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Sustainable livelihoods and environmentally sound technology

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Agenda 21, the final text of the agreements negotiated by governments at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 (UNCED, 1993), introduced a number of concepts into the policy agenda. While some have already been operationalized, there remains considerable ambiguity about others. This article focuses on two of these: "sustainable livelihoods" and "environmentally sound technology". It considers both the content of these concepts, and how they might be applied, but begins with an outline of the general concepts of "sustainable development" and "environmental soundness".

Sustainable development

"Sustainable livelihoods" and "environmentally sound technology" are subcategories of the general concepts "sustainable development" and "environmental soundness". Sustainable development was introduced into the lexicon of development policy by the World Commission on Environment and Development – known as the Brundtland Commission. The report of the Commission, *Our common future* (WCED, 1987), popularized the notion that development is sustainable only if it meets the needs of the present generation without compromising the interests of future generations. Sustainable development in this sense is very much the leitmotif of Agenda 21. But where Agenda 21 differs from earlier discussions of sustainable development is in the assumption that sustainability of the whole implies sustainability of each of the parts. Agenda 21 seeks to promote sustainability not just of the development process, but of each aspect of the development process and for each level of society (UNCED, 1993). This

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requires not only the sustainable development of all communities within a society, but also the sustainable livelihood of individuals within those communities, and the environmental soundness of each process.

Any infinite-horizon economic process may be said to be sustainable (from the perspective of the present) if the utility it offers is non-declining in terms of the present structure of preferences (Pezzey, 1989). This proposition is widely accepted in the literature, explicitly or implicitly. It is also well understood that a necessary condition for the real consumption expenditure of future generations to be no less than that of the present generation is that the value of the capital stock should be non-declining (Solow, 1974). "True" (Hicks/Lindahl) income (Hicks, 1946) is, in fact, defined by the maximum amount which may be spent on consumption in one period without reducing real consumption expenditure in future periods. In other words, it means the level of real consumption expenditure that leaves society as well off at the end of a period as at the beginning, and society can only be as well off at the end of the period if it is not consuming its productive assets. Since productive assets include the resources of the natural environment, it follows that a necessary condition for the protection of the consumption possibilities open to future generations is that the value of the produced or man-made capital stock plus the value of the resources of the natural environment should be non-declining (see Hartwick, 1977, 1991; Solow, 1986; Mäler, 1990; Pearce and Mäler, 1991; Perrings, Folke and Mäler, 1992).

There is general consensus that maintenance of the value of the asset base allows for some substitution between natural and produced capital, but there is also consensus that the degree of substitutability is limited. This is because of the properties of biotic and abiotic cycles, the multifunctionality of biotic resources, and the irreversibility of many environmental effects. Differences of opinion regarding the degree of substitutability between produced and natural capital have led to a distinction in the literature between weak sustainability (involving maintenance of the value of the aggregate capital stock) and strong sustainability (involving maintenance of the value of natural capital alone) (Pearce and Turner, 1990). The significance of this distinction will become clear later. For now, what is important is that a flow of income to an individual household or community will be judged to be sustainable only if it involves no net depreciation in the value of the set of all assets or natural assets affected by the income-generating activity.

If there exist well-functioning, complete and competitive markets, if there are no policy distortions and if there is full information, then the price of individual assets will be a good approximation of their value to society. There are very few environmental assets for which these conditions are satisfied. However, it is in principle possible to determine the private value of assets to individual users. The private value of assets includes not only their value in some current use, but also the value that they may have independent of current use (Krutilla, 1967; Pearce and Turner, 1990), or the value of the option to make use of them in the future (Weisbrod, 1964;

Arrow and Fisher, 1974). Most methods of estimating such private value are susceptible to bias in several directions (Kolstad and Braden, 1991) but, subject to this, the aggregation of such values may be taken to approximate the social value of assets.

A sufficient – though not a necessary – condition for the social value of the stock of all assets (approximated by such estimates) to be non-declining over time is that each and every activity involves no net depreciation of the asset base affected by that activity: that each and every resource user makes good any loss in the value of natural assets in their possession by an equivalent investment in substitute assets. This requires that resource users take the social value of assets into account in making their consumption and investment decisions. The problem here, however, is that the users of environmental resources are seldom confronted by the social cost of their use of the resource due to the absence of markets and the existence of distortionary policies (Repetto, 1989; Warford, 1989; World Bank, 1992), while their own valuation of the resource is biased (often in the same direction) by ignorance, uncertainty, insecurity of tenure and myopia – all of which are positively correlated with poverty (Dasgupta, 1990; Perrings, 1989a).

The necessary condition for the value of the asset base to be maintained over time is that the potential productivity of assets be maintained. If some individuals are consuming capital, the overall allocation of resources will still be sustainable providing that other individuals are investing sufficient to compensate. In general, it will always be the case that individuals are net consumers for at least some part of their lives. The requirement in Agenda 21 that all activities be sustainable needs to be interpreted with this in mind. It is unrealistic to expect that, for example, refugees, victims of famine, the disabled, children or the old should behave sustainably. Similarly, it is unrealistic to expect that each and every resource will be used in a sustainable way: that it will either be used at a rate less than or equal to its natural rate of regeneration, or that the proceeds of its consumption will be diverted to investment in a resource of at least equal value. However, if one thinks in terms of the behaviour of communities rather than of the individuals within communities, and if one thinks in terms of ecological systems rather than the component organisms of those systems, one comes closer to an operational concept.

If sustainable development requires zero net depreciation of the asset base, then it requires that any consumption of assets, including environmental assets, be compensated through investment. Whether consumption of one asset can be compensated by investment in another asset depends on the degree of substitutability between them. The argument about strong and weak sustainability hinges on this. Given the multifunctionality of many organisms within an ecological system, and given the complementarity between them, there are many ecological goods and services which cannot be manufactured. These need to be safeguarded by suitably constraining patterns of both consumption and investment, and this is where the concept of environmental soundness comes in.

Environmental soundness

The notion of environmental soundness is less well developed in the economics literature than the notion of sustainability. There is certainly no body of literature debating the nuances of environmental soundness in the same way as there is for sustainability. Nor is there a literature on the way in which environmental soundness is related to the concept of sustainability (but see Pereira, 1991). Most of the debate over environmental soundness has taken place outside the discipline of economics. The term "environmentally sound technology" incorporates two separate ideas, one from the engineering sciences and one from the biological sciences. The most operational of these is that from the biological sciences and conveys some notion of environmental safety. Indeed, it is this notion that is emphasized in Agenda 21.[1]

The engineering literature on the environmental impact of technology contains references to a number of very closely related concepts: "clean technology", "cleaner technology", "best practicable technology", "low waste technology" and "resource conserving technology". These are not, however, the same as "environmentally safe and sound technology". Whereas environmentally safe and sound technology applies the safety of the technology with respect to the external environment as the criterion of assessment, the other concepts all use the relative volume of environmental inputs or outputs in some process as the criterion of assessment – without reference to the external environment.

The valuation of environmental resources depends, in large part, on the use they have in either production or consumption. This may be direct (if the resources are used directly) or indirect (usually in the form of the services provided by the ecological systems whose functions they support). The total social value of environmental resources is the combination of this direct and indirect "use value", together with any non-use value they might have. The notions of environmental safety and soundness refer primarily to the indirect value of environmental resources.

Human society depends on access to a range of environmental services which are supported by the interaction between the organisms, populations and communities – the ecological systems – of the natural environment. These include not just essential life-support services, such as photosynthesis, but also those which add to the quality of life by enhancing environmental amenity. What characterizes ecological systems is that their ability to provide such services is a non-linear function of the mix of biotic and abiotic resources which they comprise. There exist threshold values for most resources below which ecosystems cannot function. If certain resources fall below their threshold values, the ecosystem will tend to lose resilience or

[1] The preamble to the report states that wherever the term "environmentally sound" is used, it should be interpreted to mean "environmentally safe and sound", and that this is particularly the case in respect of energy and technology.

productive potential. Holling (1973, 1986, 1987) has described terrestrial and some marine ecosystem behaviour in terms of the sequential interaction between four system functions: exploitation (represented by those ecosystem processes that are responsible for rapid colonization of disturbed ecosystems by plants and other organisms in the earliest stages of succession); conservation (as resource accumulation that builds and stores energy and material); creative destruction (where an abrupt change caused by external disturbance releases energy and material that have accumulated during the conservation phase); and reorganization (where released materials are mobilized to become available for the next exploitative phase). Ecosystem resilience is measured by the effectiveness of the last two system functions. It describes the ability of the system to satisfy exogenous demands for ecological services and to respond creatively to exogenous shocks. It can be thought of as a measure of the productive potential of the system.

Ecological systems are able to provide ecological services at given levels of stress providing that they are resilient with respect to that level of stress. Environmental safety and environmental soundness may accordingly be interpreted in terms of the resilience of ecological systems. More particularly, technologies may be said to be environmentally safe and sound if they do not threaten the supply of essential ecological services by transgressing the thresholds of ecosystem resilience. The essentiality of ecological services depends, in large part, on the degree to which they can be substituted by investment in produced capital. It follows that environmental soundness is related to the weak and strong sustainability debate.

One of the difficulties to be addressed in the operationalization of this concept is that there is still considerable uncertainty about which ecological services are essential, and so which thresholds need to be protected. Some environmental goods and services are obviously indispensable to humanity. These include maintenance of the gaseous quality of the atmosphere, amelioration of climate, operation of the hydrological cycle including flood controls and drinking water supply, waste assimilation, recycling of nutrients, generation of soils, pollination of crops, provision of food from the sea, maintenance of the genetic library and so on (Ehrlich, 1989). But there may be other services that are less obviously critical, but still essential. Alteration of primary productivity (production by photosynthetic organisms), nutrient availability and hydrological cycles all affect the quality and quantity of ecosystem services exploited by human societies. Landscape transformations at the regional level typically change a range of biogeochemical cycles at the ecosystem level. Emissions of toxic pollutants have similar effects. Such changes affect recycling, feed-back loops and internal control mechanisms in the ecosystem. They accordingly affect both the production and maintenance of ecological services. If the system's internal cycling of nutrients and materials is reduced, it can become both more dependent on external inputs of energy and less resilient.

One of the main threats to ecosystem resilience, and hence to environmental safety and soundness, derives from activities which reduce the functional diversity of ecosystems. Functional diversity, in this context, refers to the range of responses to environmental change, including the space and time scales over which organisms react to each other and to the environment (Steele, 1991). Since loss of functional diversity generally implies loss of system resilience, it also implies loss of productive potential. The almost universal tendency of economic development to seek productivity gains through ecological specialization – crudely, the tendency towards monoculture – has the effect of reducing functional diversity, and so resilience. This is typically masked, in the short term, by the use of exogenous inputs such as imported water, industrial energy, fertilizers, pesticides, and so on. Indeed, this is the substance of much modern environmental management. But it also pushes ecosystems much closer to the thresholds of resilience, and this is where the main problems are reckoned to lie in the longer term (Holling and Bocking, 1990; see also Conway, 1987; and Conway and Barbier, 1990 for an application to agriculture).

The key elements in the concepts of sustainable development and environmental safety and soundness are, respectively, the maintenance of the value of the asset base, and the protection of thresholds of ecosystem resilience. No development process may be said to be sustainable unless the value of man-made and natural capital together is non-declining. No practice may be said to be environmentally safe and sound if it causes the loss of resilience of those ecosystems on which human life and livelihood depends. What is the link between these concepts? First, if the set of prices on which resources are valued are optimal prices, then the condition of maintaining the value of the asset base ensures that the value of the flow of services derived will be non-declining. That is, the value productivity of the asset base will be non-declining. Second, if the resilience of the ecosystem is protected, this will conserve what has been described as the potential biophysical productivity of the system.

Both concepts accordingly address the problem of productivity, which ultimately refers to the physical potential of the system in some state of nature. The difference between them lies, in part, in the difference in the perception of the system dynamics in each case. The cyclical dynamics of almost all terrestrial and many marine ecosystems, and the tendency for periodic destruction and renewal within the system, are reasons why the biologists focus on the potential of those systems. The economic models behind the key concepts of economic sustainability are not characterized by dynamics of this sort. In reality, economic systems behave much like terrestrial ecosystems. They are characterized by strongly cyclic dynamics which also involve creative destruction and renewal of assets, and this is recognized in the more recent literature on non-linear economic system dynamics (see, for a review, Rosser, 1991). Hence the notion of potential productivity, secured by conserving certain resilience properties of the system, turns out to be relevant to both concepts: environmental soundness and sustainable development alike can be conceptualized as the conservation of the resilience of the system concerned, i.e. its ability to respond creatively and positively to both stress and shock.

In Agenda 21 the broad focus is on the protection of a set of critical ecological functions via the incentives faced by people using the ecosystems which provide those functions – where incentives may take the form of prices or regulations. This is equivalent to the protection of the resilience of those systems. The main concern addressed in Agenda 21 is that current incentives do not safeguard those ecological functions. All resource management activities discussed include activities designed to get the structure of incentives right, and the emphasis on liberalization of markets is at least partly motivated by the same consideration. The main problems identified in Agenda 21 relate to conditions that inhibit the development of incentives to protect key ecological functions, including both market and government failures. Indeed, the discussion of environmentally sound technology is dominated by the question of technology transfer, which stems from the failure of markets for "best-practice" technologies.

Sustainable livelihoods and environmentally sound technology

Sustainable livelihood (SL) and environmentally sound technology (EST) may be thought of as applications of the general concepts of sustainable development and environmental soundness. As has already been remarked, Agenda 21 proceeds from the assumption that sustainability and soundness of the whole imply sustainability and soundness of the parts. This can be interpreted in one of two ways: either that each household, firm or community should itself be, in some sense, sustainable; or that each household, firm or community should behave in a way that is consistent with the sustainability of the wider system. These two interpretations must be considered separately.

Under the first interpretation, protection of the biosphere is taken to imply preservation of each of its component parts, and sustainability of the economy is taken to imply that the income and assets of each household or firm should be non-declining. This is too stringent a requirement to be useful. Indeed, conservation of the productive potential of environmental or economic systems is not generally compatible with conservation of the productive potential of each component part of the system. Particular communities which thrive at some points in the ecological cycle may crash at other points without prejudice to the resilience of the ecological system. Similarly, individual households and firms, even whole industries and the regional economies they support, may expand the capital they command at some points in the economic cycle and may contract it at others without prejudice to the resilience of the economic system. Indeed, both restructuring and market liberalization encourage such changes to take place. Preservation of the economic and the ecological status quo is not an option.

Under the second interpretation, the use of environmental resources by communities, households and firms should not prejudice the resilience of either the economy or the biosphere. This is a more consistent and more easily operationalizable interpretation. It has already been remarked that it is a sufficient condition for assuring both sustainability and environmental soundness. It is more restrictive than is needed, but is at least intuitive and it has rather natural policy implications. It is this interpretation which is discussed in what follows.

Sustainable livelihoods

The concept of sustainable livelihoods (SL) is introduced in Agenda 21 in the context of a programme to combat poverty. Although the programme's rationale derives from the link between the state of environmental resources and poverty, there is a sense in which the environment is incidental. The objectives of the programme are to provide everyone with "the opportunity to earn a sustainable livelihood" by addressing the causes of poverty, hunger, the inequitable distribution of income and low human resource development. The numerous target groups indicated in Agenda 21 as currently disadvantaged are: women and children; the urban unemployed and the urban poor; the rural poor including smallholders, pastoralists, artisans, fishing communities, landless people, indigenous communities and migrants; and refugees. The activities envisaged under the programme are similarly very wide-ranging and include the empowerment of communities and a variety of development and aid initiatives.

It is useful to separate these target groups into those who are, by definition, net consumers and those who are net producers. Many of those targeted in Agenda 21 do not and cannot invest a sufficient proportion of their income to protect the productive potential of the assets on which they (directly or indirectly) depend. Indeed, many survive solely on transfers. If the livelihood of such people is to be sustainable, then it must be secured by economic activities that are sustainable – i.e. activities that do not threaten the integrity of the environmental assets on which both donor and recipient depend. SL may thus be interpreted as the requirement that each community of resource users to which these target groups belong should behave in a way that is consistent with the sustainability of the wider asset base on which that community depends, and that the distribution of income within that community should be such that the needs of all its members are met. This is not a requirement as to the value of the assets commanded by each individual. It is a requirement that the productive potential of the assets on which the community depends – including both public and private assets – should be protected.

This has three important implications: (i) that individual decisions about the use of environmental resources should take full account of the future costs to society – the user costs – of the allocation of those resources; (ii) that the value of the asset base be conserved by an appropriate investment strategy; and (iii) that the distribution of income within the community should meet the needs of productive and non-productive members alike. Operationalization of the SL concept therefore requires that private decision-makers be confronted by the social cost of their use of environmental resources, that the value or productive potential of the total asset base be protected, and that the needs of those who are net consumers by reason of age or disability be secured through transfers.

Indeed, it is most useful to read Agenda 21 as a statement of intent about the broad changes that would be needed to make the communities to which the target groups belong both economically and environmentally sustainable. It is then possible to focus on the conditions for the sustainability of the livelihood of the community, namely, an appropriate microeconomic decision making environment, an appropriate macroeconomic balance between consumption and investment, and an appropriate distribution of income. The important point is that the livelihood of dependent members of the community should not be considered in isolation. It is possible to discuss the net effect of the consumption and investment decisions of one group given the consumption and investment decisions of the rest of the community, but this may not be very helpful, especially for policy: it could imply that the unsustainable consumption level of the poor should be reduced to a sustainable level without reference to the profligacy of the rich.

Environmentally sound technology

In Agenda 21 environmentally sound technologies (ESTs) are defined as those technologies which protect the environment by being less polluting, recycling more waste, and disposing of waste in a more sustainable manner than the technologies they replace. ESTs are total systems which include know-how, procedures, goods and services, and equipment and well as organizational and managerial procedures. They are, in addition, compatible with nationally determined socio-economic, cultural and environmental priorities. By this definition, ESTs are the set of all feasible technologies which are in some sense cleaner than existing technologies. They are, in other words, the set of "clean technologies", "cleaner technologies", "best practicable technologies", "low waste technologies" and "resource conserving technologies" referred to above. The EST programme includes promotion of access to and transfer of technology, improvement of the capacity to develop and manage technology, and the establishment of collaborative arrangements and partnerships (UNCED, 1993, pp. 252 ff.).

It has already been remarked that this combines environmental safety and the relative cleanliness of technology in a way that is unhelpful. If EST means cleaner technology, the condition is very easily satisfied: any technology which reduces environmental inputs, waste or emissions per unit of economic output will do. But this is a source of difficulty in practice. It gives no indication of the importance of the environmental impact of the technology, entailing both qualitative and quantitative problems. For example, nuclear fission is cleaner than coal-fired thermal power generation in respect of sulphur emissions, but not in respect of ionizing radiation. Should one rank them using the criterion of relative cleanliness? A 500 MWe coal-fired plant may be dirtier than a 1,000 MWe oil-fired plant in terms of emissions per unit of output, but will have a smaller total effect on the environment. Does it imply a more environmentally sound technology? Given the necessity for ESTs to be compatible with socio-economic, cultural and environmental priorities, the choice of technology involves very much more than its cleanliness relative to the existing technology. There are trade-offs between the depletion of environmental resources and the emission of environmental pollutants on the one hand, and a range of development objectives on the other. These trade-offs make it impossible to provide a simple ranking or classification of technologies based on relative cleanliness.

The element of environmental safety introduced in the preamble to Agenda 21 is a much better place to start, as has already been suggested. Pereira (1991) distinguishes between technologies which are environmentally sound, technologies which may not be environmentally sound but which are acceptable, and technologies which are intolerable or unacceptable. The last set of technologies are the only set which are environmentally unsound in the sense of being environmentally unsafe, and it is on these we need to focus. If EST is to be operationalized it is important to home in on those characteristics which may readily be tested against some criterion. In terms of the criterion of environmental safety discussed above, technology (or any other factor conditioning human production or consumption activities) may be said to be environmentally safe and sound if its use does not cause the ecological system in question to lose resilience. In what follows, this is the criterion that is used.

The impact of a technology is critically dependent both on the scale on which it is applied, and on the context. The parallel with preferences is instructive. Consumer preferences may bias demand for environmental resources in some direction, but whether a change in preferences has a significant effect on ecosystem resilience will depend on the level of consumption of environmental resources, and this will depend on income and the set of relative prices. There is scope for changing demand for environmental resources by changing preferences. The substitution towards consumer goods that are perceived to be "environmentally friendly" is evidence of this. But consumption of environmentally friendly consumer goods may be just as threatening to the resilience of the system as consumption of environmentally harmful goods if it occurs at high enough levels.

The safety of production technology, like the safety of consumer preferences, is scale dependent. The thresholds of ecosystem resilience consist of critical values for either biotic or abiotic components of the system. These would include, for example, critical population levels for particular species, critical levels of acidity or alkalinity, or critical densities for atmospheric pollutants. If a technology requires the extraction of some environmental resource or the emission of some pollutant for which there exist threshold values in the system concerned, its environmental soundness will depend on the level of extraction or emissions relative to those thresholds. It may be that what is environmentally unsafe in one ecosystem will be environmentally safe in another, because different thresholds apply. This is most easily illustrated by an example. Alauddin, Mujeri and Tisdell (1992) indicate that the adoption of new agricultural technologies in Bangladesh has increased productivity of selected crops, but at the cost of a management regime that includes much higher levels of pesticide, herbicide and fertilizer use, and much lower levels of crop diversity. The net effect is that the resilience of the agricultural system is substantially lowered through greater susceptibility to pest infestation and soil degradation. The loss of resilience shows up as an increasing risk that crops will fail if the system is perturbed, and this is critically dependent on the scale of agricultural activity relative to the carrying capacity of the environment. Markandya (1991) notes that in the agricultural sector this risk is primarily a function of population growth: the application of technologies involving the mining of environmental resources (including the assimilative capacity of the environment) that is safe at one level of population may be wholly unsafe at another.

To operationalize this concept requires the protection of ecosystem resilience, which, in turn, requires an appropriate set of incentives for the users of environmental resources. To ensure that the technology used is environmentally safe, given all the other factors affecting the economic decision involved, it is once again necessary that the decision-maker be confronted by the true cost of choosing each of the available technologies. Since the true cost of environmental resource use will depend on the demand for environmental resources relative to the system thresholds or carrying capacity, it follows that the appropriate incentives will be sensitive to this. Pereira (1991) argues that wherever a technology is "intolerable", the appropriate protection is provided by regulatory instruments which he distinguishes from economic instruments. Such regulatory instruments include those conventionally termed "command and control" measures. These impose a range of restrictions on the level of resource use or waste emissions, of which hunting and harvesting quotas, open and closed seasons, emission caps and safe minimum standards are all examples. What these physical restrictions mean in effect is that wherever technologies are intolerable, the cost to the individual of using such technologies should be "very high". That is, the penalties for exceeding critical ecological thresholds should be such that individual resource users will avoid doing so.[2] The problem with the present system of incentives in most low-income countries is not only that important ecological thresholds are unprotected. It is also that the private cost of technologies, whether they threaten thresholds or not, does not reflect their environmental costs. The private costs of older and dirtier technologies are usually less than those of newer and cleaner technologies.

In the literature on EST, this last issue has been discussed in the context of the transfer of technology. The problem has been the subject of numerous research programmes focusing on the effect of the system of property rights on the ability of users in low-income countries to acquire technologies involving lower social cost. From the perspective of the low-income countries, the difficulty is said to lie in the system of patents, which is argued to have restricted the availability of clean technology in two ways. First, it has allegedly enabled patent holders to extract monopoly profits, thereby inflating the cost of clean technologies. Second, it has discouraged patent holders from distributing clean technologies in those countries that offer weak protection for intellectual property rights. There is undoubtedly some justification for both claims, but it is more instructive to look at the demand side. Demand for patented technologies in the high-income countries is largely driven by environmental regulation, which has the effect of raising the equilibrium price in those countries with stringent environmental regulations. Hence, from the perspective of the suppliers of environmentally clean technologies, the solution to the problem of low demand in the low-income countries lies in the imposition of stronger environmental regulations in those countries – along with concessionary pricing (OECD, 1992).

The following section argues that environmental regulation and the use of safe minimum standards are indeed the most effective way of assuring the resilience of ecological systems. This confirms the conclusions reached by recent ILO and OECD studies (see Pereira, 1991; OECD, 1992). But it is worth repeating that whether a technology is sustainable or not depends on the demand for environmental resources under that technology relative to the carrying capacity of the environment. That is, it will depend on the use of environmental resources relative to carrying capacity. "Clean" technologies may be no more sustainable than "dirty" technologies at low levels of use.

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[2] Regulatory instruments are, in reality, economic in exactly the same way as are taxes, or user charges. The economic incentive in a regulation, or a standard of some kind, lies in the cost to the individual of breaching that regulation or exceeding that standard. The economic instrument is the penalty. Hence the only difference between "regulation" and "economic incentives" lies in the shape of the private cost function associated with each. In the case of regulations cost pattern will tend to be discontinuous at the maximum admissible use of the resource.

Operationalizing the concepts

Sustainable livelihoods

A considerable amount of work to operationalize the sustainability concepts has already been undertaken by the World Bank and other agencies. Three questions have been raised in the literature. First, since the driving forces behind environmental degradation are the factors that condition decisions on private resource use, what is the best way of addressing these factors? Second, since sustainability does imply some judgement about intergenerational equity, what is the best means of assuring such equity? Third, since sustainability implies the need to avoid crossing thresholds involving irreversible welfare loss, how should these thresholds be protected?

The initial approach by the international organizations to the operationalization of sustainability considered the problem in the context of project spending. The questions raised by UNCED are much wider than this, but the approach is instructive nevertheless. The starting point for work in this area was the observation that conventional cost-benefit analysis of projects involving significant environmental effects failed to test for sustainability for two reasons: the pervasiveness of externalities (including the existence of crowding effects) for which it was impossible to provide reasonable shadow prices; and the difficulty of dealing satisfactorily with the intergenerational equity issues.

The problem of externalities in projects has been addressed through the valuation of their non-marketed effects. This has relied on a variety of techniques, but principally on: (i) direct valuation of productivity changes, loss of earnings associated with environmental impacts, and expenditures to protect against environmental degradation; (ii) the use of surrogate markets to give proxies for environmental amenities; (iii) the inclusion of non-marketed environmental resources in functions explaining the production of marketed goods; and (iv) the use of direct estimates of willingness to pay or accept. All these methods have severe limitations in terms of their ability to provide realistic estimates of the present and future values of environmental effects of economic activity (Lutz and Munasinghe, 1993). But they do serve to highlight the options open to policy makers to influence private decisions. The cost-benefit framework provides a means of comparing alternative actions given the set of relative input and output prices, the rate at which future costs and benefits are discounted, and the set of constraints within which the action is undertaken. The valuation approach selects relative prices as the vehicle through which to influence the decision. But while intervention to align the private and social cost of resource use is undoubtedly an important component of any strategy for sustainability, it is not the only one. Nor is it the most effective means of protecting ecological thresholds.

There is general consensus in the literature that it is inappropriate to use the discount rate as the primary means of influencing future relative to present costs. Initially, it was thought that securing intergenerational equity required adjustment of the social rate of discount, since this is the measure of societal preference for consumption now relative to consumption in the future. However, the observation that adjustment of discount rates would have uncertain and potentially perverse effects discouraged this approach (Markandya and Pearce, 1988). The alternative proposed subsequently was a "sustainability constraint". This has two variants. The first is a restriction on the use of environmental resources to protect the stock of natural capital transferred to future generations to assure intertemporal equity in the distribution of income (Norgaard, 1991). This has been motivated by an interest in protecting essential natural assets for which there exist no close substitutes (the strong sustainability requirement) (Daly and Cobb, 1989) or about which there is considerable uncertainty (von Amsberg, 1993). The appropriate environmental price in a cost-benefit framework is the shadow price of the environmental constraint. The second variant is what amounts to a sustainability levy, or a compensation component invested over the lifetime of a project sufficient to yield an asset of equal value to the environmental resource used (von Amsberg, 1993). This satisfies the requirement for economic sustainability, that the value of the asset base is preserved, but it is blind to threshold effects and the non-substitutability of produced and natural capital.

This first variant of the sustainability constraint comes very close to assuring system resilience where there are important scale effects. It is argued that expansion in the demand for environmental resources, driven partly by population growth and partly by economic growth, has pushed many human activities up to and possibly beyond the carrying capacity of the natural systems being exploited (Daly, 1991). Carrying capacity may appear to be a rather static concept, and in this case – where it is argued that growth pushes society beyond carrying capacity – it does appear to be so. But it is recognized that carrying capacity may change as both technology and ecosystem functions change. In some cases, it is clear that technological change has increased the human carrying capacity of ecosystems, but in other cases it is equally clear that degradation of the system has resulted. These cases clarify the link between carrying capacity and thresholds of resilience, since exceeding the carrying capacity reduces the ability of the system to accommodate stress. By capping the level of demand for environmental resources, a sustainability constraint can be seen as a means of protecting against the costs of crossing an important threshold.

The operationalization of SL requires the development of a method for changing the cost-benefit analysis conducted not just by the major development agencies but by every single user of environmental resources. Rational individuals faced with prices that are less than the social opportunity cost of environmental resources will overuse those resources. This remains the case for prices in many agricultural markets. The divergence between private and social costs in this case is the result of incomplete marketing of outputs (many environmental externalities of agriculture are ignored); of the particular structure of property rights (there is often an implicit subsidy on agricultural land offered by traditional land tenure systems); of economic policies (agricultural subsidies are still extremely widespread); and of the international trading system (including agreements such as those reached under the GATT or the Lomé Convention). There is a case for reconsidering international agreements from an environmental perspective. The problem of implicit environmental subsidies, such as the provision of free access to scarce natural timber and water resources, should be on the agenda in the next round of the GATT (or WTO). But in the short and medium term, operationalizing the concept of sustainability of livelihoods will require domestic policy reform to remove many of the distortions to the private cost of environmental resources.

Price reform may also be one of the more effective means of dealing with the distortions to the private valuation of environmental resources due to poverty. It has long been observed that poverty amongst the users of natural resources has been a consequence of the control of agricultural prices and the manipulation of agricultural markets (Sen, 1981). However, price reform will not help those with access only to uneconomic holdings of land. Inequality in the distribution of both assets and income has tended to widen over time in many of the low-income countries, partly as a result of the erosion of traditional rights of access to the resource base. This is particularly a problem for female-headed households, which show the highest levels of relative deprivation (UNDP, 1990).

The problem of externalities can be dealt with in part by the assignment of property rights. There currently exists a very wide range of rights conferred by law or custom on the users of environmental resources. The incentive effects of these various rights are not very well understood, and a prerequisite to the operationalization of the sustainability of livelihoods is to establish what these incentive effects are. This is particularly important where environmental effects have a long gestation period (due to the nature of the biogeochemical cycles involved). While it is clear that open-access common property does not provide the right incentives, it is not at all clear that private rights in perpetuity are the most appropriate alternative.

Environmentally sound technology

Two key problems need to be addressed in operationalizing EST: the scale dependence and threshold effects; and the information, institutional, property right and related issues associated with technology transfer. To some extent EST is peripheral to the second set of considerations. The recent emphasis on intellectual property rights in technology and the issue of technology transfer are not driven by environmental concerns. It can be helpful to think of EST as environmentally appropriate technology. As the literature on appropriate technology makes clear, the optimal choice of technology for the production of any set of goods and services is a function of a wide range of factors, including the set of relative prices, the state of knowledge, output levels and so on. EST is any feasible and efficient technology which does not threaten the resilience of the ecosystems in which it is employed. In other words, it is any practicable and efficient technology which does not approach the thresholds of ecosystem resilience given the set of relative prices, state of knowledge, output levels and so on.

For the most part, the cost of technology is reflected in the cost of the capital in which it is embodied. So the pricing of assets at marginal social cost – where this includes the cost of future environmental external effects – should ensure the adoption of environmentally appropriate technology. For any given technology, environmental sustainability can then be guaranteed by the use of regulatory instruments restricting the extraction of environmental resources or the emission of environmental pollutants. What is important about such restrictions in this context is that they imply discontinuities in the private cost functions associated with the environmental resource or pollutant in question. For example, where firms are fined for catching fish above quota, the cost of the catch will be discontinuous at the catch limit.

The form taken by restrictions to protect ecological thresholds under any given technology will depend on the nature of the technology. Most ecological thresholds are conditional, in the sense that whether the emission of some pollutant at a particular level and under a particular technology does cause loss of resilience will depend both on natural conditions and on the other emissions under the same technology. Whether cadmium depositions on arable land are dangerous to human health, for example, depends critically on soil pH, since this affects its solubility and hence uptake by plants. Consequently, the level of depositions that is safe under some technology will depend on the impact of the same technology on soil pH.

Any technology which is economically feasible for levels of output less than the standard set to protect ecological thresholds (whether or not it is economically efficient at such levels of output) may be said to be environmentally sound, in the sense that its application will not threaten the resilience of the underlying ecological system. It should be noted, however, that no matter how "environmentally friendly" a technology may be by the criteria of Agenda 21, it will be unsustainable at some level of output, just as it will be economically infeasible at some set of relative prices. This again raises the important issue of scale. Assuring the environmental soundness of a technology means restricting its application to levels that are environmentally safe.

The set of restrictions to protect ecological thresholds at present is very wide. It includes harvesting and extraction quotas, together with open and closed seasons (in fisheries, hunting, gathering, some forestry); restrictions on the species to be harvested including the size or age of harvestable species (also in extractive industries and sometimes taking the form of equipment such as fish net size restrictions); emission caps or "bubbles" (in industrial activities generating liquid or gaseous wastes); and safe minimum standards (usually governing the composition of emissions and including the so-called critical loads). These correspond to a parallel set of economic instruments, the prices, that are discontinuous around the restriction. These include – on one side of the restriction – royalties and other user charges in extractive industries, effluent charges, environmental taxes and subsidies, deposit refund systems, and environmental performance bonds. On the other side of the restriction, they include fines, surrendered deposits and bonds, and other penalties.

Concluding remarks

Recent work on the concepts of sustainability and environmental soundness highlights two general requirements. The first is a requirement that essential ecological services be protected by restricting the use of environmental resources to "safe" levels. This derives from the need to protect essential natural assets for which there exist no close substitutes (the strong sustainability requirement). In this article it has been argued that this requirement implies mechanisms to assure the resilience of the ecological systems concerned with respect to the levels of stress and/or shocks to which they are subjected by the economic process. The second is a requirement that those who exploit environmental assets should be confronted by the full future cost and user cost of their actions, and that the resources generated should be invested so as to conserve the value of the total stock of natural and produced assets.

In considering how these two requirements apply to sustainable livelihoods and environmentally sound technology, the first problem to be addressed lies in the assumption made in Agenda 21 that the sustainability of development is divisible, in the sense that sustainability of the whole implies sustainability of the parts. If sustainability requires only that the value of the aggregate capital stock be maintained over time, is it meaningful to talk of the sustainability of the actions of individual agents? It has been argued here that it is not reasonable to expect the individual behaviour of refugees, victims of famine, the disabled, children or the old to be sustainable. Nor is it reasonable to expect that all environmental resources will be used in a sustainable way. So in what sense is sustainability divisible? It is certainly possible to characterize the sustainability of any one of the factors conditioning economic decisions given the remaining factors. It is, for example, possible to characterize the sustainability of preferences or property rights, given relative prices, incomes and so on. It has already been remarked that it is also possible (but unhelpful) to characterize the sustainability of the consumption and investment decisions of one group of agents, given the consumption and investment decisions of all other groups of agents. Getting the economic environment right means identifying the most cost-effective policy adjustments, which requires a general rather than a partial view of the problem.

The development of a policy for the promotion of sustainable livelihoods requires three things: an appropriate decision-making environment, an appropriate balance between investment and consumption expenditure, and an appropriate distribution of income. To ensure that individual decisions on resource use are consistent with the sustainability of the assets available to the community it is necessary to intervene in the private decision-making process. It follows that all of those factors which enter the decision process (and which may be influenced by policy) are natural targets for intervention. Aside from those economic instruments which can be used to alter the private costs of resource use (microeconomic and macroeconomic policy), the targets include the state of knowledge (information policy), cultural and social values and the preferences to which they are related (education policy), security of tenure of land and other environmental resources, market and institutional conditions (policy on property rights and competition), and so on. The effectiveness of a policy designed to address one parameter in the decision-making process will be conditioned by the remaining parameters, and so by the policies addressing those parameters. Disseminating information on the user cost of ground water depletion, for example, will be ineffective if the resource is subject to open-access common property rights. Similarly, imposing water charges in irrigated agriculture may be ineffective if there is a countervailing subsidy on complementary agricultural inputs. It follows that identifying the most cost-effective way of changing the decision-making environment requires appraisal of the impact of all policies bearing on that environment.

Ensuring that the productive potential of the community asset base is preserved is also difficult to translate into effective policy. At the project level the problem is easy to overcome. Von Amsberg (1993) argues that this implies a sustainability levy or a compensation component invested over the lifetime of a project which is sufficient to yield an asset of equal value to the environmental resources used. However, where the problem is the sustainability of the private behaviour of members of a community, the solution is less obvious. An investment tax or charge for the environmental resources used by economic agents might generate adequate funds to undertake compensating investment, but it is not clear how such investment should be undertaken. Private investment incentives are one option, but private investment naturally favours private goods and eschews public goods. Many of the environmental resources being lost through private economic activity constitute essential public goods. The private response tends to be an increase in private defensive expenditures against the loss of public environmental goods, which both biases conventional measures of income and investment (El Serafy, 1989) and fails to address the problem of sustainability. An appropriate investment strategy would include public cover for the depreciation of environmental public goods, or protection of essential ecological services. In other words, while charges for environmental public goods may provide the correct signal to the immediate user, if the revenues generated are inappropriately invested the overall strategy will be unsustainable.

From an operational perspective, environmentally sound technology should be regarded as any technology which does not threaten essential ecological services at current levels of resource use, and given current methods and procedures of application. A definition such as "cleaner" or "less wasteful" technology is not operational, or at least not in a satisfactory sense. The key feature of EST is that it is environmentally safe at some scale of use – i.e. that it does not threaten thresholds of ecological resilience at that scale of use. The appropriate policy therefore comprises incentives to ensure that the scale of use does not exceed the safe limit. The nature of the limit and the penalties for exceeding it will be case specific. Carbon monoxide emissions, for example, are handled through restrictions on vehicle emissions. Fisheries are protected through a combination of quotas and equipment restrictions. Such restrictions have been described here in terms of a set of fixed constraints on decisions. What is important is that such constraints should be sensitive to changes in the level of resource use under the technology as well as changes in conditions of application.

Both SL and EST have major implications for national policy, which have been briefly discussed in this article. However, they also have implications for international policy. Although both concepts are intended to apply at a disaggregated level, many of the main threats to environmental sustainability come from the degradation of global environmental public goods. The appropriate decision-making environment in such cases is the global environment, and the loci of compensating investment for any given project may be spread very widely. Since the soundness of any technology will be a function of local conditions, this does not mean that there should be uniform restrictions to protect critical thresholds. But it does mean that there should be general dissemination of information about the conditions in which technologies may threaten thresholds. This is an aspect of the technology transfer problem that has not been explored in the literature, but it is necessary to do so if the users of technology are to evaluate its environmental costs.

The point has been made that income and wealth distribution is important for two different reasons. Not only does the sustainability of the livelihoods of dependent members of the community require an appropriate distribution. The decisions of productive economic agents are also influenced by the distribution of income and assets. The pattern of payoffs to the adoption of different technologies in different countries will depend on the distribution of income and assets between those countries. This is clear in the case of assets. The payoff from the adoption of environmentally sound relative to environmentally unsound agricultural technologies in each of two countries, for example, may depend on the infrastructure or support services available in each. That is, the payoff to a country from adopting an environmentally sound technology may be low just because it does not have the assets that would enable it to make best use of that technology. This point is partially recognized in the OECD (1992) recommendation for technology transfer to be aided by either subsidizing the technology or assuring the finance needed to acquire it. However, the payoff will also depend on income. It has long been recognized that newer agricultural technologies may not be adopted in some countries because farmers cannot afford to accept the attendant risks (Lipton, 1987). In this case, the appropriate transfer may take the form of an insurance policy against such risks. The general point is that neither SL nor EST can be treated at the level of individual agents, firms, household, or occupational groups. Achieving sustainability and soundness alike requires that the overall decision-making environment be sustainable and that the broader asset base be protected. While it may be sensible to evaluate the sustainability of autarkic communities in isolation, the ever-greater integration of the world economy makes such an approach increasingly inappropriate.

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