP.) Along an optimal program, the social profitability of the last project is nil; that is, its contribution to NNP is nil. This follows from the fact that the controls are chosen so as to maximize expression 7. All this is well-known, and our purpose here is to obtain some additional insights. Scrutiny of equation 9 tells us the following:

- Were wages to equal the marginal ill-being of work effort, wages would not be part of NNP. Put in other words, the shadow wage bill ought to be deducted from gross output when we estimate NNP. However, if labor is supplied inelastically, it is a matter of indifference whether the wage bill in this optimizing economy is deducted from NNP. Conversely, were we to recognize a part of the wage bill as a return on the accumulation of human capital, that part *would* be included in NNP.

- Current defensive expenditure, R, against damages to the flow of environmental amenities should be included in the estimation of final demand (see the third term in equation 9). Moreover, investments in the stock of environmental defensive capital should also be included in NNP (see the final term of equation 9). Now, expenditures which go toward enhancing the environment find expression in the value that is imputed to changes in the environmental resource stock. We may conclude, therefore, that such expenditures should not be included in estimates of NNP. (Notice the absence of sQ in equation 9.)

- The value of *changes* in the environmental resource base (K_2 and K_3) should be included in NNP. However, anticipated capital gains (or losses) are not part of NNP.

Uncertainty

In this part of the appendix we present a sketch of the arguments involved in the definition of NNP when there are random events in the future that are expected to have an effect on the value of the then-existing capital assets. As an example, we could imagine the discovery and installation of cleaner production technologies which make existing abatement technologies less valuable. For simplicity of exposition, we will assume that such discoveries are uninfluenced by policy; for example, research and development policy, although such policy can easily be incorporated. The analysis builds on Dasgupta and Heal (1974) and Dasgupta and Stiglitz (1981). However, these earlier studies did not address the measurement of NNP, which is our present concern.

It is most striking to consider discrete events. Thus, imagine that at some random future date, T, an event occurs which is expected to affect the value of the then-existing stocks of capital. We consider the problem from the vantage point of the present, which we denote by $t = 0$. Let us assume that there is a (possibly subjective) probability density function, π_t, over the date of occurrence. (We are thus supposing for expositional ease that the event *will* occur at some future date.) From this we may define the cumulative function Φ_t.

We take it that the social good is reflected by the expected value of the sum of the discounted flow of future well-being. Were the event in question to occur at date T, the economy in question would enter a new production and ecological regime. In what follows we continue to rely on the notation which was developed in the first part of the appendix. As is proper, we now proceed to work backwards. Thus, let K_i^T(with $i = 1, 2, 3, 4$) denote the stocks of the four assets at date T. Following an optimal economic policy subsequent to the occurrence of the event would yield an expected flow of aggregate well-being. This flow we discount back to T. This capitalized value of the flow of well-being will clearly be a function of K_i^T. Let us denote this by $B(K_1^T, K_2^T, K_3^T, K_4^T)$. It is now possible to show that until the event occurs, the optimal policy is to pretend that the event will never occur, and to assume that the flow of aggregate well-being is given, not by $W(.)$, as in the first part of the appendix, but by $(1 - \Phi_t)W(.) + \pi_t B(.)$. We may therefore conclude from the analysis of the first part of the appendix that NNP at any date prior to the occurrence of the event is given by the equation

$$
\begin{aligned}
\text{NNP} = {} & (1 - \Phi)[W_C C + W_X X + W_Z Z + W_{K_2} K_2 \\
& + W_L(L_1 + L_2 + L_3) + p dK_1/dt + q dK_2/dt + r dK_3/dt \\
& + s dK_4/dt] + \pi[B_{K_1} K_2 + B_{K_2} K_2 + B_{K_3} K_3 + B_{K_4} K_4].
\end{aligned}
\tag{11}
$$

(As in the first part of the appendix, we are suppressing the time index for clarity.) Notice that if the event is not ever expected to occur, then $\pi_t = 0$ for all t, and consequently $(1 - \Phi_t) = 1$ for all t. In this case, equation 11 reduces to equation 9. Note also that no marginal economic activity can affect the terms within the second pair of square brackets at date t. It follows that we could as well drop these terms from estimates of NNP. Now, were we to do this, equation 11 would *look* the same as equation 9. But their *values* would not be the same. This is because the shadow prices (for example, p, q, r, and s) appearing in equation 11 assume quite different values from those in equation 9: future possibilities hypothesized in this model economy are quite different from those assumed in the model economy of the previous section of the appendix. Finally, we should note that the shadow prices appearing in equation 11 are Arrow-Debreu contingent commodity prices.

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Comment on "The Environment and Emerging Development Issues," by Dasgupta and Mäler

Mohan Munasinghe

This lucid and concise paper by two leading researchers neatly encapsulates and explains the essential relationships between the environment and development from an economic viewpoint. The broad scope of the subject matter has, however, forced the authors to skim over several vital areas that need further exploration. Because conferences put limits on discussants as well as authors, I will attempt only to expand on a few key implications arising mainly from the practical implementation of the elegant analytical framework Dasgupta and Mäler present.

From a broad philosophical viewpoint, I believe that treating environmental issues within an economic framework is the correct approach. Efficient economic management of all resources (including environmental or natural resources) helps to identify sustainable development strategies that can also comprehensively address other pressing socioeconomic problems, such as poverty. Nevertheless, let me pose to the authors a basic question that some noneconomists might raise—that is, whether disciplines other than economics might provide useful insights into environmental problems. As we know, the neoclassical economic approach depends on a number of underlying assumptions, such as the self-interest of economic agents and their rationality (Hirschleifer 1985). Researchers in other disciplines, however, have identified nonselfish patterns of individual and group behavior characterized by altruism and cooperation. Similarly, evidence of preference reversal, status quo bias, and so on demonstrates that human behavior is not always rational. Thus environmental analysis must deal not only with physical resources and human-made capital but also with biological and social behavior systems. Biology, for example, has produced broad underlying theories, such as the "selfish gene," to explain diverse aspects of behavior. Is there then some fruitful synthesis possible of these other disciplinary approaches with the standard neoclassical economic worldview?

Moving to the specific subject matter, a central feature of the paper is the current value Hamiltonian (CVH). If we accept the economic approach, the CVH is indeed a useful metaphor and organizing principle to identify how environmental resources could be identified and valued—thereby improving the quality

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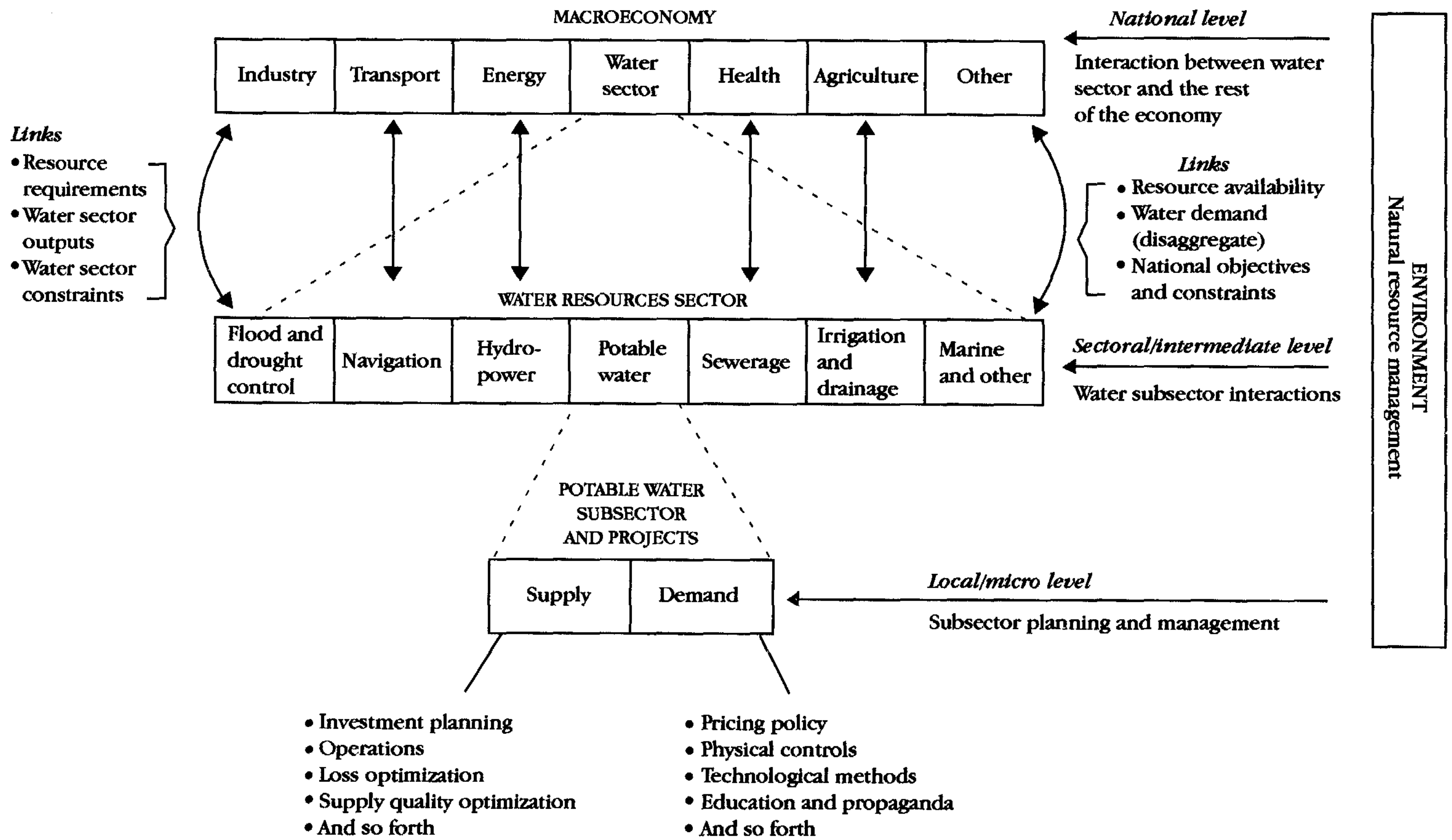
Figure 1. *Conceptual Framework for National Economic Decisionmaking and Sustainable Environmental Management*



of economic decisionmaking. In brief, if one had a set of optimal shadow prices, perfect foreknowledge, and so on, one could arrive at optimal decisions. But we live in an imperfect world, and this raises formidable problems in practically implementing the conceptual model described by the authors. For example, many countries are unable to calculate even conventional net national product (NNP); they basically rely on gross product figures that do not reflect the appropriate depreciation of physical infrastructure and capital goods (Lutz and Munasinghe, forthcoming). Clearly, the priority in such cases is to estimate conventional NNP, and ascertain whether economic performance is satisfactory on this basis, before seeking more "refined" corrections of national product to account for degradation of "environmental capital."

Although Dasgupta and Mäler provide a useful conceptual framework for incorporating environmental resources into economic decisionmaking, their concluding assertion that they have done this in a meaningful way is not justified because they do not adequately explore the practical implementation of this conceptual framework. In section II they do recognize the difficulty of applying their methodology broadly, and they prudently advocate a piecemeal approach. Nevertheless, a discussion of specific steps for improving the current way of doing things would have been helpful. For example, the authors state that "the planning exercise generates the entire set of intertemporal accounting prices." Many countries do not follow this process in a meaningful sense, and it is not clear whether the authors are suggesting a move in the direction of more centralized economic planning. If they are, we should recall the very severe environmental degradation now being revealed in Eastern Europe.

An appeal to real NNP that incorporates depletion of environmental resources is pedagogically attractive and correct. The paper could have helped the practitioner, however, by making clearer how one gets to this measure. There is some ambiguity about whether we should go straight to this measure using accounting (shadow) prices or whether we should correct conventional NNP by incorporating the net "nature" product. An intermediate step would be to start with the latter on the way to the former. Another issue is whether to estimate these measures in currency units or as indexes. The authors seem to agree with the consensus in the U.N. System of National Accounts on the use of satellite environmental accounts to supplement the usual national income accounts. However, even delineating meaningful physical indicators of basic environmental resources, such as forests and water resources, remains elusive but is required before we address the more difficult problem of valuing such assets.

Dasgupta and Mäler demonstrate the elegance of the CVH approach well in their paper, but the degree of aggregation in the presentation tends to understate the formidable difficulties at more detailed levels—when we deal with disaggregated vectors of consumption goods, C, and asset stocks, S. To see the point more clearly, consider figure 1, a broad conceptual schema of the decisionmaking framework and structure of a typical economy. The vertical bar on the right reminds us that the environment is a continuum that cuts across these often arbitrary institutional structures. At all levels of the hierarchy in the figure, the World Bank is seeking ways of practically incorporating environmental effects into its mainstream macroeconomic, sectoral, and project analyses, but the move from concepts to real-world applications is far from straightforward. There is also a global, transnational level above the national one, which I discuss below.

The application of the authors' approach at the highest level in the national hierarchy (the multisectored macroeconomy) has been explored earlier in the discussion of corrected NNP. But in the World Bank's own research and policy work, we have to start with much more mundane problems. It would be helpful to have Dasgupta and Mäler's views on which issues of environmental resource degradation could be effectively incorporated into, for example, the intersectoral resource allocation process or public expenditure reviews that we often carry out at the macroeconomic level in collaboration with finance or planning ministries. Another pressing set of questions focuses on how natural resource management issues interact with conventional macroeconomic policy concerns such as structural adjustment, stabilization measures, and trade liberalization.

If we move down to the intermediate (sectoral) level, much of the problem lies in the contrast between the holistic nature of environmental issues and the fragmented way in which human societies and institutions are structured. A typical case is the water resource sector depicted in figure 1. Policy analysis of water resources should look at *all* sources and uses of water within a country (and if necessary, across national borders as well!). Nevertheless, the data are invariably fragmented among different sectors dealing with irrigation, pipeborne water supply and sewerage, hydropower, navigation, and so on. The cross-cutting nature of environmental analysis will help to develop a comprehensive water resources strategy, but even then policy application often becomes less effective because analysts and decisionmakers must work with many uncoordinated implementing agencies.

Focusing finally on the lowest (subsectoral-project-microeconomic) level, the ubiquitous valuation problem has become particularly pressing in the World Bank's country and lending work. The World Bank's recent environmental assessment policy has elevated environmental impact analysis (EIA) to the same level of importance as the more traditional economic, financial, and technical analyses of World Bank projects. In this context, would the authors advise us to seek the "holy grail" of valuing all environmental impacts and incorporating them into a single economic cost-benefit analysis (CBA)? Or would they recognize that some impacts cannot be valued meaningfully and instead use (for example) multicriteria objective functions to trade off economically quantifiable and nonquantifiable consequences of projects? It is likely that future World Bank project evaluations will uncover difficult cases in which the EIA-oriented analysis and conventional CBA suggest opposite conclusions regarding the project decision. Thus our own ongoing research program seeks to push the use of CBAs as far as possible before falling back on multicriteria objective functions.

Even if a fully satisfactory methodology is not developed for trading off high economic returns against significant nonquantifiable environmental externalities, the exploration of these issues will help the World Bank redesign policies and projects more effectively in order to reconcile such conflicting goals.

Let us now turn to some of the stimulating issues concerning the conceptual treatment of resource stocks raised in this paper. The authors' emphasis on the sad neglect of environmental issues in the development economics literature should be applauded. One could make a more general case that until recently, economics has tended to ignore the fundamental fact that economic systems are integrally embedded in a broader ecological system whose carrying capacity is not necessarily infinite.

Another issue of interest is raised toward the end of the authors' remarks on environmental resources and their physical characteristics. Here the authors make a tantalizing reference to the complementarity of environmental and other productive inputs for the poor in developing countries, which may lead to more inequitable impacts of environmental degradation. It is not clear, however, whether Dasgupta and Mäler are implying that there is much greater substitutability between (for example) human-made capital and environmental resources in the industrialized countries. There are many counterexamples. Furthermore, in many instances there may be a threshold of irreversibility (in both developed and developing countries) beyond which it would not be wise to deplete some environmental resources. The life support services of the environment (for example, those provided by the stratospheric ozone layer) clearly fall into this category. In this context, the paper offers an uncharacteristically ungenerous interpretation of Pearce, Barbier, and Markandya (1988). In my own understanding of their writings, the necessary condition for sustainable development and constancy of natural capital stock does not imply nonuse. Although some substitution is feasible, it is the depletion of nonsubstitutable or indispensable environmental resources below sustainable levels that should be avoided.

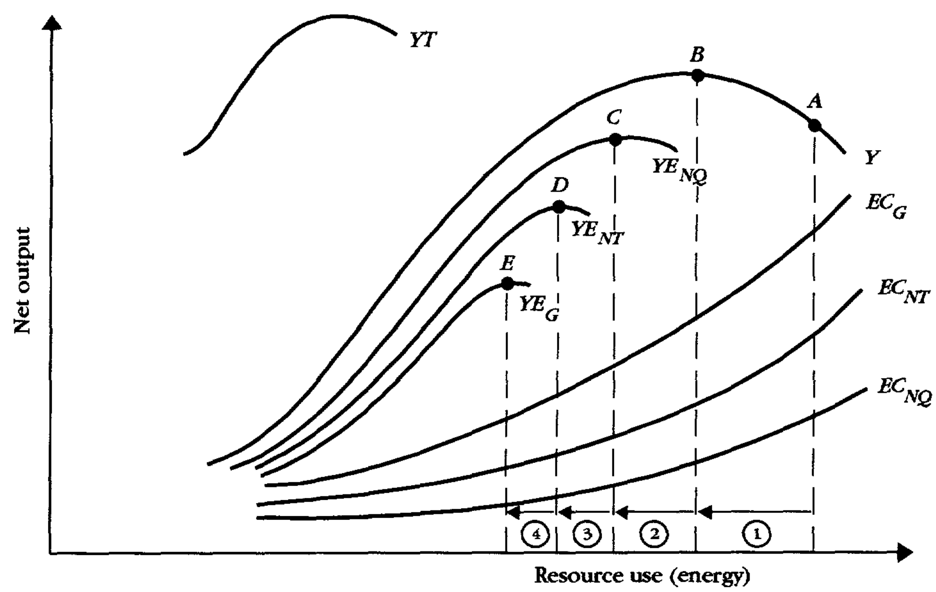
Another point I would note is that in their discussion of estimating a broader measure of NNP, the authors make an abrupt switch from resource depletion to the somewhat different issue of environmental protection expenditures. I should clarify that El Serafy and Lutz (1989), whom the authors cite, refer to an approach that proposes to treat current environmental restoration costs as intermediate expenditures (that do not contribute to sustainable NNP). El Serafy and Lutz did not recommend the mixing of capital and current expenditures for environmental protection.

The paper also draws an important distinction between problems of local and global commons. The authors make the valuable point that traditional societies have evolved effective means of using local shared resources in a sustainable manner, but these arrangements frequently break down in the process of economic change because of modernization and externally imposed changes, such as government patronage, distorted pricing or incentives, and population pressures. The distributional impact of local environmental degradation also is likely to be severe.

The foregoing discussion inevitably raises the question of whose current value Hamiltonian is to be maximized—a point the authors could have discussed further. This can be illustrated with a simplified static analysis at the national, global level that has practical policy implications (Munasinghe 1990). In figure 2, Y represents the net output of productive economic activity, as a function of some resource input (say, energy), without accounting for environmental impacts. Because of policy distortions (for example, subsidized prices), the point of operation in many developing countries might be A, where the resource is being used wastefully. Therefore, without invoking any environmental considerations, both economic efficiency and resource intensity (that is, energy efficiency) could be improved by moving from A to B. One example of such a move might be to improve energy end-use efficiency or to reduce energy supply system losses.

Now consider the curve EC_{NQ}, which represents easily quantifiable national environmental economic costs associated with resource use. These might include air-pollution-related health costs of a coal power plant or the costs of environmental protection equipment (such as scrubbers and electrostatic precipitators to reduce noxious gas and particulate emissions) installed at such a plant, or the costs of resettling populations displaced from a dam site. A new net output curve

Figure 2. *Net Output, Resource Use, and Environmental Cost*



Note: $YE_{NQ} = Y - EC_{NQ}$. $YE_{NT} = Y - EC_{NT}$. Y = net output (uncorrected); YE = net output (environmentally corrected); YT = net output (technologically advanced); EC = environmental costs. Subscripts are defined as follows: NQ = national easily quantifiable environmental costs; NT = national total environmental costs; G = global.

is defined by $YE_{NQ} = Y - EC_{NQ}$. The maximum of this curve at C lies to the left of B, implying less use of (now more costly) energy.

Next, the curve EC_{NT} shows total national environmental costs (both easily quantifiable and difficult-to-quantify negative impacts). With this further correction, the corresponding net output curve is $YE_{NT} = Y - EC_{NT}$. The maximum has shifted to D, and the optimal energy consumption level has also declined.

Finally, EC_G represents global environmental costs of energy use (including national impacts), and $YE_G = Y - EC_G$ is the correspondingly corrected net output, which implies an even lower level of optimal energy use. The curve YT shows net output for a technologically advanced future society that has achieved a much lower resource intensity of production.

The foregoing discussion illustrates the crucial policy dilemma for already poor developing countries: how to reconcile responsible stewardship of the environment with development goals and the elimination of poverty (which will require increased use of energy and raw materials). Thus in figure 2 all countries (including the poorest) would readily adopt measures that will lead to shift 1 (shifts are marked by a circled numeral in the figure), which simultaneously and unambiguously provides both economic efficiency and environmental gains. Most developing countries are indicating increasing willingness to undertake shift 2. Implementing shift 3, however, will definitely mean that many developing countries will have to cross a "pain threshold" as other pressing socioeconomic needs compete against the costs of mitigating adverse environmental impacts that are poorly defined or difficult to value. Shift 4 implies optimization of a global CVH. Because benefits would accrue mainly to other countries, this would hardly appeal to a poor developing nation unless concessional external financing was made available.

Let us extend our inquiry by exploring some issues relating to better management of the global commons, which the authors single out in their concluding paragraphs as central to the policy process in the immediate future. Although scientific analysis has provided only broad and rather uncertain predictions about potential global warming, it would be prudent for humankind to buy an insurance policy in the form of actions to mitigate greenhouse gas emissions. An attractive insurance premium for the developing world would be a set of inexpensive measures that could address a range of national and global environmental issues without hampering development efforts. Several proposals have been made recently for setting up a global environmental fund to help developing countries in their efforts, and some industrial countries already have indicated their willingness to contribute. Currently discussions are going on among world bodies and governments to define effective criteria and mechanisms for both generating and disbursing funds from such a facility. Although a broad, workable agreement will not be easy to reach, global financing issues might be analyzed and resolved through a trade-off involving several criteria: affordability, additionality, and concessionality; fairness and equity; and economic efficiency.

Consider, in the context of the affordability criterion, the energy sector, which is the major contributor to potential global warming. The developing world cannot afford to finance its normal power development needs of about $100 billion per year for the next ten years (billion equals 1,000 million). Even though economically viable energy management options that lower overall costs could reduce this burden significantly, some growth in the use of energy by developing countries is inevitable. The adoption of pollution abatement policies that further increase energy costs—thereby crossing the pain threshold—will not be feasible without external funding on concessional terms. Furthermore, such financial assistance should be additional to existing conventional aid received by developing countries.

The fairness criterion arises because of sharp disparities in the global distribution of income. The per capita gross national product (GNP) of low-income economies (with half of the world's population) averaged US$290 in 1987, or less than one-sixtieth of the U.S. value ($18,530). In the two largest developing countries, China and India, per capita GNP was $290 and $300, respectively. Correspondingly, the U.S. per capita energy consumption of 7,265 kilograms of oil equivalent in 1987 was fifteen and thirty-five times greater than that of China and India, respectively.

A more historically linked dimension of equity is noted in the recent Brundtland Commission report (World Commission on Environment and Development 1987), which argues that past growth in the industrial countries emphasized needs rather than resource limitations. Such growth exhausted a relatively high share of global resources (including physical resources consumed in productive activity as well as the waste-absorbing capability of the global ecosystem). For example, the developed countries accounted for more than 80 percent of fossil-fuel-related cumulative carbon dioxide emissions worldwide during 1950–86 alone, and on a per capita basis, these countries were responsible for more than eleven times as much total cumulative carbon dioxide emissions as the developing countries. Clearly, any reasonable growth scenario for developing nations that followed the same material-intensive path as the industrialized world would result in unacceptably high levels of greenhouse gas accumulation as well as more general depletion of natural resources. Indeed, this resource-intensive historical growth path suggests that the developed countries owe an environmental debt to the larger global community. This approach could help to determine how the remaining finite global resources may be equitably shared and used sustainably. The authors touch on this point in their summary (when they mention the initial allocation of national rights to use the remaining global commons), but they do not pursue the international equity implications far enough.

The final consideration in any global agreement on the environment is economic efficiency. If global environmental costs of human activity can be quantified, the "polluter pays" principle may be applied to generate revenues, which will open up a rich array of economic options. For example, if total emission limits are established for carbon dioxide, then market mechanisms such as trading in emission permits among (and within) nations could be used to increase efficiency, as Dasgupta and Mäler note.

We conclude that pressures to address environmental issues (especially global ones) place a severe burden on developing countries. Even with additional external assistance, the feasible near-term response of the developing countries cannot extend much beyond sound economic management of natural resources that is consistent with their domestic developmental and environmental goals. But the developed countries could facilitate this process by providing concessional financial and technical assistance that the developing countries need today. They could also show leadership now, by trading off some growth for improved environmental quality and by pioneering the use of advanced technologies that will usher in the less material-intensive economies of the future (curve *YT* in figure 2). Such a successful demonstration would help convince the developing countries to undertake more costly abatement measures and cross this pain threshold early in the twenty-first century.

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COMMENT ON "THE ENVIRONMENT AND EMERGING DEVELOPMENT ISSUES," BY DASGUPTA AND MÄLER

John Whalley

Partha Dasgupta and Karl-Göran Mäler have produced a useful and compact paper, for which they are to be complimented. They point out that the conventional development economics literature makes little explicit reference to environmental issues, and they summarize what literature there is. They survey the distinguishing characteristics of environmental resources, and they discuss determinants and measurement of well-being, taking into account environmental factors, market failures and the environment, and global and local "commons" issues. They conclude with some comments on what they see as needed directions for future research.

Useful though the paper is, it might have been better if it had begun with a statement of issues and moved on to discuss them, drawing on the academic literature as needed, rather than constraining itself to the literature and trying to extract from it what might be relevant to environmental issues. I stress putting the issues foremost because I think it is important to recognize that many policymakers in developing countries are now struggling with two sources of pressure to take environmental considerations into account. The first is the pressure from the developed world to cut emissions, slow deforestation, and so on, because of concerns over global warming. The second is the growing pressure from their own domestic groups to pursue industrialization and development, as the developed world has done, and yet avoid the relative neglect of the environment. Researchers, academic literature, and even the World Bank do not seem at present to have much to say about these matters.

The problem of global warming needs to be looked at carefully. Although there is a general scientific consensus on the likelihood of global warming, research and opinion remain ambiguous on its consequences. Opinion on consequences seems to point to a "2 x CO_2 scenario," in which carbon dioxide concentrations are predicted to double from their current levels of about 350 parts per million (ppm) to 700 ppm by the years 2030 to 2075. This doubling probably will increase global mean temperatures by between 1.5 and 4.0 degrees Celsius; it will raise sea levels by 20 centimeters to 1 meter; it will increase the

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incidence of flooding, typhoons, hurricanes, and other extreme climatic events; and it will have microclimatic effects (such as local desertification or increased rainfall) that are hard to pinpoint accurately today.

Pressures are growing in the developed world for some form of policy response to global warming, perhaps through a carbon tax or tradable permits scheme. Tax rates currently being discussed are large (100 percent), and developed countries want developing countries included. Developed countries are expressing similar concerns over deforestation, especially in Brazil, but also more and more in a larger number of developing countries.

Developing countries have argued for special treatment on policy responses to global warming on the grounds that they have not been the primary source of greenhouse emissions and that their full inclusion in schemes for carbon taxes or tradable emission permits will truncate their development.

Questions of causation and responsibility aside, recent research is pointing to at least four strong conclusions on the problems and effects of these global environmental policy approaches. First, a carbon tax (or tradable permit scheme) will not prevent a 2 x CO_2 scenario but will only delay it, perhaps by only ten to fifteen years. Second, what happens to the revenues from such a tax is of enormous relevance for developing countries. Current estimates suggest that the difference to developing countries between a national-based tax scheme and a tax collected by an international agency with revenues redistributed among countries on an equal per capita basis could be approximately $150 billion per year or, say, four times current aid flows (billion equals 1,000 million).

A third research finding is that exemption schemes such as an annual emission level per capita may cause energy-intensive manufacturing activity to relocate to the developing world. Fourth, the free-rider and enforcement problems with such schemes are extremely large, pointing to a long-standing concern among developing countries that other policy measures (such as threats to use trade measures or conditionality in lending programs) will be employed to force developing countries to reduce emissions.

The other major issue that deserves greater recognition is the sketchiness of our knowledge about the interplay between developmental objectives on the one hand and environmental concerns on the other. Developing-country policymakers and citizens, enlightened by information now becoming available on environmental degradation in Eastern Europe and the Soviet Union, are asking whether they want to (or indeed can) develop in the same way as the developed countries, and what the options are. Here the guidance of experience and theory is even more hazy than it is on the consequences of global warming. But the concerns are, if anything, stronger.

The economies that have experienced strong growth in recent years (the Republic of Korea, Taiwan, the countries that belong to the Association of Southeast Asian Nations, and now Turkey and Mexico) have all gone through an energy-intensive heavy industrialization phase. To my knowledge, no precedent yet shows clearly how this stage can be circumvented. Moreover, when environmental concerns have come to the fore in developing countries—such as proposals for automobile emission controls in Mexico City, or for preventing soil erosion at the village level in India—they have not usually won out over developmental concerns. In these instances developing countries have judged the costs of environmental action and the constraining effects on growth too severe. What we know about this question is limited, but the dominant hypothesis for now, at least, seems to be that "green development" is both unproven and likely very costly.

To conclude, let me return to Dasgupta and Mäler's paper and reiterate my main point. It is helpful to the environmental policy process in developing countries to survey the issues as framed by the development economics literature. But my sense is that it would be even more helpful for us to directly address the issues that development policymakers in these countries see as crucial.

Floor Discussion of the Dasgupta-Mäler Paper

The discussion started with a participant agreeing with Dasgupta and Mäler's focus on a correctly defined and calculated net national product (NNP) that includes environmental resource use. The participant argued that other complementary measures of welfare may be justified in arriving at such a comprehensive NNP concept, but they should not take the focus away from the correct NNP measure. The participant then commented on the authors' discussion of defensive expenditures in the conference paper and suggested that they should be included in NNP only to the extent that there is an investment component to them.

Another participant observed that a fair degree of equality is necessary within a decisionmaking group for the management of local common property resources to work well. He wondered whether the authors agreed that there would be considerable pressure for inequality to develop as one moves to market-oriented private property resources.

Responding to the comments by John Whalley (discussant), Partha Dasgupta said that Karl-Göran Mäler and he had emphasized the literature in their paper precisely because they wanted to highlight the fact that environmental resources have unfortunately not been a part of standard economic thinking until recently. One of the first steps in tackling these issues is the valuation of environmental resources. This is easier to do in some cases (for example, productivity losses from soil erosion), and much harder in others (for example, the value of a lost species). The obvious measurement difficulties should not deter us from pursuing measurement questions, nor for that reason should we separate out and treat environmental resources differently from other goods and services. Keeping environmental resources separate is really a bad tactic, because then the onus is always on the preserver to show that it is worth taking a closer look at such resources. And the fact that intertemporal concerns are important is not something that is special to the environment; it applies to anything in an economy that survives for any length of time.

In further response to Whalley, Dasgupta said that the paper had deliberately gone beyond issues such as global warming and international negotiations, important though they are, to highlight the badly neglected links between destitution and environmental degradation in developing countries. Humdrum

This session was chaired by Francis Colaco, principal economic adviser, Office of the Vice President for Sector Policy and Research, the World Bank.

resources such as firewood and water that children and women collect on a day-to-day basis do not get the same attention as global warming.

Answering Mohan Munasinghe's (discussant) question about whose Hamiltonian the authors would seek to optimize in their framework, Dasgupta clarified that the use of a Hamiltonian in their paper was no different from the standard valuation of an investment project or the shadow wage rate, as, for example, in project evaluation. Munasinghe was quite right that there is a difficult valuation problem for depreciation of even standard industrial infrastructure, let alone natural resources—mostly we see gross national product (GNP) figures, not NNP figures, for many developing countries. Nevertheless, there is the view that the NNP growth rate should reflect changes in the well-being of a society. The paper sought to emphasize that if it is a welfare index one is trying to measure, then depreciation of all of society's capital assets must be incorporated. Whether it is an exhaustible resource or a renewable resource, it is still a resource, and the rate of change in the stock, however measured, should be valued and deducted from the conventional NNP growth rate.

Referring to the adjusted NNP calculation embodied in the authors' Hamiltonian approach, a participant raised the danger of double-counting the value of environmental resources. The question was whether one should rely on the idea that natural resource use is another element of investment, possibly negative investment, that should enter into the measurement of the NNP at appropriate shadow prices, or whether the resource depletion should also go directly into the measure of the NNP adjustment for environmental effects. The participant thought that one could not use both approaches simultaneously. He felt it was much better to focus on the goods and services that are produced, among which there are some negative quantities, as, for example, deforestation and erosion. What really matters then is to find some way of shadow pricing the goods appropriately. Although also difficult, the shadow pricing approach is likely to be still somewhat easier than the concept of having to create a quantitative notion of natural environmental stocks and then finding suitable prices to apply to them to calculate their depreciation.

The same participant also pointed out that adjusting for environmental resource use may not necessarily reduce the growth rate, as the paper maintained. If one begins from the point when environmental degradation starts, then the following year there will indeed be a reduction in the environmental stock, bringing the growth rate down compared with the conventional measure. But that is probably not going to be the case in many countries. It is likely that degradation has been taking place for a long time and that one has to change the value of the stock for previous years as well, and the growth rate may not then change.

A World Bank participant asked the authors if, in incorporating natural resources into welfare measures, they thought of them basically as substitutes for man-made capital in the traditional neoclassical sense, or as complementary factors.

Another participant asked whether the authors had any empirical experience of the priority structuring of production functions referred to by Mäler, particularly in a democratic political system. The participant thought that setting priorities was a complex and highly ambitious task, and the problem lay in who determines the priorities and who implements the policies arising from them. He cited a European point of view that held gasoline pricing in the United States to be irrational, with social costs exceeding private costs.

Another participant noted that he found the paper's treatment of economic development puzzling. He associated development with expanding specialization and market opportunities for production, trade, and use of resources in ways in which they are worth more. It also meant destruction of local, traditional institutions that the paper found indispensable for the management of local commons and the environmental resources that are inputs in local production. So, if one is to take the paper's approach seriously, what is one to make of development?

Responding to the questions, Dasgupta replied that he hoped it was clear from the paper that Mäler and he had taken pains to avoid talking about grand strategies of development in the context of the environment. This was done deliberately; the more one thinks of environmental resources as humdrum commodities, the more likely it is that they will be preserved, because we will then treat them just as other goods and services and factor them into our calculations of future costs and benefits. Clearly, some environmental goods will be ignored because of the difficulty of calculating their accounting prices.

In response to the specific question about the two approaches to incorporating environmental resources in NNP and double-counting in the current value Hamiltonian, Dasgupta clarified that their discussion of NNP notwithstanding, they were also emphasizing the accounting prices of goods and services that should be incorporated into production and investment decisions. However, Dasgupta did not think that the current value Hamiltonian involved double-counting: the Hamiltonian measures the flow of well-being in a given year plus the social value of the change in the vector of natural assets that year, the latter picking up the fact that the assets are a potential source of well-being in the future. In measuring the current flow of well-being, one needs to capture the notion that existing stocks may also provide current well-being directly. If the stocks do not provide any current flow of well-being, then this component of current well-being would, of course, disappear. Dasgupta said that he realized that in standard capital theory, capital stocks are valued for their indirect effects. There is not much delight in looking at a factory; the delight comes from one's expectations of the factory's future production. But environmental stocks may also directly yield current well-being.

On Munasinghe's question about establishing thresholds to limit resource exploitation, Mäler suggested that one could make a case for them on the basis of uncertainty about the underlying ecological, hydrological, and geochemical processes, and uncertainty about the value of these resources and their accounting prices. Responding to Whalley's comments about the importance of global warming and the potential policy choices facing developing countries, Mäler said that the main problem is to create a system that will benefit all member countries for being part of the system. The acid rain problem in Europe is similar. Mäler felt that a system with tradable emission permits could create the right kind of incentives, if the initial rights are distributed in an appropriate way.

Munasinghe and another participant had raised the question of substitutability and complementarity of environmental capital with man-made capital. Mäler responded to this by noting that the only thing the paper mentioned was that at the household level, environmental resources are quite often complements to other inputs in the household production function. However, on a larger scale, it was an empirical question.

Regarding the production function approach and setting priorities, Mäler answered that the point of using production functions was to enable the analyst to come up with estimates of the accounting prices for environmental resources. Then these accounting prices could be used for setting priorities. Mäler cited the example of Sweden, where this approach had been used to preserve certain natural areas and for designing environmental policy instruments.

On the question of the treatment of defensive expenditure, a World Bank participant adduced that if one is undertaking defensive expenditure that is entirely used up in the year and has no investment component in it, then one should net it out, as maintained by El Serafy and Lutz (cited by Dasgupta and Mäler). However, a double-entry procedure might be more correct—that is, to include the defensive expenditure and also to factor in the value of environmental damages. This procedure may be more correct generally, because if the defensive expenditure has some investment component and therefore longer-term effects, then the damage value will not be identically equal to it.

The same World Bank participant echoed the earlier question about dealing with changes in stocks arising out of changes in the state of knowledge. How does one measure changes in GNP between two years when there was a discovery of a gigantic oil field in a country? Presumably, the answer is that 1987's GNP as seen from the viewpoint of 1988 is much higher than 1987's GNP as seen from the viewpoint of 1987. But he was not sure what that said about welfare or how usable these concepts are. He thought there was a problem here.

As a parallel to the discussion of the current flow of well-being directly attributable to a resource stock, Munasinghe asked whether the level of current consumption could also affect the valuation of environmental resources and changes in them. In other words, if one was starving in the Sahara, one would put a somewhat different value on, say, global warming than if one was living in an affluent suburb of Washington or New York. So there is an interaction also between the current level of consumption and the value one might put on environmental stocks.

In concluding, Dasgupta returned to the question raised earlier about the treatment of development in the paper and its focus on traditional mechanisms to manage common property resources. He did not want to give the impression that the paper espoused a hands-off approach and the preservation of such traditional societies at the cost of integrating them into the market and denying them the benefits of increased economic specialization. Instead, the paper had tried to emphasize that it is precisely during development that traditional, destitute groups need protection to avert some of the greatest social tragedies. If common property resources are sharply eroded, it is often the poorest of the poor who bear the brunt of the resulting destitution. If fuelwood is harder to gather, it is the poor who are not able to buy it in the market, and the additional burden of more distant collection falls on the women and the children. Thus, the paper sought to raise the issue of how a possibly long and painful transition from destitution can be eased.

Francis Colaco (chair) thanked the speakers and the participants at the conference and closed the session.