World Development Vol. 6 pp. 937–965
0305–750X/78/0701–0937 $02.00/0

Growth, Technology and the Environment in Less Developed Countries: A Survey

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Summary. – This survey attempts to investigate the interrelationships between growth, technology and the environmental dimension of economic development. It is shown that the nature of these interactions is highly complex and environmental problems cannot be ascribed to any single cause, such as 'careless technology', the population explosion or economic growth. The nature of environmental problems in developing countries differs in both kind and degree from that in the developed world. Growth and preservation of the environment need not be mutually exclusive. Much depends on the composition of growth as shown by the Chinese experience which is also discussed in the paper.

INTRODUCTION

This survey contains a discussion of the relationship of growth and technology to each other and to the environment in the context of the countries of the Third World. However, the paper incorporates a fairly lengthy discussion of the causal relationships between growth, technology and the environment in industrialized countries, as a necessary precursor of any attempts to deal with the nature and causes of LDC problems, in view of the essential way in which these problems are determined by the very existence of the developed world.

In the developed country context increasing concern over environmental deterioration has led to a vast literature, spanning a number of disciplines, attempting to diagnose the causes of the environmental crisis. In the first section of the paper an attempt is made to identify the major approaches involved, each of which provides a framework for the analysis of the role played by growth and technology in the environmental context.

The literature on growth and technology in LDCs is, of course, enormous but very much less has been written about the effects of either on the environment. Section 2, within the framework of a comparison with developed countries, describes the nature and causes of environmental disruption in the Third World. Aspects of international environmental interdependence are discussed in Section 3 prior to the question of policy options for LDCs. The final section describes the differing treatment of environmental problems in socialist countries.

1. GENERAL APPROACHES

(a) *Man and the environment – the laws of physics*

It is convenient to begin at the most general and non-controversial level of the physical laws governing the relationship between economic activity and the environment. A taxonomy of approaches may then be constructed within this general framework.

Economic activity is connected to the environment on both the input and output sides and the physical relation between the two is expressed (in a closed economic system without stock accumulation) by the law of the conservation of matter which states that the amount of residuals discharged into the environment approximates the weight of inputs entering the economic system (Freeman,

*I am indebted to Keith Griffin, Frances Stewart and B. K. Roy for comments on an earlier draft.

**This article is part of a series of survey articles financed by the Ford Foundation and commissioned by the editors of *World Development*.

Table 1.

Disposed to/ weight of inputs	Air	Water	Land	Further production	Total residuals
X1	–	–	–	–	X1
X2	–	–	–	–	X2
X3	–	–	–	–	X3
X4	–	–	–	–	X4
Xn	–	–	–	–	Xn

Haveman and Kneese, 1973; Ayres and Kneese, 1969). This is merely another way of expressing the fact that matter cannot be destroyed although it may be transformed. The residuals arising from both the transformation of inputs and the final goods themselves need either to be discharged in the form of gases, dry and wet solids or re-used in the production process. This fundamental relationship between inputs and the residuals discharged to the environment may be schematized in matrix form as in Table 1.

Clearly, for any given weight of energy and material inputs the form of the residuals discharge may alter though the total must remain the same. Thus 'technological means for processing or purifying one or another type of waste discharge do not destroy the residuals but only alter their form' (Ayres and Kneese, 1969, p. 283).

Approaching the relationship between economic activity and the environment in this way indicates that no *necessary* conflict inheres. Indeed economic activity need be given no environmental dimension if either (a) inputs were perfectly convertible into outputs and the latter were totally re-used as inputs, i.e. the distinction between inputs and outputs disappears so that there is neither a problem of scarce resource depletion nor of residuals disposal, or (b) if the inputs provided by the environment as well as its assimilative capacity could practically be regarded as infinite. In the absence of these conditions where inputs and outputs are distinct and/or conditions of finitude prevail with respect to inputs and assimilative capacity the extent to which economic activity impinges on the scarcity of inputs and absorptive capacity of the environment depends upon the following interdependent factors:

(a) the limits of the absorptive capacity of the environment;[1]
(b) the usage and rate of depletion of non-renewable inputs;
(c) the convertibility of inputs into outputs, i.e. the extent of waste involved in technological processes of conversion;
(d) the durability of final goods and hence the composition of outputs of differing durabilities;
(e) the rate of population growth;
(f) the rate of economic growth; and
(g) the nature of institutions and legal systems.

That economic activity has impinged on the resources of the environment to an extent that is now serious scarcely needs documentation (Ward and Dubos, 1972; Commoner 1971), and it appears that the problem of residuals discharge and environmental degradation is somewhat less tractable than the exhaustion of non-renewable resources (Boulding, 1966, Daly 1973a).

The main aim of the first part of the paper will be to illuminate the interdependencies between the factors a–g which are many and complex. Most will emerge from a consideration of the major approaches.

(b) *The welfare economics approach*

The environmental problem is concerned on the one hand with the rapidity of the depletion of non-renewable resources and on the output side with the limited capacity of the environment to assimilate the residuals resulting from processes of production and consumption. The bulk of the literature analyses these two problems within the framework of Paretian welfare theory. Although the input and output dimensions are unlikely to be independent of each other, the presentation is simplified by dealing with the welfare theoretical approach to each in turn beginning with the question of pollution.

(i) *Pollution.*

In broad terms environmental pollution is viewed as 'an economic problem, which must be understood in economic terms' (Ruff, 1972, p. 3). The economic terms are the familiar ones of externalities and resource misallocation –

the problem being due to the public goods nature of the attributes of the environment such as clean air and oceans which make them unsuitable for private ownership and hence for pricing which reveals their scarcity. The result is a misallocation of resources wherein the competitive output of polluting products exceeds that which would result from the shadow pricing of the scarce resources of the environment (Dorfman and Dorfman, 1972; Beckerman, 1974). In game-theoretic terms the outcome is caused by the operation of 'the isolation paradox' whereby a socially irrational outcome is caused by the sum of uncoordinated individual actions, none of which may be irrational within the narrowness of the individual frame of reference.[2]

Conceived as a static resource allocative problem the welfare economic approach stresses that pollution is a question of market failure quite distinct from that of growth which concerns the allocation between consumption and investment. Thus 'the fact that resources are misallocated at any moment of time on account of failure to correct for such externalities does not necessarily mean that the growth rate is wrong' (Beckerman, 1974, p. 20).

The usefulness of this conception of the pollution problem may thus be seen to turn essentially on:

(a) the extent to which the environment can be treated as an externality on the same footing as those conventionally dealt with by welfare economics, viz. those arising between industries, firms and people and,
(b) the extent to which growth and the environment may be conceptually separated in the manner postulated above.

The extension of the externalities concept to deal with the problem of pollution has been questioned for a variety of reasons.

A number of writers (Kapp, 1974; Sachs, 1971a,b) have criticized the excessive reductionism of this method; its reduction of the problem to a purely economic dimension and its implicit premise that the effect of man's impairment of the environment can be understood in terms of the isolated effects[3] (and dealt with in an *ad hoc* manner). It is stressed that the environment is a complex system and that the total effect of discharges to it in consequence frequently amounts to something very different from the sum of the component effects.[4] Most importantly perhaps, the individual components may interact with one another in a cumulative and biologically complex fashion (Kapp, 1974; Ophuls, 1977). Such effects would not be captured by the reductionist methodology of the welfare economics approach. It is not merely that the scope of the interdependencies is too pervasive to permit a partial equilibrium type of approach (premised on minor departures from Pareto optimality)[5] but also that these relationships are qualitatively different from those which could be dealt with even in a Walras–Cassel general equilibrium framework (Kapp, 1974). The necessity of an interdisciplinary approach arises from the importance and non-linearity of the relationships between the variables of differing disciplines (Streeten, 1972).

Mishan links the nature of environmental externalities to the importance of the legal framework and is severely critical of the narrow frame of reference of the welfare economic approach (Mishan, 1969, 1971, 1975).

As compared with the spillovers traditionally dealt with in the Paretian economic paradigm those related to the environment differ, according to Mishan in the following respects:

(a) the impact is on the public at large;
(b) this impact can be substantial;
(c) transactions costs are accordingly very high.

Given these conditions the legal treatment of spillovers can affect not only the allocative decision itself but also the distribution of welfare and environmental impact. This conclusion follows principally from the fact that where the welfare impact is substantial there is likely to be a considerable asymmetrical relationship between the sum an individual is prepared to pay for something valued and the amount required as compensation for parting with it. Even in the absence of transaction costs it is plain that it may make a difference to the outcome according to whether the law is 'spillover-tolerant' or 'spillover-repressive' (i.e. requiring full compensation of all affected). As Mishan shows, the argument can be applied both to indivisible arrangements (such as whether to build an airport or not) as well as to those which are divisible (such as the number of permissible Concorde flights per annum) (Mishan, 1971).

Quite apart from the differing outcomes under different states of the law, the output under the spillover-tolerant case may be suboptimal in the Paretian sense.[6] Where large numbers are the victim of the spillover, the transaction costs (interpreted broadly to mean both time and money costs) for any one individual in gathering effective support will be considerable. Even if this can be overcome, the endeavour will also be beset by the so-called 'free-rider' problem in terms of which each victim will hope to avoid involvement (for reasons both temporal and financial) in the hope that others will not. The difficulty is analogous to that of the rationality of political inaction in a large democracy. For each individual the costs of becoming informed of the issues at stake as well as voting on them are very likely to exceed the benefits perceived in terms of the probability of his own action influencing the outcome.[7] It is thus argued in the context of a spillover-tolerant legal framework[8] that there is a very marked conservative bias at work defending a status quo which becomes increasingly intolerable. To quote Mishan, 'In sum, under the existing law, a proliferation of adverse spillover effects continues to take refuge behind the barrier of decision costs' (Mishan, 1969, p. 42).

The effects of the law regarding property rights and transaction costs are not merely confined to static resource misallocation but intrude on the nature of the growth process via the design of new products and techniques. It has been argued that the influence of the legal framework is under-estimated in shaping scientific and technological development (Tribe, 1971). Yet, 'it is the law in its commonest manifestations which, however inadvertently, supplies much of the context within which research and development are encouraged, permitted or inhibited. And it is the law which forms a large part of the framework through which the fruits of such scientific and technical endeavours are disseminated or suppressed and in terms of which the costs and benefits of their effects are distributed' (Tribe, 1971, p. 243). In particular under spillover-tolerant law there is no incentive for firms (save for altruism or goodwill) to develop products or techniques which are conducive to the preservation of the environment (Mishan, 1971).

In considering the relationship between growth and discharges to the environment and in particular the welfare economic approach to the question it is worth noting at the outset that in principle growth need not lead to environmental degradation even with a limited assimilative capacity of the environment and in a system totally unfettered by controls on residuals discharges. Firstly, growth from a low initial level of development may lead to a discharge of waste which can be accommodated by the environment, i.e. there may be an environmental impact without deterioration.[9] Secondly, growth may be accompanied by a more than proportionate increase in the technological efficiency of input conversion and output durability, in which case the amount of residuals would decline with increased production and consumption.[10] The same result is also possible if the growth in output were accompanied by a change in its composition in favour of goods (and services) which are not associated with a high relative waste discharge. None of these conditions however, appear to have been fulfilled, at least in developed economies where the threshold of environmental capacity to cope with residuals has virtually been exceeded in many important areas. In Boulding's gloomy words, 'Los Angeles has run out of air, Lake Erie has become a cesspool, the oceans are getting full of lead and DDT and the atmosphere may become man's major problem in another generation, at the rate at which we are filling it up with gunk' (Boulding, 1966, p. 12). On the technological side there is ample evidence that in the main (and particularly in the case of energy conversion) technological developments have not increased the convertibility of inputs in the sense of waste reduction (Cook, 1971). Equally, products may have tended on balance to become less rather than more durable, and the composition of output has changed in the direction of more pollution-intensive products.[11]

That growth and pollution have been associated in the past does not *de facto* invalidate the welfare economic conception of pollution as a problem of static externalities and the corollary view that the problem can be divorced from the dynamics of growth. The relevant question is whether the links between growth and pollution would persist if the scarce environmental attributes could notionally be assigned prices which reflected their growing scarcity.

There are a number of reasons why even optimal static resource allocation based on true scarcity prices would not permit growth to be dissociated from pollution. Firstly, even if developments in both products and processes were to take place in response to the pricing of the hitherto free resources so as to reduce the ratio of residuals discharge to output, any rate of change less than the growth of output would mean an increased weight of residuals and environmental impact. In other words, an absolute increase in residuals discharged will occur so long as output increases more than proportionately to the fall in the residuals–output ratio.[12]

Secondly, it is unlikely that 'getting prices right' would significantly alter the nature of technological developments from the point of view of a reduction in unit pollution. There is considerable evidence that technological choice is more a function of scale and the dictates of competition than prices.[13] The welfare economics approach fails to consider the *nature* of the growth process as it is conditioned by the dynamics of product and process developments in the context of advanced capitalism.[14]

(ii) *Depletion of non-renewable resources*

In contrast to resources such as clean air and water, inputs *from* the environment in the form of non-renewable resources are by and large divisible and subject to private ownership in free-market economies. Depletion of the environment in this sense thus coincides to some extent with the diminution of private wealth (Daly, 1973a). Although, as noted below, the rate of depletion may nevertheless be sub-optimal when the interests of future generations are invoked, this differs from the pollution case where there is no private ownership of environmental resources and the outcome may be deemed irrational even when judged solely in terms of the interests of the current generation. The externalities that give rise to the depletion problem thus fall within the category of partial market failure rather than complete breakdown of the market mechanism.

The inter-temporal failings of the market have largely been considered in the context of optimal savings and growth (Marglin, 1963; Baumol, 1968). It has been shown that inter-temporal externalities are such that the market tends to undervalue the future and hence provides insufficient investment. To the extent that faster growth (with other things equal) leads to more rapid depletion of non-renewable resources, undervaluation of the future acts to preserve such resources. On the other hand, this undervaluation has the result that prices of non-renewable resources reflect only scarcities in relation to the time horizon of the current generation. This effect operates thus in the opposite direction of encouraging a more profligate use of the resources than would be the case if a longer view were adopted. One alternative to the operation of the uncontrolled market outcome is some sort of political process which gives expression to the interests of future generations. Solow, however, doubts that the political process will in fact have a greater orientation towards the future than an unfettered market system. The reason he gives is that the time horizon of public decision-makers is determined by the need to win votes for elections which are seldom very far apart. Thus 'transferring a given individual from the industrial to the government bureaucracy does not transform him into a guardian of the far future's interests' (Solow, 1974, p. 12). Moreover, even if all decisions of importance to future generations could in principle be subject to some aggregation of individual choices, the problems in the construction of such a 'social welfare function' are only too familiar (Arrow, 1963).

The market may, of course, be controlled either in terms of prices or quantities. If it is believed that adjustment of prices may be unreliable, greater control over depletion could be exercised on the quantity side by the use of depletion quotas in so far as the government owns the scarce resources (Daly, 1973b).

Finally, Kneese notes that the environmental problems of depletion and pollution may not be independent of each other, since the absence of controls on discharges to the environment will have a feedback effect on the rate at which depletion takes place. In particular the absence of incentives to recycle, to increase the durability of products, and to adapt technology will hasten the speed at which natural resources are depleted. The converse, of course, applies where such incentives are present (Kneese, 1970).

(c) *The technological approach*

The leading exponent of this approach is Commoner who, in his quest for the determinants of the environmental crisis in the USA, begins by noting that pollution problems have greatly intensified since World War II (Commoner, 1971). He rightly rejects the view that 'any increase in economic activity automatically means more pollution' and points out that 'what happens to the environment depends on *how* the growth is achieved' (Commoner, 1971, p. 141). Growth in the USA over the 25-year period subsequent to World War II has, as he shows, been accompanied by rather drastic changes in the nature of commodities produced. Thus, for example, high powered automobiles have replaced low powered engines, detergents have replaced soap, returnable bottles have been displaced by non-returnable ones. One could go on but Commoner's thesis is that these changes in the characteristics of products serving the same broad needs have in effect caused the environmental crisis in the USA.[15]

The arguments adduced by Commoner in support of this view seem to be:

(a) that the production of the new commodities involves a greater waste discharge;
(b) that the nature of the waste flows are such that they are less easily (if at all) assimilable by the environment.

Before considering these points it is appropriate here to deal with another argument which may support Commoner's general thesis and which also fits in well with the earlier discussion in terms of the sources of residuals discharges. The question is whether products have over the period considered by Commoner become more or less durable.[16]

There has been no study devoted to examining the question of durability at the aggregated level. One can only think of a few isolated examples of the side of reduced durability such as disposable items of various kinds, the proliferation of which has led to the term 'throw-away societies' (Barnet and Müller, 1974, p. 364). On the side of greater durability Boulding mentions neolite soles for footwear, nylon socks, and wash and wear shirts (Boulding, 1966, p. 13). Clearly no overall appraisal is yet empirically possible.

Producers as a whole have no interest in encouraging longevity of products. In the context of product differentiation under oligopolistic competition the point has been made that 'developing and marketing products which put a premium on durability and long service life is counter-productive from the point of view of the individual oligopolist' (England and Bluestone, 1971, p. 41). Baran and Sweezy distinguish between the rate of wearing out and the rate of discarding though they are inextricably linked in practice. Thus frequent style changes necessitated by the competitive struggle increase the rate of discarding while built-in obsolescence (due to the link of product design to sales rather than product function) increases the rate of wearing out (Baran and Sweezy, 1966, pp. 134–153). There may thus be a theoretical presupposition in favour of reduced durability over the period.

Commoner's argument that the changed nature of products is largely responsible for the environmental crisis in the USA draws firstly on the hypothesis that the altered products involve greater waste discharge in their production than did their predecessors. He demonstrates for a number of products the much greater energy requirements per unit of the new product than per unit of the old.[17] It has also been found for the USA that the ratio of energy consumption to GNP has risen. This is attributed to the twin facts that electric air-conditioning has grown fastest of end-use consumption and that there has been a lack of advance in generating efficiency in energy conversion (Cook, 1971). Commoner's demonstration of the increased energy requirements of the new goods as contrasted with the old also shows (with equal efficiencies in conversion) that the pollution (from this cause) of the new goods exceeds that resulting from the old. It does not however show that total pollution is greater to that extent. This depends on the differential non-energy inputs of the new and old goods and the differential efficiencies in their utilization. To the extent that the new goods have substituted energy resources for other inputs the increased pollution associated with these goods will be somewhat less than that suggested by concentrating on the respective energy requirements. Commoner recognizes the crudeness of his computations and hopes that before long ecological analyses of all major aspects of the 'production, use and disposition of goods will be possible' (Commoner, 1971, p. 175).

The second hypothesis invoked by Commoner is that the waste flows associated with the new commodities are less easily assimilable by the environment than those emanating from the displaced goods. This is an interesting and important argument. It results from the fact that the new products tend to be more intensive in man-made as opposed to natural compounds and the alienation of the synthetic compounds from the environment prevents their assimilation. Thus to take one of Commoner's examples, soap made from a natural compound, fat, does not pose serious environmental problems when discharged, since the natural fat is destroyed by bacterial enzymes. Detergents however, have deleterious environmental effects when discharged since the compounds are synthetic rather than natural. Even the new 'biodegradable' varieties produce toxicity which is likely to kill fish although without the objectionable foam associated with the initial products (Commoner, 1971, pp. 155–156). A similar argument applies in the case of synthetic textiles, plastics and pesticides.[18]

These two features of the new processes of production (energy and synthetic intensiveness) account for much of the increase in pollution since 1946 according to Commoner. The precise quantification he produces will be examined in the following section along with the other estimates that have been produced for separating the relative influences of the major determinants of pollution.

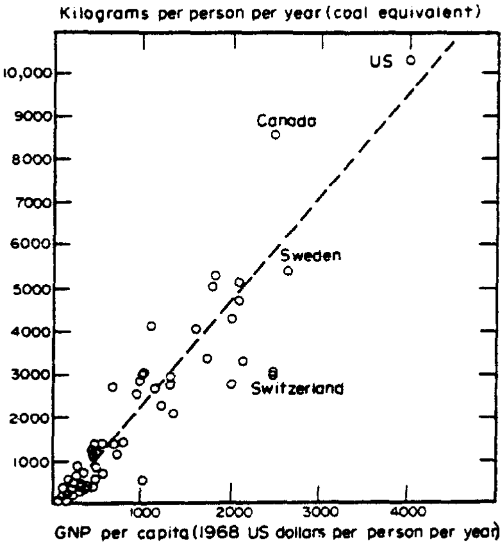
Commoner attempts to probe beyond the

ecologically damaging character of the changed technologies and finds part of the problem to lie in a reductionist orientation both in the scientific method of investigating a system in terms of its component parts and in the nature of the technology itself (Commoner, 1971, Chaper 9; 1972, pp. xxiv-xxv). Thus, 'new technologies are designed, not to fit into the environment as a whole, but only to enhance a single desired effect' (Commoner, 1972, p.xxv). There are, however, a number of important interrelations between these forms of reductionism. Firstly, even if a systems approach to understanding the environment were taken, this need not of itself change the nature of technology, since depending on the institutional setting in which the technology is used, even full knowledge of its interaction with the environment may not preclude its adoption and use.[19] Secondly, an institutional/legal setting which embraced the cost of environmental degradation may have the feedback effect of generating a more holistic method of appraising the environment among the scientific community. Commoner's treatment of the institutional and legal aspects of technological change is scanty. He confines his attention to showing the (rather obvious) link between profitability, technology and pollution in a free-enterprise economy demonstrating (not unexpectedly) that the new and polluting technologies have invariably led to increased profitability.

The technological approach to the environment emphasizes the link between the nature of the technological change that has taken place and its environmental implications. The demonstration that growth has taken this particular form of product differentiation with ecologically dangerous technologies shows clearly that 'it is not economic growth *per se* that is causing the growth in pollution, but the form that economic growth has taken' (Freeman, Haveman and Kneese, 1973, p. 32). Growth is often viewed as a mere quantitative expansion of existing goods and services which can somehow be divorced from technological change.[20] But growth has a qualitative dimension which involves not only the introduction of entirely new commodities,[21] but subtle changes in the form of existing products. It is the dynamic links between these changes and changes in technology, absent in the technological approach, which need to be considered in relating growth to the environmentally pernicious technological changes that have taken place. It is not sufficient to point out, as does Commoner, that the new technologies evolve in response to the need for increased profitability. This provides no reason for any systematic directional change in technologies.[22]

The Galbraithian argument that production begets wants rather than vice-versa becomes in a dynamic context the notion that as societies grow richer, more and more output requires the creation of ever new wants.[23] Over time such wants require increasingly sophisticated commodities for their satisfaction. This is recognized by Rosenberg, who after criticizing the conventional text-book assumptions of autonomous wants and consumer sovereignty states that 'For purposes of economic growth this assumption is seriously deficient, since a major component of the growth process is a radical transformation of attitudes toward consumption and saving and toward work and leisure. The changing structure of consumer wants and preferences, in other words, is itself a strategic variable in the growth process, as the classical economists recognized' (Rosenberg, 1976, p. 104). Occurring concomitantly with the rise in incomes and changed wants are changes in techniques to meet the desired product characteristics.[24] The rapid alteration in wants and products would frequently appear to demand new materials (for example synthetics) which may also tend to depart increasingly from the initial use of natural substances in the productive process. At the same time the rises in income and expanded markets make larger scale plants and capital-intensive methods increasingly profitable.[25] The rise in capital intensity of production will mean an increased derived demand for energy to power the machinery – a factor which probably accounts for the association between new products and energy requirements in America found by Commoner. Cross-sectionally the figure below shows the relationship between output *per capita* and *per capita* energy consumption, and in demonstrating the disproportionate amount consumed by the richest countries is also supportive of the above argument.

The outcome is what has been termed a 'bulldozer technology' which is heavily dependent on fossil fuels, lacks integration with natural processes, and which is characterized by a dominating scale of operations, and a narrow concept of efficiency (Ophuls, 1977, p. 116). Enlarged in the manner described above the technological approach illuminates much that is important in the network of interdependencies that comprise the environmental crisis.



Source: P. Milling, 'Technology in global perspective', in G. J. Stöber and D. Schumacher (eds.), *Technology Assessment and Quality of Life* (Elsevier, 1973), p. 112.

(d) *Technology, population and affluence – a problem of inseparable causality?*

The implication of Commoner's technological approach is that 'most of the sharp increase in pollution levels is due not so much to population or affluence as to change in productive technology' (Commoner, 1971, p. 177).

The basis of this assertion is a demonstration that the increases in the various pollutants over the period can be attributed to the separate influences of rising incomes, technological changes and population growth. Commoner's equation linking pollution to these three factors can be stated algebraically as:

$$E = Pcp \qquad (1)$$

where E refers to total discharges into the environment, P to population, c to the amount of a given economic good *per capita* and p to discharge per unit economic good. Since P, c and p have all changed since 1946, Commoner believes that, 'By comparing these changes with the concurrent increase in total pollutant output, it is possible to assign to each of the three factors the fraction of the over-all increase in pollutant output for which it is responsible' (Commoner, 1971, p. 176). For a number of commodities (particularly those with marked technological changes) he finds that the technology factor accounts for 80–85% of the incremental output of pollution.

Other attempts to attribute separate quantitative influence to these variables, however, yield conflicting evidence. Freeman, Haveman and Kneese, for example, argue that the major influence is rising income and disparage the role of population growth: 'it is not so much the size of the population or its growth as it is what the population is doing – producing and consuming – that is giving rise to our pollution problem' (Freeman, Haveman and Kneese, 1973, p. 32). They cite a study showing that 90% of the increase in electric power generation in the USA over the last 30 years has been caused by higher *per capita* consumption and the remainder by population growth (Freeman, Haveman and Kneese, 1973, p. 152).

Equally, proponents of the importance of population growth as a major factor are able to adduce evidence that since 1946 not only have neither technological change nor rising affluence been consistently dominant but population growth has had a numerically substantial effect if not a dominant one (Holdren, 1975).

Much of the urge for quantification of this kind appears to be born of political necessity. As Brown points out, the issue is of some importance in the rich and poor country context in so far as politicians in the former point to population growth in the poor countries as a major drain on the resources of the environment, while the Third World can draw attention to the global environmental consequences of ever-rising affluence (Brown, 1975, p. 162).

Some of the above evidence may be reconcilable in terms of differences in products covered, information on changes in pollutants emitted by new technologies, etc. but the effort hardly seems worthwhile in view of the logical and other weaknesses inherent in the simple reductionist arithmetic employed.

In the first place it is logically incorrect to calculate the change in total pollution as the product of changes in the three factors mentioned above and it is hence impossible to attribute the overall change to the separate influence of these factors.[26] Even if a reasonable approximation were obtainable in this manner, interdependencies between the three factors would negate the possibility of attribution of separate influences.

Thus the discussion above showed the close relationship between changes in technology and incomes. Technology is also influenced by and influences the growth in manpower while the association between rates of population growth and standards of living is well-known. This degree of interdependence[27] gives rise technically to the problem of multicollinearity which makes impossible any precise estimation of the separate influences exerted by the respective variables. Put another way, it is invalid to construct a counterfactual experiment such as 'pollution would have increased by x% if incomes had remained constant and only technologies and population had changed'.[28]

While both these reasons deny the possibility of precise attribution, they should not be confused with the question of the arithmetic accuracy of equation (1) above. Interdependencies *per se* do not invalidate the formulation, since a change in (say) emissions per vehicle-mile cause by rising *per capita* incomes will be reflected in the technological component of the equation. On the other hand, interactions between the residuals discharges of individual processes may produce a total effect greater than the sum of the individual parts so that the equation is not amenable to aggregation.

At the theoretical level, there may be similarities and differences in the implications for the environment of a rise in *per capita* income (with population given) as opposed to an increase in population (with *per capita* income given). Both ultimately involve the operation of Malthusian diminishing returns (Ehrlich and Holdren, 1973), though (depending on the base level of *per capita* income) the impact of population growth will be more severe than rising affluence in this respect on account of Engel's Law. Problems of urban concentration due to population expansion are also, at least in principle, separable from those of the rising affluence of a fixed urban population. On the other hand, the nature of techniques and products designed for higher average incomes will, for the reasons given above, have more marked environmental repercussions than those designed for a mere expansion of the population. A derivative of this last point is that alternative distributions of income will have differing environmental implications in terms of a composition of output which varies with the distribution of income. This will be considered in the developing country context below.

(e) *The steady-state concept and the environment*

Daly defines a steady-state economy as one in which 'the total population and total stock of physical wealth are maintained constant at some desired levels by a "minimal" rate of maintenance throughput (i.e. by birth and death rates that are equal at the lowest feasible level and by physical production and consumption rates that are equal at the lowest feasible level)' (Daly, 1973b, p. 152). The concept is thus used to denote zero growth and should not be confused with the term in the literature on growth economics.

There appear to be two distinct but related contexts in which the concept is employed although they are seldom distinguished in the literature. On the one hand, the notion of a steady-state is linked to the question of environmental limits[29] and is seen somehow necessarily to be implied by the latter. On the other it appears as the embodiment of an alternative economic paradigm, the need for which arises from a wide-ranging critique of almost all aspects of the status quo. Environmental degradation is one but by no means the only undesirable feature of the type of society fostered by the prevailing paradigm.[30] This distinction is important since if (as will be argued) the notion of zero economic growth cannot logically be granted any special status in the context of environmental finitude, additional reasons need to be adduced for the adoption of the concepts and perspective associated with such a state of the economy. Put another way, the question then becomes one of establishing why the stationary state model itself provides reasons additional to those already familiar for a paradigmatic change in economics. Before considering this question, the link between the stationary state concept and environmental limits requires investigation.

There are undeniably limits both to the availability of non-renewable resources[31] and the assimilative capacity of the environment to receive waste discharge, though there may be considerable disagreement as to how long it will take to reach them.[32] However long it may take, there are logically two options currently available. The one is to curtail entirely the depletion of non-renewable resources (at both ends of the process) by stopping all activity giving rise to depletion. In all other cases some inter-temporal allocation of the scarce resources between present and future use is required. It follows that if the stationary state of the economy does not correspond to the first possibility of zero depletion then it has no special significance as a concept in this context of limits. We may well then ask as Beckerman does 'what is so special about the figure "zero"?' (Beckerman, 1974, p. 233).

Let us then examine the properties of the stationary state from the point of view of its implications for depletion, drawing on the earlier discussion of the physical imperatives. As Daly points out, the stationary state, comprising a given and constant stock (of population and material wealth), can be associated with high or low rates of (equal) inputs and outputs, while the *size* of the maintenance throughput is a direct function of the level of the stock (which amounts essentially to the standard of living) (Daly, 1973b). Whatever the level of the stock which is chosen,[33] it is obvious that in the absence of infinite average durability of the physical wealth component (which is equivalent to a zero rate of throughput) some positive rate of throughput will be necessary to maintain the constancy of the stock. This being so, the earlier analysis demonstrated that in the absence of perfect convertibility of inputs to outputs and recycling of all outputs, there will necessarily be some waste discharge and presumably (though this is not a logical necessity) also some depletion of nonrenewable inputs, albeit at a lower rate than that associated with a stock which is permitted to grow. The *necessity* of waste discharge, as shown above, is translatable into the *possibility* of environmental pollution. It thus appears that there is nothing compelling about the figure zero when viewed in the context of environmental limits.[34] It might be argued against this that the stationary state economy is defined to incorporate an institutional system which prevents depletion but in principle at least, this can also be achieved in the growth economy.

Having established that the stationary state is merely one among many alternative time-paths involving differing rates of environmental depletion, the issue becomes one of deciding whether the concept has any separate and additional rationale.

According to Boulding, the major difference between the economy characterized by the relentless pursuit of growth and profligate consumption of resources (the 'cowboy economy') and the 'spaceman' economy is manifest in the attitude towards consumption (Boulding, 1966, p. 9). In the former type of economy the aim is the maximization of throughput (production and consumption), the additional consumption being regarded as desirable and indeed indicative of the performance of the economy. In the stationary economy, by contrast, flows of production and consumption are to be minimized and the emphasis is rather on 'the nature, extent, quality and complexity of the total capital stock' (Boulding, 1966, p. 9).[35] The justification for this inversion of the usual maximization problem is the assertion that individual welfare is largely to be regarded as comprising the satisfaction derived from the stock rather than the flow dimension. Consequently 'consumption, far from being a desideratum, is a deplorable property of the capital stock which necessitates the equally deplorable activities of production' (Boulding, 1949/50, p. 79). In more concrete terms, for example, the purpose of eating is to maintain the state of being well-fed rather than the act as such. This argument, it should be noted, is quite distinct from that which regards the usual use of the term consumption as misleading on the grounds that it suggests an actual disappearance of the goods consumed, which, from the waste disposal point of view is clearly false and may only be justified in the absence of scarcity of resources such as clean air (Ayres and Kneese, 1969).

The essentially psychological basis of Boulding's argument seems more than somewhat dubious and in any case its policy implication of minimizing production and consumption flows is not a necessary concomitant of the stationary state which can operate at variable rates of throughput. It is one thing to object to the inordinately short average durability typical of the 'cowboy economy' but quite another to claim that no satisfaction derives from the variety of consumption flows and the activity of consumption *per se*.

It is also argued that the notion of the stationary state can be rationalized in terms of risk-aversion to the possibility that growth will lead us to exceed the ill-defined environmental limits (Olson, Landsberg and Fisher, 1975). But here again the logical conclusion does not necessarily lead to the desirability of zero growth. If there is anything in the risk-aversion argument, the policy implication is enforced *ex ante* prevention of depletion rather than zero growth. In as much as there is any implication for growth it should rather be negative than zero.

In sum, while one may agree with many of the criticisms advanced against the 'cowboy economy' and the ethos of the growth economy as we know it (aptly termed 'growthmania' by Daly)[36] in the stationary-state literature, there appears to be no logical route from the critique to the stationary state. In casting the critique of the growth society in terms of the stationary state, the advocates of change may have hindered rather than advanced their own cause.

(f) *The need for an integrated approach*

Each of the approaches surveyed above illuminates a part of a more complex total system which is characterized by the highly interactive nature of the variables. Growth, technology and institutions interact in a complex network of mutual determination to produce environmental repercussions which cannot therefore be expressed as a simple multiplicative or additive function of these variables. Over-simplification and a failure to perceive the systems nature of the problem will inevitably lead to the failure of seemingly intuitively obvious solutions,[37] and it appears likely that 'nothing less than a coordinated strategy taking into account the full ensemble of problems and their interactions can hope to succeed' (Ophuls, 1977, p. 129).[38]

2. THE DEVELOPING COUNTRY CONTEXT

The approaches discussed above were concerned to explain the environmental problems of developed economies. Their relevance to the developing country context depends on the extent to which the concerns of the Third World differ in kind or degree, or both, from those which have already been considered.

(a) *The nature and scope of the problems*

Ward and Dubos assert that the environment problems of LDCs 'are sufficiently different to merit consideration apart from the issues which are the most urgent concern of high income lands' (Ward and Dubos, 1972, p. 93). The Founex Report goes further in arguing that 'the major environmental problems of developing countries are essentially of a different kind; they are predominantly problems that reflect the poverty and very lack of development of their societies' (United Nations, 1972, p. 3). The distinction underlined by the Report is that in LDCs environmental degradation is not merely one of variations in the *quality* of life but one of the *maintenance* of life itself.[39] There is in fact a symbiotic relationship between extreme poverty and the environment (Dasgupta, 1976) which, depressing as it undoubtedly is, has at least the redeeming possibility that action taken with respect to either may actually improve both.

While transgression of the so-called 'inner limits'[40] constitutes the fundamental environmental problem of LDCs, there are others inherent in the structure of LDCs more akin to those in the rich nations. The typical structural feature of an LDC is the dichotomy between a high-income and productive modern sector and a more or less traditional sphere of activities characterized by low productivity, low wages and non-wage employment. Accompanying and indeed sustaining this structure is a highly unequal distribution of income, assets and access to earning opportunities. The products and processes of the modern sector catering to the needs of those with high incomes are invariably imported from the technologically advanced nations and thus involve not only the environmental hazards due to their dissociation from the natural processes in the countries of origin, but also (and much worse) their total alienation from the host country environment. The result is that LDCs are likely to suffer from, as it were, the worst of both environmental worlds.[41] On the one hand and corresponding to part of the dual economy are in effect the difficulties associated with the pre-technical age. On the other, they suffer from a more extreme version of the pollution-intensive technologies of the modern era (Sachs, 1971b). Moreover the income differentials between sectors exacerbate the problem of urbanization by encouraging the drift to the towns which transforms rapid population growth into a problem of population density. When one adds to this the fact that little is known about the workings of tropical and sub-tropical ecosystems[42] and even less about their interaction with technologies there is every reason to argue with Kapp that 'while these countries are at an early stage of economic development and while their real growth rates may still be relatively low, they enter the process of economic and social change under conditions which are in several respects less favourable than those which prevailed in today's advanced economies 200 years ago' (Kapp, 1974, p. 103).

(b) *Ecological disasters in the Third World*

There now exists a comprehensive documentation of the pervasiveness and gravity of ecological disasters which have afflicted virtually the entire Third World. The major source[43] is the Record of the Conference on the Ecological Aspects of International Development (1968), which contains a very large number of papers designed to investigate the question, 'to what extent have the ecological costs of introducing technology affected the less-developed countries?' (Farvar and Milton, 1972, p. xv). Though the way the question is posed narrows the complexity of the issues into a technologically determinist framework, the volume nevertheless comprises a highly useful compilation of descriptive evidence. There follows a summary treatment of the major ecological disaster areas.

(i) *Irrigation and water development*

The spectacular dams and irrigation systems, such as the Aswan High Dam and the Nile Delta have been followed by outbreaks of bilharzia (schistosomiasis) on a huge scale. In the case of the Nile Delta, Farvar reports that what was once a relatively minor disease has now reached rates of astronomic proportions such as 75% and higher. The disease has now displaced malaria as the most pressing threat in Africa (Farvar, 1976). It is the perennial nature of the irrigation which, in conjunction with the insanitary habits of the local population allows the snail carriers of the disease to multiply (Ward and Dubos, 1972, p. 229).

Nor has the effect of these schemes been confined to schistosomiasis. Complex interactions between the schemes, local farmers and natural processes have produced problems ranging from silt pollution (in the Indian Damodar valley) to total destruction of surrounding agricultural systems and epidemics of sleeping-sickness,[44] in the case of the Kariba Dam in Zambia (Ward and Dubos, 1972; Farvar, 1976; Farvar and Milton, 1972).

(ii) *Pest-control and insecticides*

The most highly publicized disasters have been associated with the use of DDT and other insecticides in combating malaria. On the one hand, these insecticides have upset the natural and self-regulating pest–predator relationships and on the other, resistance has been built up through the survival and multiplication of resistant genes beginning with the survival of a small proportion of the pest population and the subsequent passing on of the resistant genes (Ophuls, 1977, p. 24). The result has been, for a wide variety of countries an escalation in the incidence of malaria (Farvar, 1976). Crop failures have also been induced by the use of synthetic compounds, while it has been established that the accumulation of DDT and other compounds in human milk has, for one case at least, reached dangerous proportions (Farvar, 1976; Farvar and Milton, 1972).

(iii) *Ecological dangers of the Green Revolution*

It is often assumed that the Green Revolution constitutes a successful manipulation of the environment in the cause of higher yields. The very success of the high-yielding varieties, however, threatens the existence of the native species which may jeopardize the maintenance of the new varieties (Dasmann, Milton and Freeman, 1973). The local varieties not surprisingly develop disease resistant traits which are absent in the high-yielding varieties and which could usefully be transferred to the latter. The problem is that the native crops are being displaced at sometimes rapid rates – in the African plain of Upper Volta for example only 10% of the rice grown is now of local origin (Dasmann, Milton and Freeman, 1973). In Iran the new wheat varieties were attacked and destroyed by a disease to which the local (and displaced) crop was immune (Farvar, 1976), an example which underlines the dangers involved in this displacement process.

Apart from the elimination of diversity there are two other ecological dangers associated with the Green Revolution. There is the danger associated with the excessive use of water and the 'ever-increasing recourse to synthetic fertilizers and insecticides' (Sachs, 1973).

(iv) *Ecologically disastrous products*

The catalogue of environmental disasters is not confined to the effects of inputs or processes of production. Ecologically disastrous products are those which when introduced into an alien climatic, cultural and dietetic setting have direct and serious physiological consequences.

A dramatic illustration was provided by the introduction of powdered baby milk in LDCs. In the absence of the complementary requirements of clean water and sterilized bottles the resultant contaminated milk contributed to increased infant mortality (Griffin, 1977). In rural Mexico it was discovered that women who fed their infants low-protein gruel were unwisely advised to change to milk in view of the bacterial content of protein rich products. The gruel by contrast was relatively immune to the bacteria (Barnet and Müller, 1974). Other examples are those of lactose intolerance and unsuitability of certain drugs[45] (Farvar and Milton, 1972: Griffin 1977).

(c) *The causes of ecological disasters*

It is obvious that in many of the above cases the environmental costs were also associated with considerable benefits – in most cases however those that have suffered have done so in part because their poverty and lack of political power have at once contributed to the disaster and prevented any redress. This situation is considerably aggravated by the fact that ecological mistakes are far more costly in a context of absolute poverty.

While, as noted above, the documentation of disasters has in one sense proven invaluable, the posing of the problem and the solution implicit in the published volume of the conference entitled '*The Careless Technology*' have engendered the false notion that the problem lies in the careless application of a technology which is somehow given and devoid of institutional content in its development and application. In other words, the impression is created that technology is the *cause* rather than the *symptom* of a more fundamental malaise. Commoner's approach (in his summary of the 1968 Conference) is typical of this conception of the flow of causality. Since technology is essentially reductionist in his view it is 'designed to construct an efficient power plant, a safe dam, or an effective cleansing agent, it cannot cope with the *whole* system on which the power plant, the dam, or the detergent intrudes; hence disastrous ecological surprises – schistosomiasis, agricultural failures, water pollution – become inevitable. Ecological failure is apparently a necessary consequence of the nature of modern technology' (Commoner, 1972, p. xxvii). The role of the institutional framework is distinctly secondary, providing only a reason why the mistakes *already committed* are tolerated. Thus 'we tolerate the operational failure of the automobile and other technological hazards to the environment only because of a peculiar social and economic arrangement; the high costs of such failures are not charged to any given enterprise but are widely distributed in society' (Commoner, 1972, p. xxvii). The possibility that the institutional and political arrangements themselves influence the nature of the technology developed is entirely missing in the 'careless technology' approach.[46] One consequence of this single-faceted conception of the problems involved is a simplistic equation of ecological mistakes in the USA with those perpetrated in LDCs. Thus Commoner sees in the Lake Kariba project the same narrow, single-minded approach which characterizes the commercialized attitudes in the USA (Commoner, 1972, p. xxvi). While this may be so it leaves out of account the reason(s), for example, why the decision-makers concerned with the Kariba project were bound by 'commercial' considerations when such projects need (and should) not be confined to a calculus in terms of private costs and benefits. This, rather than the observed similarity of behaviour and results, is surely the important question.

The disasters listed above involve differing groups of decision-makers whose objectives may differ and be influenced by political and institutional constraints of various kinds. The role of technology should be seen in this broader framework.[47] We consider these questions first in the context of public sector projects.

Large-scale schemes initiated and evaluated by the public sector are typified by those such as dams, hydro-electric power stations and irrigation systems. The decision-making process in such cases is in principle governed by social considerations in the conception of costs and benefits. The question of whose costs and benefits are to count and how they should be weighted however is obviously critical even if all the effects of the project were able to be perfectly anticipated. The answer will depend principally upon the class-interest alignment of the decision-makers.[48] In the case of the Kariba Dam, for example, it has been argued that the conception of costs and benefits was heavily influenced by the alignment of the decision-makers with the international copper companies (Farvar, 1976). The fact that no ecological surveys were completed prior to the decision to construct the dam (Scudder, 1972) *may* thus have been due to a valuation system giving little weight to ecological consequences and in particular to those associated with largely powerless groups.

Apart from such conscious neglect of the ecological dimension in the interests of political expediency (failure by design) there are, under the heading of what Sachs terms 'environmental disruption by inadvertence' a number of separate factors (Sachs, 1971b). The failure to perceive the complex interaction of variables may firstly be ascribable to the fact that some of the variables lie outside the purview of a single discipline and the lack of an inter-disciplinary approach thus fails to pick up some of the key relations.[49] The absence of this type of approach may in turn be due to a shortage of local personnel (Ward and Dubos, 1972), a lack of funds or an unwillingness to spend available funds on additional personnel (Sachs, 1971b). Even the presence of an inter-disciplinary team is not in itself sufficient (though necessary) since there may be a failure to communicate effectively, a lack of familiarity with local conditions (as with many development assistance projects) or a methodology which is reductionist rather than holistic,[50] and thus inadequate to cope with the complex systems character of the environment.

Even if all relevant[51] environmental implications are captured, there is still the problem of implicit or explicit quantification. Apart from the link between evaluation and decision-taking mentioned above, a social cost–benefit analysis incorporating environmental effects is likely, in its insistence on quantification in monetary terms, to gloss over variables which are not capable of expression in such terms (Sachs, 1971b; Kapp, 1974).

Multinational corporations cut across a number of ecological disaster areas. The first involves the export to and usage in LDCs of 'dirty technologies', i.e. those that have been banned or limited in the countries of origin. In 1972 a fungicide banned in a number of industrialized nations except for export caused the mass poisoning of Iraqis who had consumed barley and wheat imports coated with the fungicide (Farvar, 1976). 'Dirty technology' imports are permitted by LDC laws, which sometimes even encourage the establishment of polluting industries.[52] Less dramatic but potentially equally disastrous from an ecological standpoint are the products, such as powdered baby-milk referred to above, which are introduced into LDCs by multinationals and promoted by extensive advertising campaigns. These products which have a direct and deleterious effect on human health in one setting may have an altogether different and even beneficial effect in another where diets, climates and customs are taken into account in the design of the product characteristics. In an institutional context where there are no requirements concerning product conformity to health regulations nor scrutiny as to the veracity of advertisement claims or countervailing information, the unfortunate result is that disasters are only discovered *ex post*.

All this is not to suggest that the 'optimum' amount of 'dirt' is the same in rich or poor countries or that environmental standards regarding products and processes should be uniform. While poor countries can obviously learn from the mistakes of the rich and blatantly toxic imports should be prohibited, there are at least three reasons why environmental standards in LDCs could differ from those in advanced countries. The first is that some of the requirements of the rich countries (such as pollution preventive vehicles) may impose impossible and undesirable technological requirements on the capabilities of the poor countries. A second reason is that in part 'cleanliness' may be a luxury characteristic for poor countries in so far as 'preferences' depend on income levels. The final factor is that standards should relate to the present state of the environment as well as its specific features (such as climatic conditions).

An insidious effect operates indirectly via so-called 'inappropriate products', viz. those developed for high-income consumers in rich countries which embody, in the context of those at low incomes, an excess of superfluous or 'luxury' characteristics and a deficiency of others.[53] While the ecologically disastrous products are obviously also inappropriate, the latter notion has thus far lacked an environmental dimension.

High-income products tend to be more expensive than local varieties because of the packaging, advertising and greater resource requirements. To the extent that they displace local brands (largely on the basis of advertising) the resultant imbalance in consumption patterns of the poor is also frequently associated with nutritional deficiences.[54] Thus the product advertised by the multinationals, may not be harmful *per se* but its purchase, by imbalancing consumption patterns, can indirectly trigger off undesirable physiological effects. Here, as in the case of 'dirty technologies', host government encouragement is not unknown.

Much of the ecological impact of imported processes and products in LDCs can be analysed in terms of indivisibilities and their effects.[55] Thus, ecologically disastrous products such as drugs and powdered baby-milk are developed against a particular background of circumstances such as dietetic and sanitary habits and these in effect become necessary complementary inputs without which the product becomes at best disfunctional and at worst dangerous.

In the case of inappropriate products the indivisibility operates in reverse fashion. The problem here is not the absence of indispensable complementary factors as above, but rather the indivisible nature of products in terms of their characteristics. When inappropriate products displace traditional brands the effect is equivalent to an indivisibility in consumption since poor consumers have to acquire *all* the characteristics of the new product, some of which may be quite irrelevant to their needs. Put another way, in order to acquire the same amount of essential characteristics more has to be spent than before and this impoverishes the already poor.

The high-yielding varieties of the Green Revolution are also quintessentially in the nature of an inseparable package involving complementary inputs of fertilizer, insecticides, tractors, etc. Inevitably 'the use of one foreign technology calls forth – by its own logic – the transfer of other technologies' (Feder, 1976, p. 426). This indivisible aspect of the Green Revolution has had as one effect the accentuation of income inequality (Griffin, 1974) in as much as the package is accessible only to large farmers. The intensification of insecticide use involved and the provision of synthetic compounds for these purposes (by multinationals) has resulted in the associated ecological nightmares mentioned above.

The package (or indivisible) nature of product/process imports[56] and the ecological damage resulting therefrom is not a feature which is an engineering necessity. In principle it is possible to design products and processes in such a way that they embody characteristics which accord with even environments which are in some respects *sui generis*.[57] That such products and processes do not (or scarcely) exist is fundamentally the result of a world scientific and technological order in which there is a 'massive orientation of world scientific effort to the problems and objectives of interest principally to the advanced countries' (The Sussex Group, 1975, p. 185). In this order of things the institutional framework provides no incentive for designers and exporters of technology to make it in any sense more appropriate, while LDCs weakened by a dependence on such imports do not by and large have the capacity to develop their own. It is in a sense easier for LDCs to remain in a perpetual state of dependence than to face the initial difficulties involved in developing an indigenous technology. It is also more convenient since the alteration of the existing passive (or absent) laws with respect to questions of advertising, quality controls, health hazards etc., requires a distinct challenge to the vested interests associated with their preservation.

3. ASPECTS OF INTERNATIONAL ENVIRONMENTAL INTERDEPENDENCE

In some respects the environmental interdependencies existing between nations are analogous to those relating the individual agents within nations and may be analysed in the same terms.

If individual producers and consumers are replaced by nation-states as the relevant unit of analysis it becomes clear for example that the game-theoretic problem of the first part of the paper is also pertinent in the new context. In particular one may speak of the 'global irrationality' which inheres in the uncoordinated actions of individual nations with respect to the common property resources of oceans and atmosphere[58] (Ward and Dubos, 1972; Ophuls, 1977: Dasgupta, 1976). Moreover, the problem is exacerbated in the international context since 'the dynamic of the tragedy of the commons is even stronger than within any given nation-state, which, being a real political community, has at least the theoretical capacity to make binding, authoritative decisions on resource conservation and ecological protection' (Ophuls, 1977, p. 210). Any action to combat this macrocosmic version of the isolation paradox will be plagued by the inherent instability of any agreement and will require compulsory enforcement by a supra-national body if effective agreements can even be reached.[59] Pointing to the unsuccessful conventions over fisheries and hunting of whales, Clawson is pessimistic about the prospects for world-wide action on environmental problems, even those of a much more serious nature such as atmospheric pollution (Clawson, 1971, p. 43).

The analogy may be extended to cover environmental spillovers that are transmitted across national boundaries (through rivers, oceans and the atmosphere) though for geographical reasons this problem, unlike the previous one, is less problematic in the international as opposed to the national context.

In a number of respects however, the simple substitution of nations for individuals misses the singular nature of the interdependencies between nations and the analogy breaks down.

It was shown in the previous section that it is the design of products and processes within the context of advanced nations in conjunction with the dependence of poor nations with distinct and singular environmental problems on imports of such technologies which has severe dislocative effects. In this way the co-existence of rich and poor states and interdependence in the form of trade flows between them is of fundamental importance in distinguishing intra-national from international environmental problems.

At the same time there are issues which follow from the fact that while individuals within a nation cannot implement controls and regulations concerning the environment, the same is not true of individual nations in the context of the world community. Since policies regarding environmental control for a single nation (or group of nations) are likely to influence and be influenced by the policies of others, the interdependencies involved are properly speaking of the oligopolistic variety. The export of 'dirty technologies' to some LDCs, as noted above, is one consequence of differential legislation regarding pollution. This in turn may induce the rich countries to insist on uniform environmental regulations[60] if a significant number of firms are attracted by the leniency of host country conditions (Brown, 1975). The scale of this effect will depend on how rigorously controls are implemented, their effect on prices of internationally traded commodities and the importance attached to the absence of host country controls. The evidence does not as yet suggest that these factors are operating to produce a significant relocation of industries (Dasgupta, 1976). As regards LDC exports, the effect of environmental controls in DCs has been, on the one hand, an increased demand of 2–3% for natural products induced by regulations regarding the manufacture of synthetics and, on the other, a reduction in specific exports such as high-sulphur crude oil and fruits and vegetables containing traces of DDT (Dasgupta, 1976).

Much has been made of the notion that in a world of ecological scarcity, industrialization of the LDCs along the lines of the now developed countries is not feasible (Ehrlich and Ehrlich, 1972; Ophuls, 1977). One conclusion drawn from this assertion is that LDCs should strive for the 'ecologically viable alternative' which is 'a locally self-sufficient, semi-developed, steady-state society' (Ophuls, 1977, p. 211). This conclusion is spurious not only because it involves the same *non-sequitur* which characterizes the argument for a planetary steady-state economy based on ecological finitude,[61] but also because it is particularly repugnant to LDCs which are generally speaking less threatened by environmental limits than are the DCs[62] (Sachs, 1971b). The arguments for the steady-state economy, in other words, are even less cogent when viewed from the standpoint of LDCs than they are in the global context.[63] They thus miss the distinction between global and local outer limits to which we shortly turn.

The increasing recognition of ecological scarcity and interdependence between rich and poor nations complicates the problem of international inequalities and changes the atmosphere in which calls for a 'New Economic Order' are made. In the face of environmental finitude, the income gap between rich and poor can ultimately only be narrowed by an income redistribution and/or a slowing down of growth rates in the industrialized world. The latter course, however, will in part be self-defeating in as much as growth in the developing countries may fall *pari passu* with that in the rich countries. The general view is that recognition of ecological scarcity heightens rather than ameliorates conflict between the rich and poor countries (Streeten, 1976a; Ophuls, 1977; Brown, 1975)

(a) *Local and global outer limits*

The notion of outer limits which has acquired considerable currency in the literature was first coined in relation to the finitude of the global environment, but in the form of local outer limits the concept has been expanded and is purported to have 'significant implications for issues such as independence, dependence and interdependence' (Matthews, 1976, p. 16).

The context in which the notion of an outer limit is to be considered may totally alter the perspective of a problem. Thus, the fact that the global outer limit of a particular resource is very near to being reached would be of little moment in the context of the local outer limits of a nation with an abundance of the resource relative to its needs (as would be true of certain petroleum-exporting nations). By converse the fact that eutrophication of lakes in a certain small region has transgressed the local outer limits will not give any cause for global concern. As such the distinction is a useful conceptualization of the differing frames of reference involved in approaching questions of environmental concern. It is difficult, however, to sustain the view that 'in the process of articulating, elaborating and expanding the concept of outer limits, new and very significant dimensions have been added',[64] (Mathews, 1976, p. 33).

4. POLICY OPTIONS FOR LDCs

(a) *Growth versus the environment*

Two related questions will be addressed under this heading. The first is whether and to what extent there is a trade-off between growth and the environment and the second is whether, if such a conflict exists, LDCs should be encouraged to trade off in a way that differs from the weighting at the margin made by DCs.

The answer to the first question turns on both problems of *measurement* and the *nature* of the growth process. As conventionally measured, environmental impairment represents no cost since it is not subtracted from the national product. There is, however, a consensus of agreement that such costs as can be ascertained should in principle be deducted so that measured growth would no longer overstate 'true' growth. Thus far so good. A number of authors however, have argued that subtracting the costs of pollution exaggerates the extent of the conflict since measures to restore the environment involving new technologies are properly part of the GNP[65] (Streeten, 1972; Sachs, 1971b). Thus, 'outlays for environmental quality management would be, in part, self-financing to the extent that they help to reduce the amount of the actual deductions' (Sachs, 1971b, p. 1636). It is perfectly possible for these outlays to cancel out the deductions from the national product, in which case the result is paradoxically the same as that where no deductions are made, i.e. the case of no conflict.[66] The resolution of this seeming paradox is quite straightforward. In an economy operating at full capacity and full employment, the resources devoted to 'cleaning up' the environmental damage will necessarily displace resources that could have been utilized for other purposes. Thus while the 'cleaning up' may cancel out the damaged environment,[67] growth is still affected by the displaced resources (unless they would have been entirely consumed) and there is still a conflict between growth and the environment, which will vary according to the degree of slack in the economy (or more generally with the opportunity cost of the displaced resources).

While 'cleaning up' measures are thus likely to reduce the growth rate, an increase in the latter is likely to lead to the need for greater 'cleaning up'. Alternative styles of growth and development, however, will have quite different environmental implications and there is consequently nothing immutable about the extent of the conflict. (More about this below.) Suffice it to say here that it is an issue of much more substance than that of measurement.

Whatever the extent of the trade-off, the second major question posed at the outset was whether LDCs are in a position to place relatively less emphasis at the margin on the environment than the DCs. Two reasons are adduced in support of the proposition that LDCs should give higher priority to growth in their selection from the growth/environment options than DCs. Thus 'they have a more urgent need than advanced countries for increased economic output and, in addition, greater scope for producing forms of output at relatively low pollution cost' (Beckerman, 1974, p. 99).

While there is certainly a more urgent need for increased output, growth can only be considered more valuable on this account if it (a) benefits those whose needs are most urgent and (b) yields its benefits while those in need are still capable of enjoying them. Assuming away (b) for the moment, there is considerable evidence that growth does very little to assuage the needs of the poorest groups of LDCs,[68] many of which are absolutely worse off.[69] If growth of the kind hitherto experienced benefits chiefly the upper income groups, it cannot be valued more highly in the context of urgency of needs. Moreover, the very urgency of needs may in another way call for less rather than more growth. Growth involves the sacrifice of immediate for future consumption and will thus exacerbate rather than alleviate immediate consumption deficiencies. It is true that 'Rational choice depends not only on one's basic preferences between goods and services of the conventional kind, on the one hand, and environmental quality, on the other hand; it depends also on how much of each one has' (Beckerman, 1974, p. 98), but it is quite 'rational' for those with subsistence amounts of goods and services and low-life expectancies to have a very high discount rate with respect to consumption over time and hence to prefer less rather than more growth. Urgent needs argue for income redistribution and immediate increases in consumption not growth. While for these reasons there may be little warrant for a higher relative valuation of growth on the basis of urgent needs, there may be a case for such an evaluation of increases in consumption currently benefiting the lower income groups which are also associated with degradation of the environment.[70]

The argument that greater output can be produced in LDCs at a lower environmental cost is based on the assumption that the absorptive capacity of LDCs to assimilate waste discharge exceeds that of DCs. Generally speaking this assumption is valid with reference to entire geographical areas but may not be true of specific industrial areas of LDCs. Unless industries can be located in less congested areas, the environmental impact of increased output in LDCs may be just as serious as it is in advanced countries.

The most pertinent question in the growth versus the environment context is not so much how great is the trade-off nor whether it should differ in LDCs, but rather how growth and environmental preservation may be made more complementary, not as above in the trivial and artificial sense of measurement manipulation, but in the substantive sense of policies and strategies designed to achieve this end.[71]

(b) *Development strategies and the environment*

As noted above LDCs suffer from both the environmental consequences of poverty and those of affluence which are made more acute by the fact that the 'affluence' is imported into an alien environment. In large measure this situation is the result of an interplay between growth, technology, institutions and vested interests which is self-perpetuating. Recognition of the joint nature of causality involved in this process has the policy implication that only a coordinated and far-reaching set of policies as part of a different strategy is likely to achieve a *sustained* complementarity between development and the environment.[72] But cumulative and mutual causation can be a two-edged sword from a policy point of view. If an appropriate set of policies is implemented in the correct sequence the result *may* be a cumulatively virtuous spiral (depending of course, on the values of the response coefficients of the interactions).[73] Thus a strategy based on an income redistribution will facilitate the development and use of 'appropriate' techniques and products,[74] while the latter in turn will have an iteratively beneficial effect on employment and hence the distribution of income. With the contraction of the market for luxury goods, the need for multinationals would be diminished (Griffin, 1977) as would the severity of demonstration effects. In short, a change in the composition and distribution of output need not conflict with a growth,[75] which would be much less injurious in its effects on the environment.[76] Preservation of the latter is a consequence of an appropriately conceived development strategy.[77]

The difficulties of initiating such a fundamental change in strategy are only too well-known (Stewart and Streeten, 1976; Cooper 1973) and the fact that it is likely to remain a counsel of perfection limits severely the degrees of freedom in dealing with environmental problems. Nevertheless some room for maneouvre remains, partly because not all of the problems are explicable solely in terms of the prevailing strategies; a fact which is strenghthened by the additional information regarding the behaviour of ecosystems in LDCs which is now available. At the least some of the disasters of the past can be prevented.

(c) *Policies to prevent environmental disasters*

While it is arguable whether the development process is best seen from a systems perspective, there is very little doubt that this is the appropriate method of analysis in the ecological context.

If disasters stemming from inadvertence are to be avoided, there is a need firstly to draw upon the ecological principles that have now been developed in response to the lessons of the past.[78] A major lesson is that a single policy in isolation may have severely disruptive effects, while a coordinated set of measures may achieve the desired goal without such disruption. Thus in the area of pest control for instance, recognition of the hazards of a purely chemical approach have led to the policy of 'integrated pest control' which employs a mixture of biological, cultivation and chemical means to keep pest populations at tolerable levels. It has been applied with considerable success in the Canete Valley of Peru (Dasmann, Milton and Freeman, 1973).

Apart from the use of such additional knowledge of hazards and alternative designs of projects the prevention of disasters is also likely to require a procedure in project evaluation of a different order to that which is customary. There is a requirement firstly for an interdisciplinary and systems type approach to identifying the broad range of consequences of the public investment. The problem of quantification, though logically separate, often intrudes on this prior process of establishing the multiplicity of effects by restricting the choice of variables to those that are readily quantifiable in monetary terms. The result in terms of which 'the complex problem of environment is reduced to the arithmetic sum of a few pollutions and far-fetched and dubious methods of indirect estimation are put to work' (Sachs, 1971, p. 1637) is not wholly a caricatured version of traditional social cost–benefit analysis.[79] Kapp rejects even in principle the quantification of social costs in terms of a single monetary standard when dealing with questions of human health and survival, and urges instead the establishment of objective safety limits 'below which any further deterioration of the environment cannot be tolerated under any circumstances' (Kapp, 1974, p. 109). Since the establishment of environmental indicators and safety limits is only beginning in rather primitive form in industrialized countries and is clearly a long way off for LDCs, the immediate aim should be at least the prevention of crude quantification intruding on the process of ascertaining the pervasive effects of the project.

As far as the disasters associated with 'dirty technologies' and imported products are concerned, only outright prohibition will be effective. There is little point in implementing indirect controls such as taxes and penalties where the deterrent (in so far as it exists)[80] may only operate to some extent *ex post factum* (Kapp, 1974).

Attempts by LDCs to compete with each other for foreign investment on the basis of leniency regarding controls is as futile as doing so on the basis of wages[81] and is also far more dangerous. It would make much more sense for LDCs to harmonize controls regarding dangerous products/processes and to exchange information. Research into more appropriate techniques and products by multinationals is unlikely to be forthcoming as long as markets exist for the current noxious varieties.

5. THE SOCIALIST EXPERIENCE

The dynamic interrelationships between growth, technology and the environment have thus far been considered within the framework of a free market economy and a capitalistic world economic order. Much of the discussion in fact has been concerned with the specific nature of environmental problems which result from the processes of capitalist economic growth and technical change. Since there is an *a priori* presumption that 'in socialist countries environmental disruption and social costs could be taken into account in allocation and investment decisions' (Kapp, 1974, p. 118), the comparative experience of these countries is of considerable relevence to both the developed country orientation of the general approaches (of Section 1) and to the environmental issues in the developing country context. This section does not purport to represent a comprehensive or detailed account of either the Soviet or Chinese experience but rather aims to draw on these cases to highlight the major themes developed in the earlier parts of the survey.

(a) *The Soviet case*

There is no doubt that the Soviet Union has experienced severe environmental problems (Beckerman, 1974; Ophuls, 1977; Goldman, 1972) though 'overall pollution in the USSR is probably less pronounced than in major Western capitalist countries' (*Technology and the Environment*, 1977, p. 50). Does this imply that problems of pollution in industrialized countries transcend ownership and institutional structures? Some interpret the Soviet experience as a demonstration of the fact that pollution is not caused by private ownership and the uncoordinated actions of individuals under the profit motive (Ruff, 1972). That this is a *non-sequitur* follows from the fact that environmental pollution of different kinds originates from varying sources. The fact that the Soviet Union suffers from environmental problems has in no way diminished the fact that *part* of the pollution in advanced capitalist economies is attributable to the specific nature of the institutional structure in these economies. Pollution in the Soviet case is in some respects qualitatively different. Thus there are not the same problems associated with mass use of private automobiles (Ophuls, 1977) nor is there the same degree of waste from the production of disposable consumer goods (Goldman, 1972). Moreover, environmental disruption in the USSR is a highly localized phenomenon with almost half of the nation's industry concentrated in the Volga basin (*Technology and the Environment*, 1977). That there are also similarities in patterns of disruption is due principally to the subordination of the environmental dimension in the objective function of the central planning authorities to the goals of efficiency and output growth (Beckerman, 1974; Heilbroner, 1975). This goal structure is manifest at the plant level in the general absence of non-polluting techniques and a conception of cost minimization akin to that under private ownership (Ophuls, 1977).

There is thus little to be gained from an assessment of the efficacy of socialist institutions in dealing with environmental disruptions if the latter have been accorded a low weighting in terms of objectives in socialist countries. A more fruitful question is whether, if (as now seems to be the case) greater importance is attached to the preservation of the environment, the USSR is better placed than advanced capitalist countries to effectively organize this re-orientation in goal structure. This is clearly a complex question which cannot be considered in detail here though a few general comments may be in order.

Some problems, such as the technical difficulty in establishing social costs are common to both systems while indirect controls such as penalties may be less effective in a system where the fine is paid at one remove by the State itself (*Technology and the Environment*, 1977). On the other hand, coordination and implementation of preventive measures, such as the prohibition of ethyl lead in gasoline (Goldman, 1972) are likely to be facilitated under the socialist system.[82]

There are also differences between the two systems in the role and power of vested interests and environmental pressure groups. These operate in such a way as to make environmental interests less powerful in the USSR. On the one hand, economic managers intent on meeting targets at all costs to the environment possess greater political muscle than their Western counterparts (Ophuls, 1977) and on the other, the environmental lobby (including consumer groups) in the capitalist countries is not only more powerful but also growing all the time.

(b) *The Chinese example*

The Chinese approach is distinctive in that it has recognized and taken advantage of the complementarities between growth and environmental preservation (and improvement). In the physical flow terms of our earlier discussion (in Section 1), the Chinese have recognized that no necessary conflict inheres between growth and the environment and that such severe conflict as has almost universally occurred is essentially institutionally induced (Kapp, 1974; Sigurdson, 1975). On the other hand, they have taken cognisance of the fact that environmental improvement is both a cause and concomitant of balanced growth from a low initial base.

Taking first the flow dimension,[83] China has undertaken a systematic and widespread campaign of re-cycling the residuals[84] from production and consumption processes.[85] Interpretations differ as to the role played by this comprehensive recycling in the overall Chinese conception of development. Some view it as being intimately bound up with the Maoist ethic of frugality (Orleans and Suttmeier, 1970). Whitney links it to the notion of 'politics in command'[86] according to which the recovery of waste materials is required, 'not only because the country is poor and cannot afford to lose them, but also because of the harm they do to people and the environment' (Whitney, 1973, p. 103). There is thus a dual aspect to the residuals which Whitney contrasts with the Western emphasis on environmental degradation rather than waste (Whitney, 1973). Kapp places the phenomenon in a yet broader context. Thus, 'it is to be regarded at the same time as an anti-pollution measure, as a method of increasing production, as an approach to a new diversification and location of industry and an improvement of urban and rural sanitation. It is multipurpose in this comprehensive manner' (Kapp, 1974, p. 33). It remains an open question however, whether all of the recycling can be justified on economic grounds (Kapp 1974; Orleans and Suttmeier, 1970).

Though the conversion of production and consumption flow residuals has contributed at once to environmental preservation and increased output, the major complementarities have arisen in relation to the nexus between growth and the environment at a very low state of economic and social development.[87] Thus the package of measures devoted to improvements in the ecological[88] and hence the human condition 'go hand in hand with and are the preconditions for the achievement of higher levels of production and productivity' (Kapp, 1974, p. 44).

In this scheme of things, growth, distribution and the environment are all interrelated and mutually reinforcing in a dynamic and positive way. This contrasts markedly with the traditional welfare theoretical conception which stresses their separability and with the typical developing country experience in which (partly on this account), the nature of the distorted growth process has failed to foster the potential complementarities.[89]

In terms of the Chinese strategy, growth and distribution are inseparable since the latter 'affects the whole nature of the growth process, and so the extent to which income distribution itself can ever be transformed' (Paine, 1976, p. 277). To this extent much of the usefulness of the distinction between the concepts of consumption and investment is lost. Equally, by weakening the link between money incomes and standards of living the concerted[90] environmental improvements have contributed to the income redistribution (Paine, 1976).

This specific harmonization of relationships should be seen as an integral part of a more pervasive attempt to promote complementarities between all spheres and regions of economic activity and most importantly between economic and socio-political processes. The quintessence of the strategy of 'walking on two legs' lies in the achievement of positive interdependencies between regions, sectors, techniques and spheres of decision-making.[91] Favourable environmental development has *followed* from this network of balances.

A key element of the strategy aimed at sectoral and regional balance has been the promotion of an industrial sector comprising small and medium-size units employing labour-intensive techniques.[92] The location of these industries in rural areas[93] has had as one result the avoidance of environmental costs associated with the excessive urbanization so typical of most developing countries (Kapp, 1974).

The high degree of integration of these industrial units with agriculture in most counties is part of the goal of regional self-sufficiency.[94] Thus, 'the important aspect of this local industrial system is its primary emphasis on providing agriculture with the necessary inputs for ultimate, full mechanization. This is, to a considerable extent, to be achieved with local raw materials, local manpower, and local capital accumulation' (Sigurdson, 1974, p. 80). The achievement of a complementary relationship between agriculture and rural industry is in fact thought to supersede the goal of employment creation via labour-intensive rural industrialization[95] (Sigurdson, 1975).

Given the diversity in environmental and other conditions between regions, a close link is forged between the specific input needs of local agriculture and the production by the rural industrial sector. In addition the techniques of the latter themselves being largely indigenous are also attuned to the specificity of local conditions. Whitney mentions, for example, indigenous bacterial fertilizers and microbe insecticides, which are locally processed and used extensively to contain agricultural pests. Knowledge of the local environment has also led to the breeding of a special type of bee which is used as a predator (Whitney, 1973).

This aspect also emerges very clearly in relation to the general processes of innovation as analysed by Dean.[96] In seeking ultimate technological autonomy, Chinese innovative activity has passed through a number of phases with varying emphasis on worker-innovation and formal scientific principles. Since 1964–65 these two aspects have been synthesized into a complementary relationship. In addition, the design function has shifted from imitation of foreign designs to those 'suited to China's domestic conditions' (Dean, 1972, p. 195). This was assisted by the technique of 'on-the-spot designing' which involved direct cooperation between the designer and the workers and technicians concerned (Dean, 1972, pp. 192–193).

The cornerstone of this innovative process is thus the close coordination and feedback mechanisms between theoretical and applied scientific and technological capabilities which are brought to bear on local problems.[97] As Dean puts it, 'It is this development of a local innovative capability, comprising worker-innovation and the engineers, and organically linked to the scientific system and to production which may well account for the increase in technical capability which has been noted in recent years' (Dean, 1972, p. 198).

The Chinese technology policy apart from contributing to the objectives of regional and sectoral balance (with the environmental consequences noted above) thus appears to have had the following environmental implications. The considerable degree of technological independence achieved[98] has afforded the domestic scientific and technological capability the opportunity to devise an alternative technology more in accord with local environmental, cultural and other conditions.[99] As we have suggested above the domestic technology and innovative activity is systematically geared to the specificity of local conditions and needs.

On the products side, no studies dealing with the link between the nature of products in terms of characteristics and the labour-intensive industrial processes in the counties have as yet emerged.

However, there is evidence of a close relationship between the specific consumption needs in localities and the supply of goods by the light industrial sector in the county (a link which is analogous to that between agriculture and rural industry described above). Thus the major responsibility of the light industry 'is to process agricultural and sideline produce and to provide the locality with many of the needed consumer goods' (Sigurdson, 1974, pp. 79–80). The closeness of this matching between local consumption and production suggests a process akin to the Marxian concept of production for use as opposed to the production for the general market where there is an 'accidental' element in the satisfaction of specific local needs.[100] Clearly there is considerable scope for research directed towards an analysis of the nature of products produced by the local labour-intensive industrial units in rural areas.

To sum up, the central theme running through the Chinese experience is the symmetrical nature of the relationship between development and environmental preservation and improvement. The specific policies aimed at enhancing the environment have also improved the human condition while at the same time the balanced development strategy has occasioned favourable environmental consequences.[101] In large measure the achievement of this symbiosis is inextricably and indivisibly related to the unique set of historical, political and socio-economic factors comprising the Chinese experience. The totality and specificity of this experience are thus not transplantable into other developing country contexts.[102] The implication of this should not be, however, that the Chinese case is a special and perfect one which is incapable of emulation. The lesson should rather be that it suggests the core of an alternative approach to development and the environment which could be extracted and implemented in a style indigenous to different societies.

NOTES

1. A discussion of the ability of the ecosystem to cope with man-made intrusions within certain limits is to be found in Ophuls (1977, Chapter 1). Kapp (1974, p.63) speaks of a threshold beyond which further discharges to the environment have a cumulative and disproportionate effect.

2. In the literature, the 'tradegy of the commons' is an equivalent expression of this paradox. The origin of the term relates to a pasture owned by no-one but open to all. The inevitable result was over-exploitation and destruction of the commons. The residuals discharge problem is an inversion of the 'commons' result in so far as it is a question of outputs rather than inputs. See Hardin (1973) and Ophuls (1973).

3. Reductionism is the scientific method of attempting to understand the behaviour of a system in terms of its isolated components.

4. Koestler, an ardent critic of reductionism, calls this different outcome in his mystical context, 'the ghost in the machine' (Koestler, 1967).

5. See Ayres and Kneese (1969).

6. The same applies with some modification in the spillover-repressive case. In particular, it may be argued that transaction costs will be lower under spillover-repressive law, where the initiative comes from a less diffused group of industrialists (Mishan, 1971).

7. See Downs (1957).

8. It is interesting to note that the practice of discharging sewerage into rivers was sanctioned by the law in the UK in 1847 (Fitzgerald, 1902). Regarding the development of the law relating to pollution, Garner and Harris note that 'the common law, however, has grown up mainly as a defence and protector of the private rights of the landowner – rarely has it been concerned directly with the interests of the community as a whole' (Garner and Harris, 1977, p. 113).

9. What is to count as impact as opposed to deterioration is clearly to some extent subjective depending on individual perception which will be influenced by cultural and other factors (Clawson, 1971).

10. It is thus incorrect to argue that 'pollution problems are inherent in the materials throughput and energy consumption of the economy' (Olson, Landsberg and Fisher, 1975, p. 239). This is to confuse environmental impact and environmental pollution.

11. See below under the technological approach.

12. There is some evidence that pollution has grown faster than the GDP in recent years (England and Bluestone, 1971, p. 39).

13. See Stewart (1977).

14. Furthermore, as technology develops and growth proceeds in this context, the environmental impact becomes less predictable. The latest United Nations Report on the State of the Environment warns against 'industrial developments whose consequences cannot be foreseen, especially in the field of nuclear energy' (reported in *Action for Development*, 1977).

15. A rather spurious technique is employed to quantify the technological component of pollution, which we shall discuss below.

16. Since one product may have a shorter life span than another but at a lower input cost, durability should be defined to include resource cost.

17. The energy required to produce metal for an aluminium beer can for example is 6.3 times that required for a steel beer can (Commoner, 1971, p. 172). In the case of automobiles it has been found that compared to the period 1920–World War II, the last 25 years have seen a reduction in the distance travelled by the average car from 13.5 miles per gallon to 12.2 miles per gallon (Summers, 1971).

18. For a melancholy discussion of the modern trends away from natural products towards waste of paper, plastics and non-returnable packaging , see Dumont (1974, pp. 56–57).

19. Daly rightly points to the 'intemperate haste' in commercializing ecologically dangerous technology induced by the obsession with growth (Daly, 1973c, p. 275).

20. Thus 'while technological change and economic growth have been associated in the past they are

simply not the same thing' (Roberts, 1975, p. 125). Ophuls actually asserts that it is autonomous technological growth that has produced the ecological crisis (Ophuls, 1977, p. 128). A recent OECD report however takes the opposite view that 'growth and technological progress are two aspects of the same thing' (OECD, 1971, p. 96).

21 These have been introduced on a huge scale since the 1950s. For the United Kingdom case see Ironmonger (1972).

22. Heilbroner's argument that it is not the development of science and technology as such that has caused the problem, but rather its 'fusion in a civilization that has developed technology in a lopsided way without compensating 'benign' technologies' also begs the question (Heilbroner, 1975, p. 57).

23. Marx was an important precursor of Galbraith in his perception that under capitalism 'every person speculates on creating a new need in another' (Marx, 1970, p. 155).

24. Schmookler found that the bulk of inventive activity in American industry was determined by changes in the composition of demand (Schmookler, 1966).

25. For a discussion of the interconnected cycles between income, product and technique changes see Stewart (1977, Chapter 1).

26. The incremental version of equation (1) above can be expressed as:

$$\Delta E = (P + \Delta P)(c + \Delta c)(p + \Delta p) - Pcp \qquad (2)$$

If the percentage changes in P, c & p are small, (2) will be approximated by:

$$\Delta E = Pc\,\Delta p + Pp\,\Delta c + cp\,\Delta P \qquad (3)$$

Either of these forms makes it obvious that Holdren and Commoner are wrong in believing that one can 'distinguish among the relative contributions made by the rates of change of the various contributing factors to the rate of change of the total' (Holdren, 1975, p. 36).

27. For an attempt to capture some of the interdependencies within the context of a model predicting resource use in the year 2000 see Ridker (1974).

28. Freeman, Haveman and Kneese are guilty of such a counterfactual approach (Freeman, Haveman and Kneese, 1973, p. 152).

29. In the present context we are referring to global limits – those of a regional or national nature will be discussed below.

30. It is worth noting here that Ricardo's vision of a stationary state was intended to frighten his obdurately complacent colleagues and to hasten the repeal of the Corn Laws (see Blaug, 1956).

31. It is necessary to stress that the economic supply as distinct from physical availability depends on productivity in extraction, processing, etc. (Thurow, 1977).

32. See for example, Connelly and Perlman (1975), IBRD (1972), Nordhaus (1974).

33. This need not, of course, be invariant over time with technology and other changes.

34. Daly's argument here is difficult to understand. He asserts that the maintenance flows must be kept within the ecological limits though these are not precisely defined. In view of the interdependence between the size of the stock and the flows, his assertion that the stock must be precisely constant as a physical necessity seems illogical. If one cannot be precisely specified, why the insistence on precision with the other?

35. As noted above, minimization of the throughput implies maximization of the durability of the average stock. By analogy with a basin the lower the rate of inputs and outputs the longer is the period spent by the average drop of water in the sink (Daly, 1973a).

36. He defines growthmania as 'the attitude in economic theory that begins with the theological assumption of infinite wants and then with infinite hubris goes on to presume that the original sin of infinite wants has its redemption vouchsafed by the omnipotent saviour of technology' (Daly, 1973b, p. 151).

37. Forrester calls these the 'traps' set by the nature of complex systems and lists four such dangers (Forrester, 1971, p. 94). For a particularly balanced approach to the multifaceted nature of environmental problems see Kapp (1974) and on the technological aspects of these problems see Reddy (1977).

38. Some credence to this view is given by a recent report on attempts to control water pollution in a number of advanced countries. It concludes that 'the experience of the last five years serves as a reminder of how wide is the gap in modern complex societies between agreeing on environmental goals and achieving them' (*Technology and the Environment*, 1977, p. ii).

39. The materials balance approach loses much of its relevance in the LDC context since it emphasizes the effects of flows rather than problems associated with a low initial stock. For a description of both the stock and flow dimensions of environmental problems in Southeast Asia see Conway (1970).

40. Inner limits are defined as the minimum material needs required for human survival.

41. Reddy adopts a similar view, pointing to the environmental damage resulting from the overconsumption of the rich on the one hand and that

entailed in the struggle for survival by the poor on the other. See Reddy (1977).

42. What is known is that alien farming methods can be ecologically destructive. Thus 'To a European, agriculture means a clean plot of land with crops planted in neat rows. Applied to the tropics, this practice also means destruction of the tropical soils. This has occurred many times in the past and continues today' (De Gregori, 1969, p. 45).

43. See also the very useful annotated bibliography edited by Farvar (1973).

44. In East Africa Kjekshus contrasts the integrated relationship between man and the environment during the pre-colonial era with the outbreaks of sleeping sickness during the twentieth century (Kjekshus, 1977).

45. The *Times of India*, New Delhi (1 September 1977) reports that many diseases in India are becoming resistant to conventional drugs. The problem is attributed to the abuse of antibiotics which is likened in the report to the disastrous effects of excessive use of insecticides.

46. The popularity of this technologically determinist approach probably lies in the very fact of its presumptive political neutrality. With its emphasis on the scientific and practical aspects of technology 'it appears to lie beyond ideology' (Stewart and Streeten, 1976, p. 401). By contrast, the approaches of Reddy (1977) and Stewart (1977) deal explicitly with the value-laden nature of technology and technological change.

47. This type of matrix approach is based on that of Stewart (1977, Ch. 1).

48. See Stewart (1975).

49. This is stressed by Riney (1972) in relation to development assistance projects.

50. An inter-disciplinary approach should not be confused with the question of reductionism which is a question of scientific method rather than one concerning merely the incorporation of interactions between the variables of several disciplines.

51. Sachs (1971b) points out that what is to count as relevant may be important since environmental disruptions cross geographical frontiers.

52. Barnet and Müller (1974) report government advertisements in Mexican newspapers to attract investments suffering from anti-pollution legislation. The Caribbean has already attracted many refineries and petrochemical complexes.

53. See Stewart (1977) and James (1976 and 1977).

54. See James (1977) and Barnet and Müller (1974).

55. See Stewart (1977, Chapter 1) for a discussion of the nature of the technical requirements of technology.

56. The undesirability of the package nature of foreign investment has been noted aside from the ecological dimension (see Streeten, 1975).

57. 'There is no reason why plant research cannot be directed toward developing improved varieties which reflect the factor endowments and ecological conditions which most Asian farmers confront' (Griffin, 1974, p. 78).

58. A recent report indicates that the Mediterranean has nearly reached its assimilative capacity and 'many experts say that without drastic measures, nothing can save it from ecological death within a decade' (*Action for Development*, 1977). The countries concerned met in October 1977 to discuss a protocol for regulating the discharges.

59. See Streeten (1976b) for a discussion of the instability of agreements requiring compulsory enforcement.

60. On this and other aspects of international problems see US Government (1972) and the United Nations Report of the Founex Conference (1972).

61. See Section 1 above.

62. Sachs (1971a) refers to this conclusion as an 'unsophisticated version of colonialist paternalism'.

63. It is worth noting that at the 1971 Founex Conference on the Human Environment there was general agreement that the zero growth philosophy is totally unacceptable. On the economic consequences of zero growth see Thurow (1977).

64. The conclusions, although stated in somewhat technical language, appear to amount to little more than an assertion that outer limits should not be transgressed in planning and that the determination of these is essentially a societal value judgement (though no suggestion is offered as to how the implicit social welfare function is to be constructed). See Matthews (1976, pp. 36–37).

65. Thus 'cleaning up' in the context of atmospheric pollution is presumably to be regarded as the production of clean air.

66. Beckerman (1974, p. 106) goes even further in asserting that growth is probably the only means by which pollution can be kept at socially desirable levels.

67. In the LDC context where some environmental damage severely impedes production and investment processes (Sachs, 1971b), there can be no question of 'cancelling out' as there is with other forms of environmental degradation. It is curious in this connection that Beckerman calls attention to the 'damage

done to the environment from recycling paper' but fails to recognize the pollution inherent in the cleaning up process itself (Beckerman, 1974, p. 46).

68. See Stewart and Streeten (1976).

69. Griffin and Khan provide evidence of this (Griffin and Khan, 1978).

70. Rosenberg (1976) makes a case for the continued use of DDT in LDCs on the grounds that its disuse would cause an abrupt reduction in the food supply, the consequences of which are worse than the long-term hazards associated with DDT. It may be noted that DDT spraying, after a temporary ban, was resumed in India in August 1977. See *Times of India*, New Delhi (26 August 1977).

71. A strategy is defined to include both policies and the objectives they are intended to meet. Strategies may thus differ according to both objectives and proposed policies (Stewart and Streeten, 1976).

72. The same point is emphasized with regard to poverty-focused planning by Stewart and Streeten (1976) and to the developmental process in general by Kapp (1974). It follows from the general nature of complex systems (Forrester, 1971).

73. See Streeten (1972) for a discussion of the critical values necessary for response coefficients to yield cumulation.

74. The change in the composition of output following an income redistribution will not, however, be unambiguously favourable from the environmental point of view, since there will be a reduction in the demand for services which have a minimal impact on the environment.

75. See Streeten (1976a).

76. Part of this effect such as the reduction in energy and capital intensity can be captured in terms of the materials balance approach of Section 1. Other effects, such as the improvement of health and reduction in the degree of alienation of products and processes from the local environment cannot be.

77. This approach is in contrast to the somewhat mystical and vacuous approach termed 'ecodevelopment' which 'is a style of development which, in each eco-region, calls for specific solutions to the particular problems of the region in the light of cultural as well as ecological data and long-term as well as immediate needs' (Sachs, 1976, p. 48). The approach was conceived by Maurice F. Strong, former Executive Director of UNEP. It has close links with the philosophical basis of the intermediate technology movement and is an understandable reaction to the failures of development but too often finds expression in vague and unhelpful generalizations. The concept is elaborated in Sachs (1976) and Dasgupta (1976).

78. The book by Dasmann, Milton and Freeman (1973) is in the nature of a manual designed to assist the planning of development projects from an ecological point of view.

79. In the literature the concept of 'technology assessment' appears to have acquired different meanings. In the LDC context it describes an approach which eschews 'seeking a common denominator at all costs' and aims 'by means of a systems approach, to encompass all the elements, interests and relationships involved, and on this basis to start an exchange between the agents concerned' (Sachs, 1973). The technology assessment movement, however, originated in the USA in 1966, where it had the rationale of analysing 'all significant primary, secondary, indirect and delayed consequences or impacts, present and foreseen, of a technological innovation on society, the environment, or the economy' (US Government, 1972, p. 71). See also Stöber and Schumacher (1973); Tribe (1971); Winner (1972); Caroll (1977); UNESCO (1973).

80. Depending on market structures, firms may find it easier to shift the tax and go on polluting. Not only is it well-nigh impossible in some cases to attribute pollution resulting from many causes to a specific firm but it is also difficult to decide how high taxes/subsidies must be before they have any effect (Kapp, 1974). In DCs it has been recognized that 'the polluter pays' principle is insufficient to carry the whole brunt of deterrence (*Technology and the Environment*, 1977). Tax shifting and subsidies raised by income taxation raise further questions regarding their effect on the distribution of income.

81. See Streeten and James (1977).

82. Though the USSR has thus far failed to establish a central body for coordination of pollution control measures and the lines of authority and responsibility are as yet ill-defined (Goldman, 1972; *Technology and the Environment*, 1977).

83. The problems of environmental degradation in the Third World are, as noted above, due more to the level (and distribution) of the stock of material wealth than to the flows of production and consumption.

84. The waste problem in China is almost totally organic. There are no unreturnable containers, few plastic commodities and no car 'cemeteries' (Orleans and Suttmeier, 1970).

85. As illustrative of the scope and intensity of these procedures one may cite the fact that 40% of Chinese cement originates in the slag produced by iron and steel works; that in 1973 eleven million tons of iron and steel were produced from scrap; and that processed waste water irrigates some 6,650 acres of farmland (McDonald, 1975; Kapp, 1974). Under the heading of 'rural–urban symbiosis', Whitney describes the process of recycling of nutrients used in the city

back to the rural areas. The 'symbiosis' is even more vividly demonstrated by the mobilization of half a million city dwellers in the cause of carrying nightsoil to the rural areas and spreading it over the fields before ploughing (Whitney, 1973).

86. 'In economic life, this is interpreted as meaning that the whole economy, rather than a part of it, is to be taken into account when decisions are made' (Whitney, 1973, p. 102).

87. As existed before the establishment of the People's Republic (Kapp, 1974).

88. For detailed discussion of the scope and implementation of these measures see Kapp (1974), Whitney (1973) and Sigurdson (1975). The labour-intensive nature of the projects and the degree of participation by local labour (Kapp, 1974, p. 17) present a stark contrast to many of the schemes in LDCs (discussed above) which, being capital-intensive and designed centrally, are out of touch with local environmental conditions.

89. India, for example, appears not only to place little emphasis on the environmental dimension of development but also in some areas (such as sewage and waste disposal) to actually neglect it (Conway, 1970).

90. It is worth noting that the concerted nature of these measures has probably yielded 'increasing returns' in as much as the total beneficial effect has exceeded the sum of the benefits of the measures taken in isolation. On the advantages of a concerted attack on poverty see Stewart and Streeten (1976).

91. See Paine (1976) and Bhalla (1974).

92. Despite difficulties during the Great Leap Forward Phase small-scale techniques have made considerable progress. See Cooper (1972), Ishikawa (1972) and Dean (1972).

93. Rural industrial output comprises between 15 and 20% of the total value of industrial production. The total number of units in rural areas exceeds 500,000 (Sigurdson, 1975, p. 115).

94. Sigurdson reports that 96% of counties have enterprises making machinery (Sigurdson, 1974, p. 81).

95. On the magnitude of employment created in this manner see Paine (1976).

96. See Dean (1972).

97. There is also an interaction between the rural industrial sectors of different localities in terms of which technologies are exchanged and adapted (Sigurdson, 1974).

98. Over the period 1952–58, 28.1% of the machinery and equipment component of fixed capital formation was imported. By 1959–65 this figure had declined to 11.6% (Dernberger, 1974).

99. It is noteworthy that the withdrawal of Russian assistance, though probably disruptive initially, actually hastened the development of an indigenous technological and scientific base. See Ishikawa (1972), Bhalla (1974) and Stewart (1977).

100. See Heller (1976, p. 121).

101. Whitney (1973) arrives at a similar conclusion.

102. Joan Robinson's comment (at a seminar given at Oxford in 1975 on 'The Chinese Experience') that 'everything and nothing' can be learnt from China is an alternative statement of this point.

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