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KEYNES LECTURE IN ECONOMICS

The Economics of the Environment

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1. The Resource Basis of Human Activity

ALL OUR ACTIVITIES are dependent ultimately on resources found in Nature. Whether it is consumption or production, or whether it is exchange, the commodities and services that are involved can be traced to constituents provided by Nature. Thus, the ingredients of a typical manufactured product are other manufactured products, labour time and skills, and resources found in Nature. Each of the constituent manufactured products is in turn a complex of yet other manufactured products, labour time and skills, and resources found in Nature. And so on. This means that the manufactured product with which we began is ultimately a combination of labour time and skills, and resources found in Nature.

But labour, too, is a produced good. Even raw labour is an output, manufactured by those resources that sustain life; resources such as the multitude of nutrients we consume, the air we breathe, and the water we drink. It follows that *all* commodities are traceable to natural resources.[1]

In many instances, natural resources are of direct value to us as

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[1] This etymology of produced goods and services does not yield a 'resource theory of value'. Like Marx's labour theory of value, any such theory would run aground. One reason is that there are many natural resources, not one; and this alone would make the putative theory incoherent. Koopmans (1957) contains a simple proof of why.

needs or as consumption goods (e.g. breathable air, drinkable water, and fisheries); in others, they are of indirect value (e.g. plankton, which serves as food for fish, which we, in turn, consume); sometimes they are both (e.g. drinking and irrigation water). The 'value' I am alluding to may be utilitarian (e.g. the resource may be a source of food, or a keystone species in an ecosystem), it may be aesthetic (e.g. a landscape), or it may be intrinsic (e.g. it could be a living animal); indeed, it may be all these things at once. Resource stocks are measured in different ways, depending on their character: in mass units (e.g. biomass units for forests, cow dung, and crop residues), in numbers (e.g. size of an animal herd), in indices of 'quality' (e.g. water- and air-quality indicators), in volume units (e.g. acre-feet for aquifers), and so forth.

There is a small tribe of economists, known as resource economists (I happen to belong to this tribe), who tend to view the natural environment through the lens of population ecology. The focus in population ecology is the dynamics of interacting populations of different species. So, it is customary there to take the background environmental processes as given, that is, they are not subject to analysis. The best known illustration of this viewpoint is the use of the logistic function to chart the time-path of the biomass of a single species of fish enjoying a constant flow of food. Predator-prey models (e.g. that of Volterra) provide another class of examples; as do the May–MacArthur models[2] of competition among an arbitrary number of species.

Depending on the context, the flow of value we derive from a resource stock could be dependent on the rate at which it is harvested, or on the size of the stock; in many cases, it would be dependent on both. For example, annual commercial profits from a fishery depend not only on the rate at which it is harvested, but also on the stock of the fishery, because unit harvesting costs are typically low when stocks are large and high when stocks are low. The valuation of resources and the rates at which populations are harvested in different institutional settings are among the resource economist's objects of enquiry (Clark, 1976; Dasgupta and Heal, 1979; Dasgupta, 1982).[3]

[2] See May (1972) and May and MacArthur (1972).

[3] Resource economists are interested in minerals, ores, and fossil fuels as well. As the natural regenerative rate of such resources is zero, they can be regarded as a limiting case of renewable natural resources. For this reason they are called exhaustible resources. For reasons of space, I will ignore them in this lecture. For an account of what economics looks like when we include exhaustible resources in the production process, see Dasgupta and Heal (1979), Hartwick and Olewiler (1986), and Tietenberg (1988).

There is another small tribe of economists, known as environmental economists (I happen to belong to this tribe as well), who, in seeming contrast to resource economists, base their studies on systems ecology.[4] There, the focus is on such objects as energy at different trophic levels and its rate of flow among them; and the distribution and flows of biochemical substances in soils and bodies of water, and of particulates in the atmosphere. The motivation is to study the biotic and abiotic processes underlying the services ecosystems provide for us. As is now well known, these services are generated by interactions among organisms, populations of organisms, communities of populations, and the physical and chemical environment in which they reside. Ecosystems are the sources of water, of animal and plant food, and of other renewable resources. In this way, ecosystems maintain a genetic library, sustain the processes that preserve and regenerate soil, recycle nutrients, control floods, filter pollutants, assimilate waste, pollinate crops, operate the hydrological cycle, and maintain the gaseous composition of the atmosphere.[5] The totality of all the ecosystems of the world represents a large part of our natural capital stock, which, for vividness, I will refer to as our environmental resource-base.[6] Environmental problems are thus almost always associated with resources that are regenerative, but are in danger of exhaustion from excessive use. It makes sense then to identify environmental resources with renewable natural resources. The valuation of ecological services and the patterns in which they are available under different institutional settings are among the environmental economist's objects of enquiry. Economic studies of global warming, eutrophication of lakes, the management of rangelands, and the pollution of estuaries are examples of such endeavour (Costanza, 1991; Mäler *et al.*, 1992; Walker, 1993; Nordhaus, 1994).

In a formal sense, population and systems ecology differ only by way of the variables ('state variables', as they are called) that are taken to characterise complex systems. In the former, the typical variables are population sizes (or, alternatively, tonnage) of different species; in the latter, they are indices of various services. As noted above, it is often

[4] The contrast is illusory, as will become apparent below, which is why one can belong to both tribes with ease.

[5] Ehrlich, Ehrlich and Holdren (1977) remains the outstanding treatise on both population and systems ecology.

[6] As mentioned earlier, our natural capital stock includes, in addition, minerals, ores, and fossil fuels.

possible to summarise the latter in terms of indices of 'quality', such as those for air, soil, or water. Each such index should be taken to be a summary statistic (reflecting a particular form of aggregation) that enables the analyst to study complex systems by means of a few strategically chosen variables.

The viewpoint just offered, that of distinguishing population and systems ecology in terms of the state variables that summarise complex systems, allows us to integrate problems of resource management with problems of environmental pollution and degradation.[7] It reminds us that resource economics and environmental economics are the same subject. It also suggests that the environmental resource-base should be seen as a gigantic capital stock. Animal, bird, and fish populations (including the vast array of micro-organisms), water, soil, forest cover, and the atmosphere are among the components of this stock. Since it would be convenient to refer to resource and environmental economics by an overarching name, I will do so in this lecture by the term 'ecological economics'.[8]

2. The Neglect of Ecological Economics

Given the importance of the environmental resource-base in our lives, you would think that ecological matters must be a commonplace furniture of economic thinking. But you would be wrong. Not only are environmental resources only perfunctorily referred to in economics textbooks, they are also cheerfully ignored in economists' public pronouncements. Indeed, as a profession, it has been normal practice for economists to regard the environmental resource-base as an *indefinitely* large and adaptable capital stock. This has enabled them to offer macro-economic advice to political leaders, and encourage the lay public to aspire to levels of consumption that are consistent only with unlimited growth possibilities in material output. Macro-economic models involving long run production and consumption possibilities typically make no mention of the environmental resource-base; the implicit assumption being that natural resources aren't scarce now, and won't be scarce in the future. It is small wonder that ecological economics remains a fringe

[7] For a formal demonstration of this, see Dasgupta (1982).

[8] I am able to usurp the term from the literature, for the reason that it appears to have no fixed meaning: 'ecological economics' seems to mean different things to different people.

activity of what one could call 'official' economics. It is an unfortunate state of affairs.[9]

The lacuna has not been restricted to the study of economics in advanced industrial countries: more than forty years of development thinking in poor countries has also neglected environmental matters. A prime reason, often aired, is that, in earlier days, environmentalists in western industrial countries tended to focus on such problems as local air pollution (e.g. sulphur emissions) and deterioration of amenities (e.g. national parks, beaches and coastlines). To the development economist, environmental matters, therefore, appeared a trifle precious, not wholly relevant to the urgencies of poor societies. On innumerable occasions I have had this explanation offered to me by social scientists in developing countries. I wouldn't wish to doubt their claim, but the explanation doesn't tell us why, when they studied development problems, these same social scientists ignored their *own* environmental resource-base, nor why government planning models in poor countries so often have regarded this base to be of infinite size.

The neglect of the environment in development economics is ironic, because people in poor countries are in great part agrarian and pastoral. Rural people account for about 65 per cent of the population of what the World Bank classifies as low-income countries. The proportion of total labour force in agriculture is slightly in excess of this. The share of agriculture in gross domestic product in these countries is 30 per cent. These figures should be contrasted with those from industrial market economies, which are 6 per cent and 2 per cent, respectively, for the latter two indices. Poor countries are in large measure biomass-based subsistence economies, in that the rural poor eke out a living from products obtained directly from their *local* environment. For example, in their informative study of life in a micro-watershed of the Alaknanda river in the central Himalayas in India, the (Indian) Centre for Science and Environment (CSE 1990) reports that, of the total number of hours worked by the villagers sampled, 30 per cent was devoted to cultivation,

[9] Barro and Sala-i-Martin (1995) and Romer (1996) are treatises on macro-economic growth. The environmental resource-base does not appear in either exposition. By the same token, it has proved all too congenial for ecologists to regard the human presence as an inessential component of the ecological landscape. This has enabled them to ignore the character of human decisions and, so, of economics. Thus, ecologists in great part continue to think that environmental degradation resulting from increased human encroachment on ecosystems can be stemmed effectively by centralised command-and-control modes of operation (see below in the text). For further discussion of the interface of economic and ecological concerns, see Dasgupta and Ehrlich (1996).

20 per cent to fodder collection, and about 25 per cent was spread evenly between fuel collection, animal care, and grazing. Some 20 per cent of time was spent on household chores, of which cooking took up the greatest portion, and the remaining 5 per cent was involved in other activities, such as going to market. In their work on Central and West Africa, Falconer and Arnold (1989) and Falconer (1990) have shown how vital are forest products to the lives of rural people. Poor countries, especially those in the Indian sub-continent and sub-Saharan Africa, can be expected to remain largely rural economies for some while yet. The categories of natural resources that are of fundamental importance in advanced industrial countries no doubt differ from those in poor, agrarian societies; but nowhere is the environmental resource-base in unlimited supply. To treat the base as a free good is to practise bad economics.

Here is an example of how economic *analysis* can go awry when it neglects the environment. Barring sub-Saharan Africa over the past twenty-five years or so, gross income per head has grown in nearly all poor regions since the end of the Second World War. In addition, growth in world food production since 1960 has exceeded the world's population growth; by an annual rate of, approximately, 0.6 per cent. This has been accompanied by improvements in a number of indicators of human well-being, such as the under-five survival rate, life expectancy at birth, and literacy. In poor regions, all this has occurred in a regime of population growth rates substantially higher than in the past. These observations have led many economists to argue that the high rates of growth of population that have been experienced in recent years aren't a hindrance to economic betterment, but, rather, that economic development itself can be relied upon to bring down population growth rates.

But there is a problem with this argument. Statistics on past movements of gross world income and agricultural production say nothing about the environmental resource-base. They don't say if, for example, increases in gross national product (GNP) per head are not being realised by means of a depletion of natural capital; in particular, if increases in agricultural production are not being achieved by 'mining' the soil. Thus, it is today customary for international organisations to estimate social well-being by means of indices that capture only the current standard of living (e.g. GNP per head, life expectancy at birth, and the infant survival rate; see UNDP, 1993). But such measures bypass the concerns that ecologists have repeatedly expressed about

the links that exist between continual population growth, increased material output, and the state of the environment. This is a serious limitation. In section 11 I will suggest an aggregate measure of social well-being that captures not only the current standard of living, but also the effect of changes in the composition of a country's natural capital on her *future* standard of living. This measure is called *net* national product (NNP).

Now the interesting point is this: it is possible for measures of current well-being, such as the under-five survival rate and GNP per head, to increase over an extended period of time even while NNP per head is declining. We should be in a position to say if this has been happening in poor countries. But we aren't, and this is a reflection of the neglect of ecological matters in economic modelling.[10]

Despite this neglect, ecological economics has developed considerably over the years, almost by stealth. So far in this lecture I have sketched the terrain of the subject. In what follows, I will try to give you a feel for what the subject amounts to and what insights it has to offer. Over many years now, I have tried to develop ecological economics in a way that speaks to the problems of economic development in poor countries (Dasgupta, 1982, 1990, 1993, 1995*a*, *b*; Dasgupta and Mäler, 1991, 1995); so my treatment will be coloured by my own research interests. I don't think there is any harm in this. Even though many of the problems I will discuss here arise from a study of rural poverty in poor countries, their structure is generic, and I think this fact will be transparent to you.

The plan of the rest of this lecture is as follows: In section 3 I will classify the reasons we face environmental problems, and in sections 4–9 I will elaborate them. Sections 10–11 will explore prescriptions. In large part the discussion there will be confined to local environmental problems. In section 12 I will extend the discussion to global environmental problems. One overall conclusion we will arrive at is that it won't do to rely entirely on a decentralised economic environment for avoiding environmental problems: collective action at different levels is necessary. So in section 13 I will speculate on the various pathways that could sustain agreements among peoples and nations. Even though I will present a number of hard results that have been obtained in ecological economics, I won't attempt a summary at the end. My intention here is to

[10] Attempts at estimating NNP, thus defined, are currently underway at the World Bank and the United Nations Statistical Office.

get you to peer at the environment through the economist's lens. Providing conclusions at the end would detract from this.

3. Poverty and Institutional Failure as Causes of Environmental Degradation

The early literature on ecological economics identified market failure as the underlying cause of environmental problems (Pigou, 1920; Lindahl, 1958; Arrow, 1971; Meade, 1973; Mäler, 1974; Baumol and Oates, 1975; Dasgupta and Heal, 1979). Indeed, the phenomenon of externalities looms large in what has traditionally been called environmental economics.

By 'markets' I mean institutions that make available to interested parties the opportunity to negotiate mutually advantageous courses of action. However, in order for someone to be able to negotiate, they need to know the extent to which they are empowered to negotiate, the extent to which the other parties are empowered to negotiate, and so on. In other words, for you to be able to negotiate, you need to know what you can negotiate with, what the other parties can negotiate with, and so forth. So it should come as no surprise that the functioning of markets is linked closely to the structure of property rights. This observation (Coase, 1960) was the starting point of modern ecological economics.

Thus, it was noted by authors that for many environmental resources markets simply don't exist. In some cases they don't exist because the costs of negotiation are too high. (The overarching term 'transactions cost' is often used these days to refer to a common or garden variety of costs that prevent markets from operating well.) One class of examples is provided by economic activities that are affected by ecological interactions involving long geographical distances (e.g. the effects of deforestation in the uplands on downstream activities hundreds of miles away: see section 4); another, by large temporal distances (e.g. the effect of carbon emissions on climate in the distant future, in a world where forward markets are non-existent because future generations aren't present today to negotiate with us).[11] Then there are cases (e.g.

[11] Problems arising from an absence of forward markets for the distant future are no doubt ameliorated by the fact that we care about our children's well-being and know that they in turn will care for theirs, and so on, down the generations. This means, by recursion, that even if we don't care directly for the well-being of our distant descendants, we do care for them indirectly. Arrow *et al.* (1995*a*) contains a succinct account of these considerations.

the atmosphere and the open seas) where the nature of the physical situation (namely the migratory nature of the resource) makes private property rights impractical and so keeps markets from existing; while in others (e.g. bio-diversity: see Perrings *et al.*, 1994), ill-specified or unprotected property rights prevent their existence, or make them function wrongly even when they do exist.

In each of these cases, the market prices of goods and services fail to reflect their social scarcities; that is, their accounting (or shadow) prices. For example, the market price of a number of environmental resources, *in situ*, is zero, even though, being in limited supply, their accounting prices are positive. Generally speaking, *laissez-faire* economies are not much good at producing publicly observable signals that would reflect environmental scarcities. Externalities do not create market distortions; they *are* a form of market distortion.[12]

One way to improve matters is to impose regulations on resource users; for example, restrictions on effluent discharges and quotas on fish harvests. Another is to introduce a system of taxes, often called Pigovian taxes; for example, pollution charges and stumpage fees. Each scheme has its advantages and disadvantages over the other (Weitzman, 1974*a*; Dasgupta, 1982; section 12, below). We cannot enter into details here, but it bears emphasis that environmental taxes, when properly designed, remove market distortions. In addition, there is a presumption that tax revenues, thus collected, would enable the government to reduce pre-existing distortionary taxes (e.g. taxes on earned income). There is, thus, a presumption that Pigovian taxes yield a 'double dividend', a rhetorical device that has been much used in recent years to persuade governments to impose 'green' taxes. Matters of public finance have been a recurrent theme in ecological economics (see, especially, Baumol and Oates, 1975; Bovenberg and van der Ploeg, 1994).

Thus far, market failure. Recently, however, certain patterns of environmental deterioration have been traced to government failure. For example, Binswanger (1991) has argued that, in Brazil, the exemption from taxation of virtually all agricultural income (allied to the fact

[12] The accounting price of a resource (whether or not it is an environmental resource) is the increase in the maximum value of social well-being if a unit more of the resource were made available costlessly. Formally, it is a Lagrange multiplier. The accounting price of a commodity is, thereby, the difference between its market price and the tax (or subsidy) that ought to be imposed on it. Dasgupta, Marglin and Sen (1972) and Little and Mirrlees (1974) offer procedures for estimating accounting prices. Neither book, however, has anything to say about environmental resources.

that logging is regarded as proof of land occupancy) has provided strong incentives to the rich to acquire forest lands and to then deforest them. He has argued that the subsidy the government has thereby provided to the private sector has been so large, that a reduction in deforestation is in Brazil's interests, and not merely in the interest of the rest of the world. This has implications for international negotiations. The current consensus appears to be that, as a country, Brazil has much to lose from reducing the rate of deforestation she is engaged in. If this were true, there would be a case for the rest of the world to subsidise her, as compensation for losses she would sustain if she were to restrain herself. But, as Binswanger's account suggests, it isn't at all clear if the consensus is correct.[13]

This said, it is important to note that the causes of environmental problems are not limited to market and government failure; they also arise because such micro-institutions as the household can function badly. In poor communities, for example, men typically have the bulk of the political voice. We should then expect public investment in, say, environmental regeneration to be guided by male preferences, not female needs. On matters of afforestation in the drylands, for instance, we should expect women to favour planting for fuelwood and men for fruit trees, because it is the women and children who collect fuelwood, while men control cash income (and fruit can be sold in the market). This explains why, even as the sources of fuelwood continue to recede, fruit trees are often planted.

That political instability (at the extreme, civil war) is a direct cause of environmental degradation is obvious. What isn't obvious is that it is a hidden cause as well. Political instability creates uncertainty in property rights. In its presence, people are reluctant to make the investments that are necessary for environmental protection and improvement: the expected returns on such forms of investment are low. In a study comprising 120 countries, Deacon (1994) has offered statistical evidence of a positive link between political instability and forest depletion.

Taken together, these examples reflect the environmental consequences of institutional failure. They have a wide reach, and in recent years they have often been discussed within the context of the thesis that environmental degradation, such as eroding soil, receding forests, and vanishing water supplies, is a *cause* of accentuated poverty among

[13] Heath and Binswanger (1996) provide an illustration of government failure causing environmental deterioration in Columbia.

the rural poor in poor countries. There is truth in this. But there is also much accumulated evidence that poverty itself can be a cause of environmental degradation (Dasgupta, 1993; Dasgupta and Mäler, 1995; Ehrlich, Ehrlich, and Daily, 1995). This reverse causality arises because some environmental resources (e.g. ponds and rivers) are essential for survival in normal times, while others (e.g. forest products) are a source of supplementary income in times of acute economic stress. This mutual influence can offer a pathway along which poverty, environmental degradation, and even high fertility, feed upon one another in a synergistic manner over time (Dasgupta, 1993, 1995*a*, *b*). The recent experience of sub-Saharan Africa would seem to be an illustration of this (Cleaver and Schreiber, 1994). Indeed, an erosion of the environmental resource-base can make certain categories of people destitute even while the economy's gross national product (GNP) increases.

These two causes of environmental degradation (namely, institutional failure and poverty), pull in different directions and are together not unrelated to an intellectual tension between the concerns people share about an increased greenhouse effect and acid rains, that sweep across regions, nations and continents; and about those matters (such as, for example, the decline in firewood or water sources) that are specific to the needs and concerns of the poor in as small a group as a village community. Environmental problems present themselves differently to different people. In part, it is a reflection of the tension I have just noted and is a source of misunderstanding of people's attitudes. Some people, for example, identify environmental problems with population growth, while others identify them with wrong sorts of economic growth (see sections 7 and 11). Then there are others who view them through the spectacle of poverty. Each of these visions is correct. There is no single environmental problem; rather, there is a large collection of them (Dasgupta and Mäler, 1995; Reardon and Vosti, 1995). Thus, growth in industrial wastes has been allied to increased economic activity; and in industrialised countries (especially those in the former Socialist block), neither preventive nor curative measures have kept pace with their production. Moreover, the scale of the human enterprise, both by virtue of unprecedented increases in the size of the world's population and the extent of economic activity, has so stretched the capabilities of ecosystems, that humankind can today rightly be characterised as the earth's dominant species. These observations loom large not only in ecological economics, but also in the more general writings of environmentalists and in the professional writings of ecologists in the West.

For example, Vitousek *et al.* (1986) have estimated that forty per cent of the net energy created by terrestrial photosynthesis (i.e. net primary production of the biosphere) is currently being appropriated for human use. To be sure, this is a rough estimate. Moreover, net terrestrial primary production isn't exogenously given and fixed; it depends in part on human activity. Nevertheless, the figure does put the scale of the human presence on the planet in perspective.

On the other hand, economic growth itself has brought with it improvements in the quality of a number of environmental resources. The large-scale availability of potable water, and the increased protection of human populations against both water- and air-borne diseases in industrial countries, have in great measure come in the wake of growth in national income these countries have enjoyed over the past 200 years or so. Moreover, the physical environment inside the home has improved beyond measure with economic growth. For example, cooking in South Asia continues to be a central route to respiratory illnesses among women. Such positive links between economic growth and environmental quality often go unnoted by environmentalists in the West. I would guess that this lacuna is yet another reflection of the fact that it is all too easy to overlook the enormous heterogeneity of the earth's environmental resource-base, ranging as it does from the atmosphere, oceans, and landscapes to water-holes, grazing fields, and sources of fuelwood. This heterogeneity needs constantly to be kept in mind.

4. Markets and their Failure: Unidirectional Interactions

Since we economists understand market competition better than political competition, we understand market failure better than government failure. In fact, ecological economics has provided us with much insight into the nature of those allocation failures that arise from malfunctioning markets. In this and sections 5 and 7, we will study this.

Market failure is prominent in those hidden interactions that are unidirectional; for example deforestation in the uplands, which can inflict damages on the lowlands in watersheds. It pays first to concentrate on the assignment of property rights before seeking remedies. The common law in many poor countries, if we are permitted to use this expression in a universal context, *de facto* recognises polluters' rights, not those of the pollutees. So, then, let us consider first the case where the law recognises polluters' rights. Translated into our present example,

this means that the timber merchant who has obtained a concession in the upland forest is under no obligation to compensate farmers in the lowlands. If the farmers wish to reduce the risk of heightened floods, they will have to compensate the timber merchant for reducing the rate of deforestation. Stated this way, the matter does look morally bizarre, but that is how things would be with polluters' rights. Had property rights been the other way round, that is, one of 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 the farmers for the right to inflict the damages that go with deforestation. However, even if the law were to see the matter in this light, there would be enforcement problems. When the cause of damages is hundreds of miles away, when the timber concession has been awarded to public land by the government, and when the victims are thousands of impoverished farmers, the issue of a negotiated outcome doesn't usually arise. The private cost of logging being lower than its social cost, we would expect excessive deforestation.

But when the market prices of environmental resources are lower than their accounting prices, resource-based goods can be presumed to be underpriced in the market.[14] Naturally, 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 underpricing of the final product. But this in turn means that if the country were to export primary products, there would be an implict subsidy on these exports, possibly on a massive scale. Moreover, the subsidy would be paid not by the general public via taxation, but by some of the most disadvantaged members of society: the sharecropper, the small landholder or tenant farmer, the forest-dweller, the fisherman, and so on. The subsidy would be hidden from public scrutiny; nobody would talk of it. But it would be there; it would be real. We should have estimates of such subsidies in poor countries. As of now, we have no estimate.[15] An

[14] This example is taken from Dasgupta (1990). Chichilnisky (1994) provides an extended discussion of it.

[15] But see Hodgson and Dixon (1992) for an attempt at such an estimation for the Bacuit Bay and the El Nido watershed on Palawan, in the Philippines. The cause of damages (to tourism and fisheries) was logging in the uplands. In short, there is an effective subsidy on logging in the upper watershed. The authors' computations were incomplete, but such as they were, the analysis did suggest that the rate of logging ought to be lower; indeed, it is possible that logging ought not to occur there at all.

appropriate form of public policy would be a tax per unit of logging. This would be a Pigovian tax and, at an optimum, it would equal the damages that would be experienced downstream if logging were to increase by a marginal amount.

In some parts of the world, community leaders, non-government organisations, and a free press (where they exist) have been known to galvanise activity on behalf of the relatively powerless 'pollutees'. In recent years this has happened on a number of occasions in different contexts. One of the most publicised was the Chipko Movement in India, which involved the threatened disenfranchisement of historical users of forest resources. This was occasioned by the government claiming its rights over what was stated to be 'public property' and then embarking on a logging operation. Democratic protest was followed by a reversal of government action. The reversal came about because citizens could exercise their right to protest. This, and other, examples suggest that the connection betwen environmental protection and civil and political liberties is a close one. They indicate that such liberties are not only valuable in themselves, they also help realise other collective goals (Dasgupta, 1993). I will return to this most important matter in section 7, when we come to study the breakdown of communitarian forms of management of local commons.

5. Markets and their Failure: Reciprocal Interactions and the Problem of the Commons

Matters can be quite different for interactions that are reciprocal. Here, each party's actions affect all. Interactions of this sort are the hallmark of common-property resources, such as grazing lands, forests, fisheries, the atmosphere, aquifers, village tanks, ponds, lakes, and the oceans. They are often common property because private property rights are for a number of reasons difficult to define (e.g. in the case of mobile resources, such as air). Even when definable, they are on occasion difficult to enforce (e.g. in the case of forest resources in mountainous terrains). However, unlike public goods, consumption of common property resources is rivalrous: it is possible for at least one party to increase its consumption at the expense of others' consumption of them.

Resources such as local forests, grazing lands, village ponds, and rivulets, are often common property because that is how they have been since time immemorial. Moreover, in poor countries they have

remained common property for long because they are basic needs and are at the same time geographically contained. Rivers may be long, but they don't flow through everyone's land. In any case, upstream farmers would have untold advantages over downstream ones if they were in a position to turn off the 'tap'. Exclusive private territoriality over them would leave non-owners at the mercy of the owners at the bargaining table.[16] Societies typically don't risk the institution of private-property rights over such resources.[17] However, unless there is collective action at some level, the private cost of using the resource falls short of its social cost; and, so, the common property is over-exploited. This was the point of a pioneering article by Gordon (1954).

In a famous essay that popularised Gordon's analysis, the biologist, Garrett Hardin wrote:

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons . . . . As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, 'What is the utility to me of adding one more animal to my herd?' . . . Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another . . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked in a system that compels him to increase his herd without limit — in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in the commons brings ruin to all. (Hardin, 1968, p. 1244.)

The parable is compelling: it offers an example of the famous 'prisoners' dilemma' in a striking way. But is it trustworthy? The answer depends on how contained the commons happen to be geographically. Hardin's parable is apt for resources such as the atmosphere, the open seas, and urban pollution; but, as we will see in the next section, it is misleading for local common-property resources, such as ponds, streams, local forests, threshing grounds and, ironically, grazing fields. The theory of games teaches us that the local commons can in principle be managed efficiently by the users themselves, that there is

[16] And they are so left under the hundred-year-old water laws in South Africa, where small groups of upstream farmers enjoy ownership rights over the water that flows through their lands. See Koch (1996).

[17] Rulers had control over such resources in many early societies. But that was not the same as private property rights. Rulers were obliged to make them available to the ruled. Indeed, one of the assumed duties of rulers was to expand such resource bases.

no obvious need for some agency external to the community of users (e.g. government) to assume a regulatory role. (See Dasgupta and Heal, 1979, chap. 3.) A large body of evidence that has recently been collected confirms the theory's prediction: members of local communities have often cooperated in protecting their commons from excessive use.[18] I will elaborate this in section 6.

This said, the problem of the commons can rear its head through all sorts of unsuspected sources. The introduction of cotton as an export crop in Tanzania was successful in increasing farmers' incomes. But other than cattle, there were few alternative forms of saving available to farmers. So the quantity of livestock increased significantly, placing communal grazing lands under stress — to the extent that herds declined because of an increase in their mortality rate. And there have been many cases throughout the world where, for disparate reasons, neither centralised nor communitarian solutions could take hold, so that the commons degraded over time (Ostrom, 1990; Baland and Platteau, 1996). There have also been cases where control mechanisms once existed, but broke down under the pressure of changing economic circumstances. We will come to these matters in section 7.

Public concern about environmental degradation is often prompted by disasters, such as nuclear leakage or floods. The environmental impact of large undertakings (e.g. dams and irrigation systems, such as the Narmada Project in India) also catches the public eye. This is not surprising. Large-scale effects caused by single happenings are, often enough, easy to detect. So they invite debate. In contrast, environmental interactions that result in an overuse of common-property resources are not so easy to detect, at least, not unless some threshold is reached and catastrophies occur. The commons often involve large numbers of users, each inflicting only a tiny damage on each of the others, which, however, sum to a substantial amount; usually, over an extended period of time. There is now evidence that environmental degradation in poor countries is in large measure caused by those institutional failures whose deleterious effects accumulate slowly over time; it is caused less by large public projects (Repetto, 1988).

[18] See, e.g. Howe (1986); Wade (1988); Chopra, Kadekodi and Murty (1990); Feeny *et al.* (1990); Ostrom (1990); Stevenson (1991); and Baland and Platteau (1996). Seabright (1993), Young (1994), and Ostrom (1996) contain good theoretical discussions of modelling problems in this field of enquiry.

6. Local Commons and Communitarian Solutions

As noted earlier, there is a difference between global and local commons. The open seas are common-property resources, as are usually village ponds; but, what is a problem for the former isn't necessarily a problem for the latter.

Why? One reason is that individual use is more easily observable by others when the resource isn't spatially spread out; which means that it is easier to prevent individuals from 'free-riding' on the use of local commons. (Contrast the use of a village tube-well with the littering of streets in a metropolis; or cattle-grazing in the village commons with fuelwood collection in the mountains.) However, bargaining, enforcement, and information costs also play a role in the relative efficacy of the various rules that can in principle be invoked for sharing the benefits and burdens that are associated with an efficient use of common-property resources. Thus, it matters whether the users know one another (contrast a village grazing ground with oceanic fisheries: see section 13); it matters whether increased mobility makes future encounters among group members more uncertain (see section 13); and it matters whether population pressure leads bargaining costs to exceed the benefits of co-operation. The confirmation of theory by current evidence on the fate of different categories of common-property resources has been one of the most pleasing features of modern economic analysis.[19]

Typically, local commons are not open for use to all in a society: they are not 'open access' resources. In most cases they are open only to those having historical rights, through kinship ties, community membership, and so forth. 'Social capital', viewed as a complex of interpersonal networks (Putnam, 1993), is telling in this context: it hints at the basis upon which co-operation has traditionally been built.

It is as well to note though that the theory of bargaining is still so rudimentary that it offers little guidance to the analyst on how the benefits and burdens of co-operation would be shared if there were no impediments of the kind that are associated with bargaining, monitoring, enforcement, and information costs. Figure 1 demonstrates the case of two parties. The point labelled A denotes the levels of well-being the parties would attain, respectively, if they were not to co-

[19] There is now an enormous empirical literature recording both the successes and failures of common-property resource management. For an excellent discussion of what it has to tell us, see Baland and Platteau (1996, chaps. 10–13).

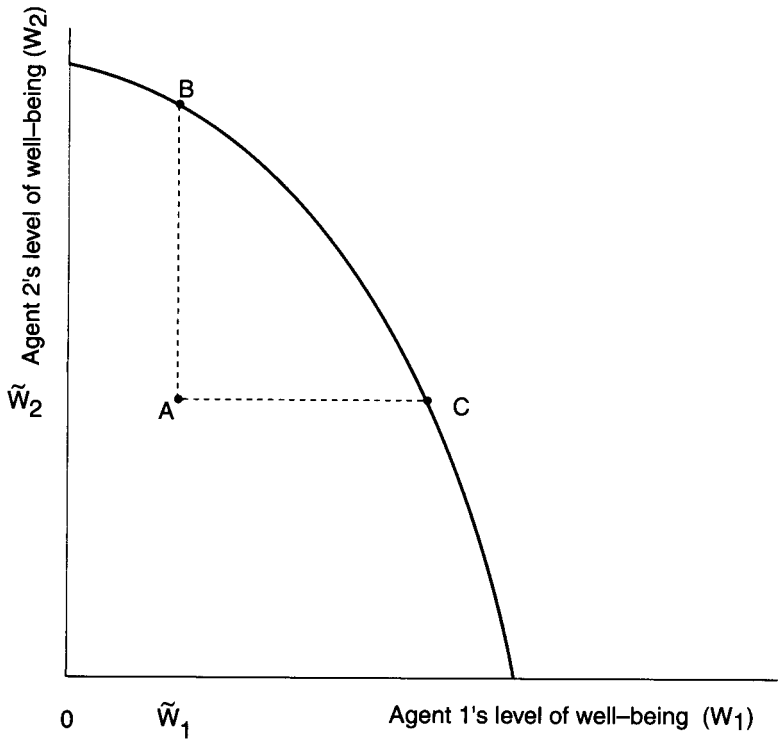

Figure 1. The Two-Person Bargaining Problem

operate in their use of the commons. Points to the north-east of A denote levels of well-being the pair would attain under various forms of co-operation. The frontier, BC, of this region represents the set of all efficient allocations of well-being. Even if we were to assume that the process of bargaining would lead the parties to agree on an efficient allocation (and there is no obvious reason why we should assume this), upon which point on BC would the bargainers converge?

The plain truth is, we don't know. It is, of course, tempting to appeal to that old war-horse of co-operative game theory, the Nash bargaining solution.[20] But, except for one (Chopra, Kadekodi and Murty, 1990), I don't know of any study that has used it to interpret observed sharing

[20] Denote by W_1 and W_2 the well-beings of persons 1 and 2, respectively. Suppose $\tilde{W}_1$ and $\tilde{W}_2$ are their values at the non-cooperative point, A. The Nash bargaining solution is that point on BC at which the function $(W_1-\tilde{W}_1)(W_2-\tilde{W}_2)$ is maximised. For accounts of the Nash bargaining solution, see Binmore and Dasgupta (1988) and Fudenberg and Tirole (1991).

arrangements of common-property resources. The Nash bargaining solution (like others, such as, the Kalai-Smorodinsky solution; see, e.g. Dasgupta, 1993) is independent of the context in which negotiation is assumed to take place. Nash (1950) regarded this as a virtue and was explicit on the point. But this feature of the solution makes it all the more likely that it doesn't often find application.[21]

If the number of parties were to exceed two, matters would be even more problematic: every bilateral negotiation would now have to be sensitive to others in the community. In addition to the Nash bargaining solution, there are other solution concepts in co-operative game theory, such as the core, the nucleolus, and the Shapley value.[22] I have not seen any of them being used in applied studies on the local commons.

In the absence of firm guidance from game theory, speculation has been rife in the theoretical literature on the commons; some, empirically dubious. For example, it has been suggested that heterogeneity of preferences amounts to transaction costs and, thereby, it impedes co-operation; or, in other words, that co-operation requires shared values. This sounds plausible, but is questionable. Every day, hundreds of thousands of people reach bilateral agreements in bazaars. How should we interpret this?

The applied literature, however, has been most illuminating. Not only has it confirmed that resource users in many instances co-operate, it has also explained observed asymmetries in the distribution of benefits and burdens of co-operation in terms of underlying differences in the circumstances of the various parties. For example, in her study of collectively-managed irrigation systems in Nepal, Ostrom (1996) has provided an explanation of observed differences in benefits and burdens among users (e.g. who gets how much water from the canal system and who is responsible for which maintenance task) in terms of such facts as that some farmers are head-enders, while others are tail-enders.

Wade (1988) has also conducted an empirical investigation of community-based allocation rules over water and the use of grazing land. Forty-one South Indian villages were studied, and it was found, for example, that downstream villages had an elaborate set of rules, enforced by fines, for regulating the use of water from irrigation canals. Most villages had similar arrangements for the use of grazing land. In

[21] Over the past several millenia, a wide variety of contextual solutions have been proposed for the problem of dividing an 'object' among claimants. See Young (1994) for an account.
[22] For a review of these concepts, see Aumann (1987).

an earlier work on the Kuna tribe in the Panama, Howe (1986) described the intricate set of social sanctions that are imposed upon those who violate norms of behaviour designed to protect their source of fresh water. Even the iniquitous caste system of India has been found to provide an institutional means of checks and balances by which communal environmental resources have been protected (Gadgil and Malhotra, 1983).

This said, it is important to caution against romanticising communitarian arrangements over the use of the local commons. Beteille (1983), for example, contains examples of how access is often restricted to the privileged (e.g. caste Hindus). Rampant inequities exist in rural community practices. I am laying stress upon the fact that the local commons are often not unmanaged; I am not claiming that they are invariably managed efficiently, nor that they are inevitably managed in ways that involve an equitable distribution of benefits and burdens. Good management of the commons requires more than mere local participation; it requires enlightened government engagement as well.

The extent of common-property resources as a proportion of total assets in a community varies considerably 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 river valleys (Agarwal and Narain, 1989; Chopra, Kadekodi and Murty, 1990). There is, of course, an economic rationale for this, based on the common human desire to pool risks. An almost immediate empirical corollary is that income inequalities are less where common-property resources are more prominent. However, aggregate income is a different matter, and it is the arid and mountain regions and unirrigated areas that are the poorest. This needs to be borne in mind when policy is devised. As may be expected, even within dry regions, dependence on common-property resources declines with increasing wealth across households. The links between undernourishment, destitution, and an erosion of the rural common-property resource base are close. They have been explored analytically in Dasgupta (1993, 1996).

In an important and interesting article, Jodha (1986) used data from over eighty villages in twenty-one dry districts from six dry tropical states in India to estimate that, among poor families, the proportion of income based directly on the local commons is for the most part in the range 15–25 per cent (see also Jodha, 1995). This is a substantial proportion. Moreover, as sources of income, they are often complementary to private-property resources, which are in the main labour, milch

and draft animals, cultivation land and crops, agricultural tools (e.g. ploughs, harrows, levellers, and hoes), fodder-cutting and rope-making 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 non-human asset at their disposal. A number of resources (such as fuelwood and water for home use, berries and nuts, medicinal herbs, resin and gum) are the responsibility of women and children.[23]

A similar picture emerges from Hecht, Anderson and May (1988), who describe in rich detail the importance of the extraction of babassu products among the landless in the Brazilian state of Maranhão. The support such extraction activity offers the poorest of the poor, most especially the women among them, is striking. These extractive products are an important source of cash income in the period between agricultural-crop harvests (see also Murphy and Murphy, 1985; and for a similar picture in the West African forest zone, see Falconer, 1990).

7. Why do Communitarian Solutions Break Down?

It isn't difficult to see why the local commons matter greatly to the poorest of the rural poor, or to understand the mechanisms by which such people may well get disenfranchised from the economy even while in the aggregate the society of which they are members enjoys economic growth. If you are steeped in social norms of behaviour and understand community obligations, you don't calculate every five minutes how you should behave. You follow the norms. This saves on costs all round, not only for you as an 'actor', but also for you as 'policeman' and 'judge'.[24] It is also the natural thing for you to do if you have internalised the norms. But this is sustainable so long as the background environment remains, approximately, constant. It will not be sustainable if the social environment changes suddenly and trust is broken.

[23] The most complete account I have read of the centrality of local forest products in the lives of the rural poor is Falconer and Arnold (1989) and Falconer (1990) on Central and West Africa. The importance of common-property resources for women's well-being in historical times has been stressed by Humphries (1990) in her work on eighteenth-century rural England. The parallels with modern-day poor societies are remarkable.

[24] Provided people are sufficiently far-sighted, norms of behaviour that sustain co-operation can be shown to be self-enforcing in stationary environments. See section 13 for further discussion.

You may 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. They descend upon people who are, in the best of circumstances, acutely vulnerable.[25]

Sources that trigger destitution by this means vary. Erosion of the local commons can come about in the wake of shifting populations (accompanying the growth process itself), rising populations and the consequent pressure on these resources, technological progress, unreflective public policies, predatory governments, and thieving aristocracies. There is now an accumulation of evidence on this range of causes, and in what follows I will present an outline of the findings in three sets of studies, covering three continents.

1 In his work on the drylands of India, Jodha (1986) noted a decline in the geographical area covering common-property resources ranging from twenty-six to sixty-three per cent over a twenty-year period. This was in part due to the privatisation of land, a good deal of which in his sample had been awarded to the rural non-poor. He also noted a decline in the productivity of common-property resources on account of population growth among the 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 from cropping and grazing as a central reason for increased desertification in the state of Rajasthan. Jodha argued that, ironically, it was government land reform programmes in this area, unaccompanied by investment in improving the productive base, that had triggered the process.

2 Ensminger's (1990) study of the privatisation of common grazing lands among the Orma in north-eastern Kenya indicates that the transformation took place with the consent of the elders of the tribe. 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 privatisation has accentuated inequalities.

3 In an earlier, much-neglected work on the Amazon basin, 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 loans from international agencies, such

[25] In Dasgupta (1988) I have tried to develop some of the micro-economics of 'trust'. But we still have little understanding of the social pathways through which trust is created.

as the World Bank. The degradation of vast tracts of valuable environmental resources was accompanied by the disenfranchisement of large numbers of small farmers and agricultural labourers from the economy. At best it made destitutes of traditional forest-dwellers; at worst it simply eliminated them (see also Barraclough, 1977; Hecht, 1985). The evidence suggests that during the decades of the 1960s and 1970s protein intake by the rural poor declined even while the production of beef increased dramatically. Much of the beef was destined for exports, for use by fast-food chains.

The sources that were identified in these studies as having transformed common-property resources into private resources differed considerably. Therefore, the pathways by which the transformation affected those with historical rights were different. But each narrative is believable. Since the impact of these forms of privatisation on the poorest of the poor is confirmed by economic theory (Weitzman, 1974*b*; Dasgupta and Heal, 1979), the findings of these case-studies are almost certainly not unrepresentative. They suggest that privatisation of village commons and forest lands, while hallowed at the altar of economic efficiency, can have disastrous distributional consequences, disenfranchising entire classes of people from economic citizenship. The point is a simple one: unless an appropriate fraction of the rents that are earned from the resource base subsequent to privatisation are given to the historical users, they become worse off.[26] Ironically, case-studies also show that public ownership of such resources as forest lands is by no means necessarily a good basis for a resource allocation mechanism. Decision-makers are in these cases usually far removed from 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 that do not take advantage of dispersed information, that are insensitive to hidden (and often not-so-hidden) economic and ecological interactions, that do not take the long-term view, and that do not give sufficient weight to the claims of the poorest within rural populations (particularly the women and children in these populations) are going to prove environmentally

[26] Weitzman (1974*b*) proves this for the case where an open-access resource is privatised. Dasgupta and Heal (1979, chap. 3) prove it for the local commons.

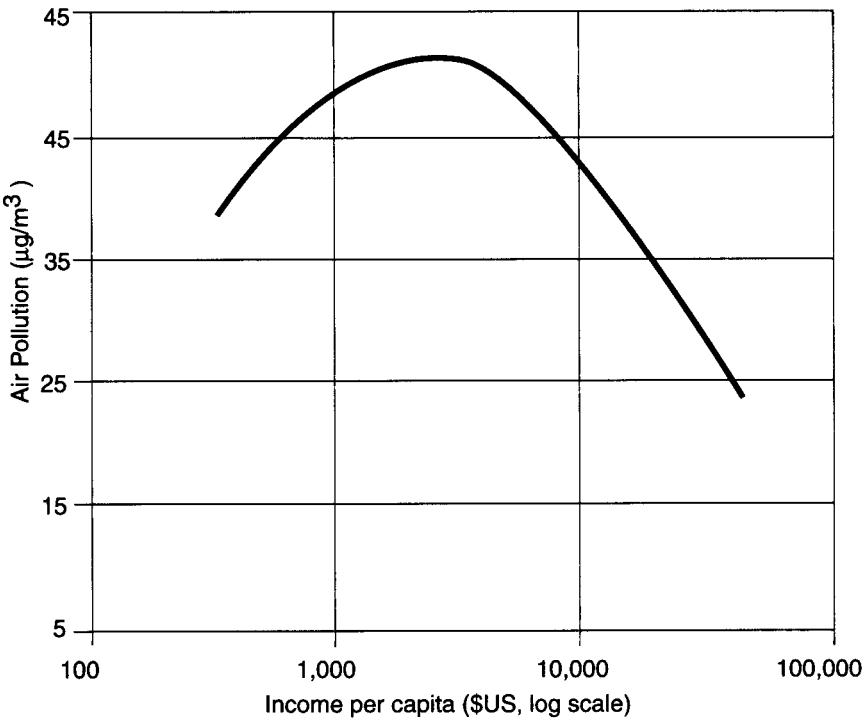

Figure 2. Income per capita versus air pollution. Source: World Bank (1992).

disastrous. It appears that, during the process of economic development there is a close link between environmental protection 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.

8. Economic Growth and the Environment[27]

Since economists have neglected the environment, it shouldn't come as a surprise that national economic policies have also neglected it. Interestingly, the idea that economic growth is perhaps even good for the environment has recently been given credence by the finding that, for a

[27] This section is taken from Arrow *et al.* (1995*b*), which was republished, with comments by a number of experts, in *Environment and Development Economics* (1996), vol. 1.

number of pollutants, there appears to be an empirical relationship between income per head and environmental quality: as income per head increases, environmental quality deteriorates up to a point, beyond which environmental quality improves (World Bank, 1992). In short, the relationship has a bell shape. Figure 2 provides an example.

It should be emphasised that Figure 2 is based on cross-section data, not time series. Nevertheless, this is how one is tempted to explain the finding; indeed, economists have been known to so explain it: People in poor countries can't afford placing weight on amenities over material well-being. Therefore, in the early stages of economic development, increases in pollution are regarded as an acceptable side-effect of economic growth. However, when a country has attained a sufficiently high standard of living, people care more about amenities. This leads them to pass environmental legislation, create new institutions for the protection of the environment, and so forth.

The argument has been invoked in the main for amenities. Even within this set, the bell-shaped curve has been uncovered for a few pollutants only. But as it is consistent with the notion that, as their incomes rise, people spend proportionately more on environmental quality, economists have conjectured that the curve applies to environmental quality, more generally.[28] It is as well to be clear, though, about the kinds of conclusion one can draw from these empirical findings. While the findings do indicate that economic growth can be associated with improvements in some environmental indicators, they imply neither that economic growth is sufficient to induce environmental improvement in general, nor that the environmental effects of growth may safely be ignored; nor, indeed, that the earth's resource base is capable of supporting indefinite economic growth. On the contrary, if the resource base were irreversibly degraded, economic growth itself could be at risk.

There are other reasons for caution in interpreting such bell-shaped curves. First, the relationship has been shown to be valid for pollutants involving local short-term costs (e.g. sulphur, particulates, fecal

[28] Whether the proportion of expenditure devoted to environmental amenities increases with rising income is an empirical matter, and little is known. The one study I have seen on this question, namely Kriström and Riera (1996), suggests otherwise: the proportion of expenditure devoted to amenities *decreases* with rising income! The authors correctly observe that the bell-shaped curve in Figure 2 is a 'reduced form', combining as it does technology, preferences, and other such primitives. From such curves we ought not to infer anything more than that the income elasticity of environmental improvements is positive.

coliforms), not for the accumulation of stocks of waste, nor for pollutants involving long-term and more dispersed costs, such as carbon dioxide, which typically increase with income (World Bank, 1992).

Secondly, the bell-shaped curves have been uncovered for emissions of pollutants, not generally for resource stocks. The relationship is less likely to hold wherever the feedback effects of resource stocks are significant, such as that which occurs in the case of mangroves.

Thirdly, the bell-shaped curves, as they have been estimated, say nothing about the system-wide consequences of reductions in emission. (For example, reductions in one pollutant in one country may involve increase in other pollutants in the same country or transfers of pollutants to other countries.) And fourthly, in most cases where emissions have declined with rising income, the reductions have been due to local institutional reforms, such as environmental legislation and market-based incentives to reduce environmental impacts. But such reforms often ignore international and inter-generational consequences. Where the environmental costs of economic activity are borne by the poor, by future generations, or by other countries, the incentives to correct the problem are likely to be weak. The environmental consequences of rising economic activity may, accordingly, be very mixed. Figure 2 is something of a mirage.

The solution to environmental degradation lies in such institutional reforms as would compel private users of resources to take account of the social costs of their actions. The bell-shaped relation is a suggestion that this can happen in some cases. It doesn't constitute evidence that it will happen in all cases, nor that it will happen in time to avert the irreversible consequences of growth. I will discuss these matters further in section 11, where we will see that growth in gross national product is a wrong objective. I will then ask what sort of economic growth we ought to be seeking, if indeed it is economic growth of some kind we ought to seek. In short, we will try to identify an operationally useful index of social well-being.

9. Trade and the Environment

Thus far national economic policy. But even in areas where the environment is beginning to impinge on international economic policy, as in GATT and NAFTA,[29] it has remained a tangential concern, and the presumption has often been that the liberalisation of international trade is, in some sense, good for the environment. Thus, policy reforms designed to promote trade liberalisation have been encouraged with little regard to their environmental consequences; presumably, on grounds that these consequences would either take care of themselves or could be dealt with separately.[30]

As a reaction to this, I would imagine, it has not been uncommon to view international trade liberalisation as a harbinger of a deteriorating environment (e.g. Daly, 1994). When stated so baldly, the view is false: it doesn't recognise the heterogeneity of environmental problems (as an extreme thought-experiment, imagine the extent to which forests, land, and water resources would be degraded if countries were to become autarkic); it doesn't distinguish between the volume and consumption effects of a growth in trade on the world's production of goods and services; it doesn't say if the growth is allied to international agreements on transfrontier pollution and a reduction in domestic market failure; and it is silent on whether the growth is brought about by a removal of government-induced distortions. To be sure, increased world trade is often associated with a relocation of production units in accordance with relative international labour, capital, and resource costs. One would expect free trade to shift polluting industries to poor countries (Copeland and Taylor, 1994), but insofar as the resultant pollution is local, this is a matter of national sovereignty. The argument that lobbies would succeed in lowering environmental standards in countries that have high standards, in order to meet competition from countries with low standards, is not dissimilar to the concern people have that trade with low-wage countries would eventually lower wages in high-wage countries. However, it is possible to design tax-subsidy schemes to offset the additional cost of higher standards, while retaining some of

[29] The General Agreement on Tariffs and Trade, and the North American Free Trade Agreement, respectively.

[30] Unless it is accompanied by judicious environmental policy, expansion of international trade should be expected to result in an increased stress on the global commons. Copeland and Taylor (1995) provide a formal analysis of the pathway through which this occurs.

the gains from trade.[31] Above all, the argument for trade protection arising from the thought that countries with lower environmental standards will become sinks for other countries' pollutants is to be resisted because of the kinds of considerations that were outlined earlier in this lecture.

A variant of these economic considerations formed the intellectual background of an argument in a widely-publicised memorandum issued in 1991 by the Chief Economist of the World Bank to his staff for discussion. It suggested that trade in pollutants should be encouraged between rich and poor nations because of at least two reasons: (i) poor countries (e.g. sub-Saharan Africa) suffer from lower industrial pollution than those in the West; and (ii) being poor, they could be expected to value environmental quality less at the margin.

The memorandum was much criticised in the international press, mostly along the lines that it read altogether too much like saying, 'let the poor eat pollution'. The arguments I have offered in this lecture imply that this is misplaced criticism. On the other hand, there are two reasons why we should be wary of the suggestion. First, it is based implicitly on the thought that there are no significant threshold effects associated with environmental pollution. If thresholds were important, it would not make sense to spread pollution evenly across geographical locations. Within municipalities, for example, household and industrial waste are typically deposited in rubbish dumps. This is a social response to the presence of environmental thresholds. We may now enlarge on this observation: assuming that it is true that poor countries currently enjoy a better environment as regards industrial waste, it could well be that global well-being would be enhanced if their environment were protected and promoted, and if selected sites in rich countries were used as global centres of deposits for industrial effluents.

The second reason one should be circumspect about the suggestion is that it doesn't note that the poor in poor countries are not the same as poor countries. There are both rich and poor people in poor countries. Typically, the rich in these countries don't absorb anything like the environmental risks the poor are forced to accept (e.g. health risks at work). In addition, the rich enjoy political advantages. Furthermore, there is nothing resembling a free press, nor open debate, in a majority of poor countries. It is then all too possible to imagine that if trade in industrial pollutants were to be encouraged, the poor in poor countries

[31] Low (1992) contains discussions of these matters.

would be made to absorb the health risks (industrial pollutants are usually spatially localised), and the rich in poor countries would grasp the income accruing from the trade (a private benefit). This should make for a difference in our attitude towards the proposal. As elsewhere in economics, the issue of governance lies somewhere at the heart of the matter.

10. Valuing Environmental Resources

As noted earlier, much ecological economics begins with the observation that prices in a decentralised economic environment often do not reflect social scarcities of goods and services. If they did, the criterion of private profitability would suffice, and there would be no need to pay special attention to the environmental resource-base. As they don't, a project's private profitability can't be regarded as an adequate indicator of its social worthiness.

So then, what criterion should we use for selecting among public policies? One idea, much pursued in recent years, is to estimate accounting prices and choose policies on the basis of their accounting profits.

How we should estimate accounting prices is a complex matter, but it isn't uniformly complex. There are now standard techniques for commodities like irrigation water, fisheries, timber, and agricultural soil.[32] The same techniques can be used for estimating losses associated with water-logging and overgrazing.

For commodities such as firewood and drinking and cooking water, the matter is more complex: they are inputs in household production. This means that we need estimates of the way households convert inputs into outputs; that is, we need to estimate household production functions. As an example, transportation costs (in particular energy costs, as measured in calories) for women and children would be less if the sources of fuelwood and water were not far away and receding. As a (very) first approximation, the value of water or fuelwood for household production can be estimated from these energy needs. In some

[32] See, for example, Brown and McGuire (1967) for irrigation water; Cooper (1977) for fisheries; Magrath and Arens (1989) and Repetto *et al.* (1989) for soil fertility; Anderson (1987) and Newcombe (1987) for forestry; and Solorzano *et al.* (1991) for the latter three. Dixon and Hufschmidt (1986) and Dixon *et al.* (1988) are excellent sets of case-studies on these matters.

situations (as on occasion with fuelwood), the resource is a substitute for a tradable input (e.g. paraffin or kerosene); in others (as with cooking water) it is a complement to tradable inputs (for example, food grain). Such facts enable one to estimate accounting prices of non-marketed goods in terms of the accounting prices of marketed goods (Mäler, 1974).[33]

The approach outlined above allows us to capture only the direct use-value of a resource. As it happens, its accounting price may well exceed this. Why? The reason is that there may be additional values 'embodied' in a resource. One additional value, mentioned in section 1, is applicable to living resources: it is their intrinsic worth as living resources. It is absurd to suppose that the value of a blue whale is embodied entirely in its flesh and oil, or that the value of the game in Kenyan safari parks is simply the present-discounted value of tourists' willingness-to-pay. The idea of 'intrinsic worth' of living things is inherent not only within traditional religious systems of ethics, but also in modern utilitarianism. The question is not so much whether living things possess intrinsic worth, but rather, about ways of assessing this worth. As it is almost impossible to get a quantitative handle on intrinsic worth, the correct thing to do is to take note of it, keep an eye on it, and call attention to it in public debate if the resource is threatened with extinction.

What is the point of basing accounting prices solely on use-value when we know that resources often possess intrinsic value as well? The answer is that it provides us with biased estimates of accounting prices, and this can be useful information. For example, in a beautiful paper on the optimal rate of harvest of blue whales, Spence (1974) took the accounting price of these creatures to be the market value of their flesh, a seemingly absurd and repugnant move. But he showed that under a wide range of plausible parametric conditions, it would be most profitable commercially for the international whaling industry to agree to a moratorium until the desired long-run population size were reached,

[33] A second approach to the estimation of accounting prices of environmental resources is based on contingent valuation methods (CVMs). They involve asking concerned individuals to reveal their valuation of hypothetical changes in the flow of environmental services. CVMs are useful in the case of amenities, and their applications have so far been confined to advanced industrial countries. As I am not focusing on amenities in this lecture, there is no point in developing the idea underlying CVMs any further here. The most complete account to date on CVMs is Mitchell and Carson (1989). See also the report on the NOAA Panel on Contingent Valuation (co-chaired by K. J. Arrow and R. M. Solow) in the *Federal Register*, 58 (10), 15 January 1993.

and for the industry to subsequently harvest the creatures at a rate equal to the population's (optimal) sustainable yield.[34] In other words, in Spence's analysis, preservation was recommended solely on commercial grounds. But if preservation is justified when the accounting price of blue whales is estimated from their market price, the recommendation would, obviously, be reinforced if their intrinsic worth were to be added. This was the point of Spence's exercise.

Environmental resources often possess another kind of value, one which is more amenable to quantification. It arises from a combination of two things: uncertainty in their future use-values, and irreversibility in their use. Genetic material in tropical forests provides a prime example. The twin presence of uncertainty and irreversibility implies that preservation of its stock has an additional value—the value of extending society's set of future options. Future options have an additional worth 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 accounting price of a resource is, at the very least, the sum of its use-value and its option value.[35]

11. Net National Product as an Index of Social Well-Being

Ideally, institutions should be in place that make it possible for market prices and accounting prices to coincide. In practice, they don't coincide. Private agencies choose their actions on the basis of market prices, not accounting prices; but it is public agencies with which I am concerned here.

The argument that the right criterion for choosing among alternative policies is their accounting profitability is closely related to the suggestion that in measuring changes in social well-being, we should estimate changes in net national product (NNP); that is, gross national product (GNP) corrected for the value of changes in the country's entire capital base, including its environmental resource-base. This suggestion is based on a well-known theorem in modern economics. The theorem states that, provided certain technical restrictions are met (on which, see

[34] During the moratorium the whale population grows at the fastest possible rate. In his numerical computations, the commercially most-profitable duration of the moratorium was found to be some ten to fifteen years.

[35] The pioneering works on option values are Arrow and Fisher (1974) and Henry (1974).

below in the text), for any conception of social well-being, and for any set of technological, transaction, and ecological constraints, there exists a set of accounting prices of goods and services that can be used in constructing a linear index of social well-being. The sense in which it can serve as an index of social well-being is this: small policy changes, including small investment projects, that are recorded as an improvement (deterioration) by the index are at once those that result in an increase (decrease) in social well-being.[36] This index is popularly known as 'green NNP'.

I cannot enter into details here, but (green) NNP, in a closed economy, reads as:

> NNP = Consumption + value of net investment in physical capital + value of the net change in human capital + value of the net change in the stock of natural capital − value of current environmental damages.[37]

Current estimates of NNP are biased because depreciation of environmental resources is not deducted from GNP. To put it another way, estimates of NNP are biased because a biased set of prices is in use: prices imputed to environmental resources on site are usually zero, and this amounts to regarding the depreciation of environmental capital as

[36] Dasgupta and Heal (1979), Dasgupta and Mäler (1991, 1995), Mäler (1991), and Dasgupta, Kriström and Mäler (1996) prove this in models of increasing generality. Lutz (1993) contains a collection of articles that explore the practicality of moving to a system of national accounts that includes the environmental resource-base.

[37] All values are assumed to be measured in terms of consumption. This involves no loss of generality, since all remaining objects that help realise social well-being (including distributional considerations) can in turn be valued in terms of consumption (Dasgupta, 1993). Note also that, in an open economy, the value of net exports ought to be deducted from the expression for NNP in the text (Sefton and Weale, 1996). Furthermore, the expression is correct only if labour is supplied inelastically (in this case it is a matter of indifference whether or not we include the wage bill). However, if the supply of labour is responsive to wages, the wage bill should be deducted from the expression (Nordhaus and Tobin, 1972).

By the value of net 'investment' in the expression in the text, I mean the value of net changes in capital assets, not changes in the value of these assets. This means that anticipated capital gains (or losses) should not be included in NNP. As an example, the value of the net decrease in the stock of oil and natural gas (net of new discoveries, that is) ought to be deducted from GNP when NNP is estimated.

Finally, it has been argued by Putnam (1993) that, in addition to manufactured, environmental, and human capital, 'social' capital (involving, among other things, trust and interpersonal networks) matters in the production of goods and services. Assuming that a suitable index of social capital were in hand, the expression for NNP in the text would include net investment in social capital. The answer to the question how we should estimate NNP should not be a matter of opinion today; it is a matter of fact. The problem is not that we do not know what items NNP should ideally contain, rather it is that we don't have adequate estimates of various accounting prices.

zero. But this in turn means that profits attributed to projects that degrade the environment are higher than their social profits. A consequence is that wrong sets of projects get selected, in both the private and public sectors.

The extent of the bias will obviously vary from project to project, and from country to country. But it can be substantial. In their work on the depreciation of natural resources in Costa Rica, Solorzano *et al.* (1991) have estimated that, in 1989, the depreciation of three resources — forests, soil, and fisheries — amounted to about ten per cent of gross domestic product and over one third of gross capital accumulation. Since, under current practice, environmental resources are often unpriced, resource-intensive projects look better than they actually are. In consequence, installed technologies are often unfriendly towards the environment.

One can go further: the bias extends to the prior stage of research and development. When environmental resources are underpriced, there is little incentive on anyone's part to develop technologies that economise on their use. The extent of the distortion created by this underpricing will vary from country to country. Poor countries inevitably have to rely on the flow of new knowledge produced in advanced industrial economies. Nevertheless, poor countries need to have the capability for basic research. The structure of accounting prices there is likely to be different from those in advanced industrial countries, most especially for non-traded goods and services. Even when it is publicly available, basic knowledge is not necessarily usable by scientists and technologists, unless they themselves have a feel for basic research. Often enough, ideas developed in foreign lands are merely transplanted to the local economy; whereas, they ought instead to be modified to suit local ecological conditions before being adopted. This is where the use of accounting prices is of help. It creates the right set of incentives, among both developers and users of technologies. Adaptation is itself a creative exercise. Unhappily, as matters stand, it is often bypassed. There is loss in this.

There is further loss associated with a different kind of bias, something we noted earlier: that arising from biased demand. For example, wherever household demands for goods and services in the market reflect in the main male (or for that matter, female) concerns, the direction of technological change would be expected to follow suit. Among poor countries, we would expect technological inventions in farm equipment and techniques of production to be forthcoming in

regions where cultivation is a male activity (there would be a demand for them); we would not observe much in the way of process innovations in threshing, winnowing, the grinding of grain in the home, and in the preparation of food. Entrepreneurs have little incentive to bring about such technological innovations. Household demand for them would be expected to be low.

Such biases in NNP as I have identified here occur in advanced industrial countries as well. So then why do I stress their importance in the context of poor countries? The reason is that poor people in poor countries cannot cope with the same margin of error as people living in rich countries can: a 10 per cent drop in the standard of living imposes greater hardship on a poor household than a rich one. Recall too that the rural poor are especially dependent upon their local environmental resource-base. Losses in well-being due to an underpricing of this base are absorbed by them disproportionately. The estimation of accounting prices of environmental resources should now be high on the agenda of research in the economics of poor countries.

There is an important qualification to all this. The principles underlying the construction of (green) NNP assume, among other things, that ecological processes do not display threshold effects.[38] If threshold effects were important, a purely decentralised economic environment wouldn't do: accounting prices would need to be augmented by quantity controls on the use of a number of environmental resources. This would be a way of ensuring that the magnitude of economic activity does not reach a level that places undue stress on key ecosystems.

I conclude that economic liberalisation and other policies that promote growth in gross national product are not substitutes for environmental policy. On the contrary, it may well be desirable that they be accompanied by stricter policy reforms. Of particular importance is the need for reforms that would lead to an improvement in the quality of the signals on the basis of which resource users reach decisions. They include an array of prices, allied to more direct types of information concerning resource stocks. Environmental damage, including the loss of resilience of ecosystems, often occurs abruptly and is often not reversible. But abrupt changes can seldom be anticipated from signals

[38] The existence of thresholds means that an ecosystem can flip to a quite different state in a short space of time when subjected to stress. Formally, and more generally, an exclusive reliance on accounting prices is justified only if production technologies are convex. Threshold effects are a prime example of non-convexities. Key articles on this matter are Baumol and Bradford (1972) and Starrett (1972).

that are characteristically received by decision-makers in the world. Furthermore, the signals that are generated are often not observed, or are wrongly interpreted, or are not part of the incentive structure of societies. This is due to ignorance about the dynamic effects of changes in the variables that characterise ecosystems (e.g. thresholds, buffering capacity, and loss of resilience). It is also due to the presence of institutional impediments, such as a lack of well-defined property rights. The development of appropriate institutions depends, among other things, on understanding ecosystem-dynamics. Above all, given that we are vastly ignorant about the extent to which ecosystems are resilient, we should act in a precautionary way so as to maintain their diversity.

Economic growth is not a panacea for environmental quality; indeed, it is not even the main issue. What matters is not economic growth *per se*, but the content (i.e. the composition of inputs and outputs) of growth. The content is determined by, among other things, the economic institutions within which human activities are conducted. Such measures will not only promote greater efficiency in the allocation of environmental resources at all income levels, but would also assure a sustainable scale of economic activity within the ecological life-support system. Protecting the capacity of ecosystems to sustain human well-being is of as much importance to poor countries as it is to those that are rich.

12. International Governance and the Global Commons

Unlike the local commons, open access to the global commons is more the rule than the exception. This makes Hardin's parable apt. Moreover, the option of 'voting with one's feet' as a way of avoiding global environmental problems is unavailable. This gives added bite to the political economy of global common-property resources.[39]

Space forbids that I go into global issues in any detail here. So I will sketch a few mechanisms that have been suggested for dealing with them. It will prove convenient to do this in the context of two global commons: the atmosphere as a sink for gaseous emissions and international fisheries. I will take them up sequentially.

[39] See Barrett (1990), Mäler (1990) and Hoel (1992) for a more detailed discussion of these issues.

Global warming and ozone depletion

Emission of carbon dioxide (CO_2) at rates in excess of the capacity of the oceans and forests to 'absorb' it is a cause of global warming. This has been known for about a century. So too are chlorofluorocarbons (CFCs), a 'greenhouse' gas, (and there are others still). However, a little over two decades ago, the CFCs were found to have a more immediate and dramatic effect: they deplete the ozone shield that protects us from excessive ultra-violet radiation from the sun. For this reason, today the CFCs are discussed almost exclusively in the context of their effect on the ozone layer.

Even though the externalities that nations inflict upon one another when emitting, say, CO_2 are reciprocal, they are not symmetric: the costs and benefits of reducing emission rates differ greatly across nations. This means that, if agreements on major reductions are to be reached, financial transfers would be necessary (Carraro and Siniscalco, 1993; Heal, 1994). Several alternatives have been suggested, debt relief for developing countries being one. This isn't to say that agreements can't be reached in the absence of side-payments; it is only to say that they would tend to be less efficient (Carraro and Siniscalco, 1993). Barrett (1990) has argued, for example, that, while one would have expected a number of countries to sign the Montreal Protocol on CFCs, one shouldn't expect all countries to sign it. The reason is that if only a few countries were to sign the Protocol, national benefits from further reduction in CFC emission would be high. This would induce more countries to sign. However, if many countries were to sign the Protocol, national benefits from further reduction would be small, and it wouldn't then be worth a country's while to sign.

Nevertheless, international negotiations over the protection of the ozone layer have been remarkably successful. Nearly all countries have co-operated in creating a regime in which the emission of CFCs will soon be reduced to nil. In contrast, little has been achieved in the case of CO_2 emission. Why?

Barrett (1996) has pointed to a number of salient differences between the two cases. Ozone depletion increases the risk of skin cancer, and so kills people; in contrast, the economic consequences of an increase in the atmosphere's average temperature, though most likely to be very large, will be diffuse across the globe in unpredictable ways. The aggregate cost of reducing the consumption of fossil fuels in any significant amount would be gigantic; in contrast, the costs of

moving away from CFCs to their substitutes are small. And so forth. Whatever the reasons, the public perception is that the ratio of benefits to costs of a ban on CFCs is large, whereas, for significant reductions in the use of fossil fuels, it is small. This interpretation of the public's perception must be right; otherwise, it is hard to see why the Montreal Protocol (in which the signatories agreed to ban the use of CFCs and to ban trade with non-signatories in goods involving CFCs) has been so effective, whereas the Framework Convention on Climate Change (which merely urges countries to stabilise their CO_2 emissions at 1990 levels by the year 2000, but does not require them to do so) resembles a toothless kitten. Unless an agreement is so designed that the parties have an incentive to comply, it amounts to little.[40]

What mechanisms, other than quantity restrictions and Pigovian taxes, are there for implementing international agreements, if agreement can be reached?[41] One broad category, well worth exploring, 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 USA. The idea, if extended to the international sphere, would have the community of nations set an upper bound on the total use of a global commons, such as the atmosphere; have it allocate transferable national rights (which add up to the global upper bound); and allow the final allocation among different users to be determined by a market in these rights.

To give an example, consider the emission of CO_2. Suppose it is desired by the community of nations that the global emission rate should be reduced to some prescribed level. Countries would receive an assignment of permits which add up to the global bound and would be allowed to buy and sell permits. It transpires that under a wide range of circumstances, this scheme has informational advantages over both taxes and quantity controls. Furthermore, if the permits were to refer to *net* emissions (i.e. net of absorption of CO_2 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) coun-

[40] French (1994) argues that such incentives are lacking in most of the 170 or so environmental treaties that have been drafted in recent years.

[41] Admittedly, the one is not independent of the other; but for expositional ease, I will suppose they are.

tries to participate in the agreement could be made through the initial distribution of emission permits. Countries that do not expect severe damage from global warming would also wish to participate, if only they were to be provided initially with a sufficient number of permits.

The sticking point would clearly be in reaching an agreement on the initial distribution of permits among nations.[42] However, if the bound established on annual aggregate emission were approximately optimal, it would be possible, in principle, to distribute the initial set of permits in such a way that all countries have an incentive to join the scheme (Mäler and Uzawa, 1995). Having said this, it is important to note that in practice it is difficult to devise a rule for the distribution of initial rights that would satisfy all countries (recall the bargaining problem in Figure 1). So progress in this sphere of international co-operation can be expected to be slow. Nevertheless, one cannot over-emphasise 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 pathway by which all nations can enjoy such gains. The argument that national sovereignty would be endangered is no argument: the point about the global commons is precisely that they are beyond the realm of national sovereignty.

International fisheries

If biodiversity and the emission of greenhouse gases dominate the literature on the global commons today, it isn't because international fisheries pose no problems; rather, it is because global food production hasn't been on the agenda of international concerns in recent years. But disputes in the Atlantic and the Pacific reflect unresolved conflicts of interest among contending parties. At the widest international level, the United Nations Law of the Sea Conferences were initiated several decades ago because of a clear recognition that the open seas pose a serious resource allocation problem.

The maximum potential harvest of ocean fisheries is estimated to be in the range 60 to 90 million metric tons.[43] There is evidence that,

[42] How a national government would allocate the nation's rights among agencies within the country is a different matter.

[43] Maximal potential harvest is not the same as maximum sustainable yield. This is because a good fraction of a fishery's production has to be left unharvested on ecological grounds. World Resources Institute (1994) and Safina (1995) offer succinct accounts of the problem of marine fisheries.

globally, stocks have declined in recent years through overfishing: worldwide, the extraction rate of wild fish reached a peak of 82 million metric tons in 1989. It is not only increases in world population and incomes that have caused this; fishing technology has become awesome, having both lowered the unit cost of large-scale fishing considerably and increased the rate of what is euphemistically called 'bycatch'.[44] Allied to this is the enormous subsidy a number of the most prominent national fishing industries receive from their governments. Recently, the cost of catching $US 70 billion worth of fish amounted to $US 124 billion. The deficit was largely covered by subsidies (Safina, 1995).

Cooper (1977) estimated that the annual revenue that could be generated from international marine fisheries by a Pigovian tax on harvests is of the order of $US 2.5 billion. He suggested that the tax could be administered by the United Nations, possibly as a contribution to its Development Fund. This is another illustration of the possibility of a 'double dividend', mentioned in section 3. But we are nowhere near such a form of international co-operation.

13. Collective Agreements and the Structure of Authority

A striking difference between local and global environmental problems is this: unlike agreements on the use of, say, local commons, there is no obvious central authority that can enforce agreements among nations over the use of transnational commons. To be sure, there are international authorities that have the mandate to act as overseers. But they don't, at least in principle, possess the coercive powers that national governments ideally enjoy. This has implications for the extent to which international authorities are able to enforce agreements.

Insights into the range of options open in the international sphere can be obtained by asking a prior question: How are agreements implemented in the case of local environmental problems? Notice that, while related, this is different from asking what agreement would be expected to be reached if the parties were to bargain. In section 6 we noted that the theory of games offers little guidance on the latter question. But it has things to say about the former.

[44] Bycatch refers to inadvertent harvest. Roughly, one of every four animals harvested from the open seas is unwanted.

Broadly speaking, there would appear to be three mechanisms by which an agreement can be implemented. (Of course, none may work in a particular context, in which case people will find themselves in a hole they can't easily get out of, and what could have been mutually beneficial agreements won't take place.)

In the first mechanism the agreement is translated into a contract, and is enforced by an established structure of power and authority. As noted in section 6, this may be the national government, but it need not be. In rural communities, for example, the structure of power and authority are in some cases vested in tribal elders (as within nomadic tribes in sub-Saharan Africa), in others in dominant landowners (such as the zamindars of eastern India), feudal lords (as in the state of Rajasthan in India), chieftains, and priests. On occasions there are even attempts at making rural communities mini-republics. Village panchayats in India try to assume such a form. The idea there is to elect offices, the officials being entrusted with the power to settle disputes, enforce contracts (whether explicit or only tacit), communicate with higher levels of State authority, and so forth. Wade's account (1988) of the collective management of common-property resources in South India describes such a mechanism of enforcement in detail.[45]

The question why such a structure of authority as may exist is accepted by people is a higher-order one, akin to the question why people accept the authority of government. The answer is that general acceptance itself is a self-enforcing behaviour: when all others accept the structure of authority, each has an incentive to accept it (or, in short, general acceptance is a Nash equilibrium). Contrariwise, when a sufficiently large number don't accept it, individual incentives to accept it weaken, and the system unravels rapidly. General acceptance of the structure of authority is held together by its own bootstraps, so to speak.

The second mechanism consists in the development of a disposition to abide by agreements, a disposition that is formed through the process of communal living, role modelling, education, and the experiencing of rewards and punishments. This process begins at the earliest stages of our lives. We internalise social norms, such as that of paying our dues, keeping agreements, returning a favour; and higher-order norms, as for example frowning on people who break social norms (even shunning them), and so forth. By internalising such norms as keeping agreements,

[45] See also Gadgil and Guha (1992) for a narrative on India's ecological history as seen from this perspective.

a person makes the springs of his actions contain the norm. The person therefore feels shame or guilt in violating a norm, and this prevents him from doing so, or, at the very least, it puts a break on his violating it unless other considerations are found by him to be overriding. In short, his upbringing ensures that he has a disposition to obey the norm. When he does violate it, neither guilt nor shame is typically absent, but the act will have been rationalised by him. A general disposition to abide by agreements, to be truthful, to trust one another, and to act with justice is an essential lubricant of societies. Communities where the disposition is pervasive save enormously on transaction costs. There lies its instrumental virtue. In the world as we know it, such a disposition is present in varying degrees. When we refrain from breaking the law, it isn't always because of a fear of being caught. On the other hand, if relative to the gravity of the misdemeanour the private benefit from malfeasance were high, some transgressions could be expected to take place. Punishment assumes its role as a deterrence because of the latter fact.

However, where people repeatedly encounter one another in similar situations, agreements could be reached and kept even if people were not trustworthy; and even if a higher authority were not there to enforce the agreements. This is a third kind of mechanism.

How does it work? A simple set of contexts in which it works is one where far-sighted people know both one another and the environment, where they expect to interact repeatedly under the same circumstances, and where all this is commonly known.[46] By a far-sighted person I mean someone who applies a low discount rate to the future costs and benefits associated with alternative courses of action. This means in particular that people in the community are not separately mobile; otherwise the chance of future encounters with others in the community would be low, and people would discount heavily the future benefits of co-operation.

The basic idea is this: if people are far-sighted, a credible threat by others that they would impose sanctions on anyone who broke the agreement would deter everyone from breaking it. Let us see how this works.

For expositional ease, consider those circumstances where actions are publicly observable, and where everyone has perfect memory of

[46] These are not necessary conditions, they are sufficient. For a good account of what is known in this line of inquiry, see Fudenberg and Tirole (1991).

how all others have behaved in the past.[47] Imagine, then, a group of people who have agreed upon a joint course of action (e.g. in the case of two people, a point on BC in Figure 1). The agreement could, for example, be over the sharing of the benefits and burdens associated with the construction and maintenance of an irrigation system. We may suppose that the co-operative arrangement that has been agreed upon assigns various responsibilities to the parties on a period-by-period basis (e.g. maintaining a canal system annually, diverting to one's own fields only the quantity of water that is one's due, and so forth). How is this agreement to be kept in the absence of an external enforcement authority?

One might think that a social norm, requiring people to keep their agreements, has a role here. But this merely begs the question: we would want to know why the norm is accepted by all; that is, what incentives people have for not violating the norm. Since by a social norm we mean a rule of behaviour that is commonly obeyed by all, we would need to show that it is in the interest of each party to obey the norm if all others were to obey it.[48] For simplicity of exposition, consider the case where the private gain to someone from breaking the agreement unilaterally for a period is less than the discounted value of the loss he would suffer if all others were to refrain from co-operating with him in the following period. Call a person deserving if and only if he co-operates with all who are deserving. This sounds circular, but isn't; because we now assume that the norm requires all parties to start the process of repeated interactions by keeping their agreement (namely, maintaining the canal system, diverting to one's own fields only the quantity of water that is one's due, and so forth). It is then easy to confirm that, by recursion, it is possible for any party in any period to determine who is deserving and who is not. If someone's actions in any period made him non-deserving, the norm would enjoin each of the other parties to impose a sanction on him (i.e. not co-operate with him) in the following period (e.g. deny him the water he needs). The norm therefore requires that sanctions be imposed upon those in violation of an agreement; upon those who fail to impose sanctions upon those in violation of the agreement; upon those who fail to impose

[47] Each of these qualifications can be relaxed. See Radner (1981) for weakening the first qualification, and Sabourian (1988) for relaxing the second.

[48] In technical parlance, for a rule of behaviour to be a social norm, it must be a subgame-perfect Nash equilibrium. Fudenberg and Tirole (1991) offer an account of this.

sanctions upon those who fail to impose sanctions upon those in violation of the agreement; and so on, indefinitely. This indefinite chain of what amounts to higher and higher order norms makes the threat of sanctions against deviant behaviour credible; because, if all others were to obey the norm, it would not be worth anyone's while to disobey the norm. In short, keeping one's agreement would be self-enforcing.[49]

This argument generalises to other situations. Provided people are sufficiently far-sighted, a social norm which instructs one to co-operate with, and only with, deserving parties, can lift communities out of a number of potentially troublesome social situations, including the repeated 'prisoners' dilemma' game. The reason each party would conform to the norm if a sufficient number of others were to conform is pure and simple self-interest: if someone were not to conform (i.e. were not to abide by the norm), they would suffer from sanctions from others for a sufficiently long period of time, long enough to make non-conformism 'unprofitable'.[50]

This sort of argument, which has been established in a general setting only recently, has been put to effective use in explaining the emergence of a number of institutions which facilitated the growth of trade in medieval Europe. Greif (1993), for example, has shown how the Maghribi traders during the eleventh century in Fustat and across the Mediterranean acted as a collective to impose sanctions on agents who violated their commercial codes. Greif, Milgrom and Weingast (1994) have offered an account of the rise of merchant guilds in late medieval Europe. These guilds afforded protection to members against unjustified seizure of their property by city-states. Guilds decided if and when a trade embargo was warranted against the city. In a related work, Milgrom, North and Weingast (1990) have analysed the role of merchant courts in the Champagne fairs. These courts facilitated members in imposing sanctions on transgressors of agreements.

A somewhat reverse set of actions also occurred in medieval Europe, where transgressions by a party were sometimes met by the rest of society imposing sanctions on the entire kinship of the party, or on the guild to which the transgressor belonged. The norm provided collec-

[49] Notice though that, as co-operation is self-enforcing, there would be no deviance along the path of co-operation; so, no sanctions would be observed. The higher-order norms pertain to behaviour off the path of co-operation.

[50] Of course, the non-co-operative outcome (e.g. the point A in Figure 1) is also self-enforcing; that is, it is also a subgame-perfect Nash equilibrium. Repeated games, such as the one I am studying here, have many equilibria.

tives with a natural incentive to monitor their own members' behaviour. (For a different instance of this, the context being the use of local common-property resources, see Howe, 1986.)

As matters stand, international agreements on environmental matters could be expected to be sustained by the latter two mechanisms in the list I have just discussed, not by the first. Ultimately, however, it is the second route that offers the strongest hopes for the emergence of collective responsibility over transnational commons. The problem is that institutional changes are easier to bring about than changes in personal and collective attitudes; or so it would seem. Economists generally take 'preferences' and 'demands' as given and try to devise policies that would be expected to improve matters collectively. This is the spirit in which ecological economics has developed, and there is an enormous amount to be said for it. But in the process of following this research strategy, we shouldn't play down the strictures of those social thinkers who have urged the rich to curb their material demands, to alter their preferences in such ways as to better husband the earth's limited resources. If such strictures seem quaint in today's world, it may be because we are psychologically uncomfortable with this kind of vocabulary. But that isn't an argument for not taking them seriously.

Note. I am grateful to Kenneth Arrow, Edward Barbier, Scott Barrett, John Dixon, Paul Ehrlich, Carl Folke, Frank Hahn, Geoffrey Heal, C. S. Holling, Bengt-Owe Jansson, Bengt Kriström, Simon Levin, Mohan Munasinghe, Charles Perrings, Jonathan Roughgarden, Ismail Serageldin, Robert Solow, David Starrett, Andrew Steer and, in particular, Karl-Göran Mäler, discussions with whom over the past many years have improved my understanding of the subject matter of the lecture.

Discussion

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Professor Dasgupta's lecture succeeded in enlivening a topic which can prove to be deadly dry. Following a wide-ranging lecture on a hugely diverse field, it is impossible for a discussant to do more than to pick up a few topics which may merit further discussion. I have chosen to offer brief comments on just three topics:

1 the idea of 'Greening' net national product;
2 planning with environmental risk; and
3 induced technical change and the environment.

Greening NNP

There can be no question that it is possible to define a measure of 'Green NNP' and to compute estimates of it. Such an exercise can be useful and enlightening. Indeed I favour a multiplicity of concepts and methods, on the grounds that the contrasts thus provided can only enrich. However, I confess that the prospect of national accounting being substantially re-defined to make it 'environmentally correct' causes me to feel considerable apprehension.

It is a merit of established NNP aggregates that they are familiar and routine, and we know what kind of things they measure. Broadly speaking, NNP measures the scale of national value-added activity roughly corrected for capital depreciation. Economists know that such a measure is non-ideal in all kinds of ways. NNP plunges when millions of rich men marry the old-time housekeepers who become old-time stay-at-home wives. Yet the measure is useful, to track national economic activity over trade cycles, and for admittedly rough-and-ready international comparisons of economic prosperity, particularly when corrected for differences in purchasing power.

If 'green corrections' were as clear and boring as the standard measures, they could be accepted as welcome refinements. But they are not, and there is a danger that their introduction would politicise NNP estimates without making them genuinely more useful. Take as a case in point the popular notion that over-inflated NNP estimates would be reduced were an allowance for using up exhaustible fossil fuels to be deducted. If all fossil fuel reserves were to be known and proven that would indeed be the case. In the real world, however, NNP estimates would at times leap up by very substantial fractions of the total following new discoveries. And if logic is to be respected, why should not NNP measures be augmented following technical innovations? How are pen-pushing census of production statisticians to estimate such corrections?

Risk and planning

The problem of how to compute the value of innovations arises because the future is dreadfully uncertain. There at least we have the option to

walk away from the problem by leaving our NNP estimates alone, while recognising that they are most imperfect. That option does not exist where the possibility of catastrophic outcomes exists. How should we react to uncertainty, especially when catastrophic possibilities are involved? Standard economic theory of rational choice under uncertainty teaches that low probability disaster outcomes should carry high weights in our calculations because extreme utility weights multiply the low probabilities concerned. It also teaches that positive (possibly large) values attach to open options, so that at the margin doing nothing is preferable to jumping in and causing irreversible effects to the environment.

Such arguments work well in the classroom but run the danger in the cut and thrust of debate on real environmental issues of allowing the argument to be hijacked by the imagination of someone who can dream up a nightmare possibility, however improbable, which can certainly be avoided by doing nothing. The hypothetical example cheats by introducing an unnaturally sharp discontinuity between the safe and the risky.

In reality downside risks attach even to environmental correctness. What exactly will happen should a fear of global warming induce a drastic curtailment of carbon dioxide emissions is uncertain. Serious harm to human populations caused by energy shortage is a real possibility but complex to predict and analyse in detail. The probable good outcome is outweighed by the improbable catastrophic outcome because of the extremely different weights which multiply the widely differing probabilities. Nuclear engineering is rightly all about planning for highly improbable events and paying high costs to cope with them. In much of life, however, the not wildly improbable poor outcome stands beside the dreadful outcome on more equal terms.

Induced technical change and the environment

Economists' attempts to forecast the future to allow for environmental crisis, from Malthus, through Jevons to Forrester, were wrecked on the rocks of technical change. Innovation is the new goddess of Fortune, rewarding hugely but never promising or submitting to manipulation. The pattern is often that innovation tends to bypass shortage and to exploit abundance. Yet what that implies for the huge (although shrinking, as a proportion of total numbers), numbers of poor rural labourers of the world, and particularly for the women and children among them, is far from clear.

Should population pressure and mass urbanisation bring it about that the country can no longer feed the cities with existing foodgrain cultivation methods, however far the recombinant DNA scientists may take that technology, the next step may bypass the rural cultivators and their possibly degraded land rather than heaping rents upon them. Fermentation of biomass, for instance, could produce protein-rich nutrients for animal feed or for poor humans, out of capital intensive urban factories which are unlikely to favour women and children in employment.

The happy outcome that the solutions to environmental problems and the solutions to problems of inequality and human exploitation will all point in the same direction is something to pray for, not an economic theorem.

Scott Barrett, *London Business School*

I can't think of a social problem more momentous than the subject of Professor Dasgupta's lecture: that of how to improve the lot of the worst-off people living in the worst-off countries.

That economics not only could be used to address this problem but *should* be is a lesson I learned from Partha Dasgupta ten years ago when I came to study under him at the LSE. At our first meeting, Professor Dasgupta asked me what I intended to write my Ph.D. on. I had given this a lot of thought, and proceeded to tell him my ideas. He listened attentively and when I finished he said, 'Very interesting . . . but have you thought of the desertification problem?' Now I needn't tell you what my idea for a thesis was except to say it had absolutely nothing to do with the desertification problem. It couldn't have, because at the time I didn't even know there was such a problem. Suffice it to say that three years later I submitted a thesis that I wouldn't have written had I not understood the message that Partha Dasgupta was conveying to me. And though I have since turned to work on different subjects, even today, if you were to hold any of my work up to the light I think you'd find the Dasgupta watermark.

For my discussion, I would like to demonstrate this by applying the apparatus Professor Dasgupta has sketched in his lecture to a different class of problem: global, rather than local, environmental degradation. This would seem appropriate, not least because global environmental degradation also affects the lives of the poor. Let me, however, qualify the analysis which follows by saying that it is deliberately rough. To do

a proper job of the subject would require more space than I am permitted.

A tale of two global environmental problems

Consider two, superficially similar, examples of global environmental degradation: stratospheric ozone depletion and global climate change. Both of these problems affect every country; and in both cases, effective management of the environment requires co-operation by at least a very large number of countries. There the similarities end, for the outcomes as regards these two problems couldn't be more different. Global co-operation in protecting the ozone layer has been miraculous: almost every country in the world has co-operated in a regime to protect the ozone layer, and in a very short time virtually all the important substances which deplete the ozone layer — I'll call them CFCs — either have been or soon will be eliminated. By contrast, next to nothing has been done to address the problem of global climate change. This is a puzzle: Why should the outcomes for such similar problems be so different?

A brief history of the science

It would be natural to suppose that the answer might relate to the science of these problems, but this turns out not to be the case. That CFCs could deplete ozone was not even contemplated until 1974 when it was first posited as a hypothesis. By contrast, the theory of global climate change, resulting from the burning of fossil fuels, goes back to the last century. In fact, in 1895 a Swedish chemist, using the back of an envelope, predicted that a doubling in carbon dioxide concentrations would increase global mean temperature by about 5°C. Today's climatologists, using the most advanced supercomputers, predict that the increase will be smaller — about 1°–3.5°C by the end of the next century. What the Swedish chemist didn't take account of were important feedbacks. Still, it is remarkable how little the estimates for climate change have shifted, despite a century's advancement in atmospheric science. So, while we have known that carbon dioxide emissions alter the climate for much longer than we have known that CFCs destroy ozone, we have done much more to address the latter problem than the former.

The nature of the environmental damage

If the science can't explain the different outcomes, what can? At least an important part of the answer can be found in the economics.

Ozone depletion would increase the incidence of skin cancer. Put bluntly, it would kill people. People in rich countries are willing to pay a lot to avoid this, and so the benefit to them of reducing ozone depletion is high. The cost to them of doing so, it turns out, is very low. In one economic study by the US government, the benefit to the US of signing the international treaty controlling CFCs exceeded the cost by about 170 times. There are not many public choices that have such a favourable benefit–cost ratio.

With global climate change, most of the available economic studies show that only modest reductions in carbon dioxide emissions would be warranted. Climate change damages are expected to be small, partly because climate change hasn't been shown to kill large numbers of people, but also because of certain offsets and behavioural responses. Consider what appears to be the most vulnerable economic sector: agriculture. If a warmer temperature reduced agricultural output in already warm regions, it would probably increase output in colder ones. Added to this, farmers could change the crops they planted and their use of inputs like water. Finally, the new biotechnology could develop seed varieties better suited to the changed climate. Furthermore, the costs of abating carbon dioxide emissions are expected to be large in proportion to the benefits: to reduce carbon dioxide emissions substantially would require reducing fossil fuel consumption, and our economies depend on them.

I have some doubts about the analyses which show that the damages from climate change would be low. They have been based largely on the assumptions that the damage is a function of *average* temperature change, and that damage estimates for the US can simply be prorated across the rest of the globe. Professor Dasgupta's attention to ecology and the nature of environmental damage should make us wary of these assumptions.

The average temperature change may in itself matter very little. Much more important may be the changes triggered by the average temperature change, such as a flip in the Gulf Stream. And, as regards prorating US damage across the globe, consider the effect of increasing temperature in malaria-prone regions. Already, malaria strikes at 100 million people in the poor countries each year, killing 1–2 million of

them. Even ignoring such scenarios, as Partha Dasgupta would be the first to observe, a $100 drop in the standard of living of a poor household would impose much greater hardship than would an equivalent reduction for a rich one. This last observation does not by itself mean that emissions should be reduced substantially, but it does mean that poor countries will potentially be harmed more severely than rich countries in well-being terms.

Abatement costs and incentives to innovate

Unfortunately, merely acknowledging that expected damage is high won't necessarily commend substantial abatement of greenhouse gases, for we still have the problem that the costs of abatement are large. To affect the outcome significantly would require substantial abatement. This essentially means finding a substitute for fossil fuels. What we require are incentives for innovation.

In the case of ozone depletion, the Montreal Protocol didn't just ban CFCs. For in doing this it created a market for CFC-substitutes, and thus provided incentives for innovation. By contrast, the Framework Convention on Climate change does not require that greenhouse gas emissions be cut, and for this reason the incentives to develop carbon-saving technologies are weak at present. These incentives will remain weak until business comes to believe that governments will be able to establish an international regulatory regime for the climate like the Montreal Protocol which is capable of imposing stiff abatement requirements. Perhaps the biggest challenge for climate change policy is to make the threat to impose such requirements credible.

Free riding and trade leakage

One reason the Framework Convention does not demand a sharp reduction in emissions is that the high expected costs of abatement make the temptation to free-ride hard to resist. The result is that each country abates its emissions very little. Furthermore, this would be true even if all countries believed that they would be better off if they all abated their emissions substantially. Again, much of Partha Dasgupta's work has been concerned with situations of this type, facing households or rural communities: situations in which, even if all parties make the decisions that are good for themselves, the result is bad for everyone.

In the case of global environmental problems, these 'free-rider'

incentives are exacerbated by trade. If a country increases its abatement, its production costs rise, with the consequence that comparative advantage in the pollution-intensive good is shifted abroad: foreign output rises; and so do foreign emissions. Hence, as a direct result of reducing emissions at home, foreign emissions rise.

'Sticks'

This problem of 'leakage' was eliminated in the Montreal Protocol by the use of trade sanctions. Parties agreed not to trade with non-parties in CFCs, products containing CFCs, and products made using CFCs. The trade sanctions fundamentally altered the incentives to free-ride. Once enough countries were parties to the agreement, there was a huge loss in the gains from trade to non-signatories. This was the stick that made participation attractive to so many countries. Trade sanctions in the case of carbon dioxide would, however, probably not be as attractive. Greenhouse gases are emitted in the process of making every good or service. A comprehensive trade ban between signatories and non-signatories may not be credible, while a partial trade ban may in this case threaten the existing multilateral trading regime.

'Carrots'

Just as the Montreal Protocol needed to include all the major countries in the world, so any agreement to limit greenhouse gas emissions must include a large number of poor as well as rich countries. The UK emits no more today than it did twenty to twenty-five years ago. In China, emissions are rising about 7 per cent a year. This implies a doubling in emissions every ten years. There is not much point in negotiating an agreement to limit greenhouse gas emissions which doesn't include China and certain other poor countries. China and the other poor countries have other priorities, however. Sure, they would be harmed by climate change; but if they reduce their emissions they will receive only a fraction of the expected global benefit, and even this won't be realised for decades. At least as regards a significant abatement programme, the return on investment will be higher for them in other areas.

So the rich countries will have to pay poor countries to reduce their emissions. The Montreal Protocol again succeeded in this. You might recall the concern expressed a few years ago of the implications if every Chinese household owned a refrigerator. This is no longer a worry

because under the Montreal Protocol China and other poor countries will be compensated for the higher cost of using CFC substitutes. It turns out that the cost of this substitution is small: in the order of a few hundred million pounds. By contrast, the cost of effecting a substantial shift away from fossil fuel burning will be more than all the rich countries currently spend on overseas development.

Concluding remark

I don't have time to go into any more detail. Professor Dasgupta's lecture has taught us that economics provides the means for understanding why the rural poor are in the terrible straits they are in, and what can be done to improve their condition. My goal was to reinforce this message, by showing how the same theoretical apparatus could be employed on the global scale.

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