Economic Growth and Sustainability: A Simple Framework

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Abstract

The debate about the relationship between economic growth and the environment embraces many different strands, some emphasise the limits to the capacity of the earth to sustain economic activity, some focus on options at the local level, some suggest that growth and environment are complementary. This paper suggests a framework based on elementary concepts from economics that illustrates the essential characteristics of these diverse elements and the relationships between them. The framework identifies limits to technological options which may press against a sustainability constraint.

1. Introduction

The debate about the relationship between economic growth and the environment is long-standing, multifaceted, complex and essentially unresolvable. Only a global catastrophe could offer the final resolution. The debate is often traced back to the ideas of Thomas Malthus (1909) who wrote his Essay on Population in 1798, but no doubt the limits to human economic development have always been a concern to human populations. The pessimistic views have tended to predominate in the debate, perhaps as particularly exemplified by the Club of Rome report by Meadows *et al.* (1972) and more recently Meadows *et al.* (1992). Other writers have emphasised the limits associated with population growth (Ehrlich and Ehrlich, 1970) and the need to achieve a steady state economy (Daly, 1991). In contrast to the concern with physical constraints, Hirsch (1977) has concentrated on the social limits to growth. Against these, the more recent discussions, associated with the ideas of sustainable development, have sometimes argued that economic growth and environmental quality can be complementary (notably, Brundtland, 1987). Indeed some argue that environmental regulations can stimulate economic growth (Porter, 1991); we examine these arguments below. Alternative to these positions others have failed to find empirical evidence of resource limits. For example, Barnett and Morse (1963) and Smith (1979), emphasised the potential for resource substitution to adjust to resource scarcities (e.g. Dasgupta, 1989) and argued (e.g. Beckerman, 1992) that the priority should be on improving the conditions of the poor rather than worrying about long term resource conservation.

This paper presents a simple framework, based on elementary economic concepts, within which alternative views can be identified. The analysis applies with respect to whole economics, within which policy decisions are taken about the level of environmental regulation. It shows how trade-offs between economic growth and environment within a period are still potentially consistent with a simultaneous achievement of both growth and environmental improvement. We also introduce a sustainability constraint in order

to illustrate the concerns that a failure to maintain a sufficient stock of natural capital may limit future development options or even in an extreme case lead to economic collapse.

This simplified neo-classical approach inevitably involves numerous assumptions that abstract from the real world. They are outlined in the many economics texts which introduce these constructs. The approach has been developed in respect of environmental applications in such texts as Lecomber (1975) or Pearce and Turner (1990), although there are many critics who would emphasise the more fundamental limits of the approach, for instance in its neglect of institutional issues (eg Bromley, 1991) or ecological relationships (eg Ehrlich, 1994, Jansson and Jansson, 1994). This analysis should be read in this context.

2. The trade-off between environment and income

Before presenting the framework, we need to consider some aspects of the more extreme arguments that environmental regulations stimulate economic growth and hence question the reality of a trade-off between environmental quality and the costs of production (Porter, 1991; Gore, 1992). The argument is sometimes illustrated by reference to the success of the German economy (e.g. *Economist*, 1993), which applies high environmental standards and yet achieves high rates of economic growth. There is an immediate danger with this type of argument in that the causality involved is unclear. It seems likely that countries where incomes are growing may show more enthusiasm for higher environmental standards. Thus the causality of the relationship may work in the other direction too. Not only might higher environmental standards lead to higher rates of economic growth, but higher economic growth may also lead to higher environmental standards.

A further complication in international comparisons of this sort may arise because it is often cheaper to adjust to higher environmental standards through the use of new technology rather than by adding on end-of-pipe pollution control equipment. In successful economies, which are growing relatively quickly, the rate of investment in new plant and equipment will tend to be relatively high and this creates more opportunities for technological change. Thus benefit cost ratios will be higher for environmental improvements in growing economies and so we may expect higher standards to be adopted.

At the level of the individual firm, the argument that high environmental standards and economic success is sometimes supported by the observation that manufacturers with high environmental standards, either in terms of the characteristics of their products or of their production processes, often appear to be more profitable than their less environmentally aware competitors. At this level too, we may expect that successful firms have a higher rate of reinvestment, effectively lowering the costs of complying with environmental standards.

There are several explanations of these observations which are consistent with a more general assumption that the introduction of higher environmental standards does tend to raise total costs of production, leading either to lower profits or higher consumer prices, depending upon the market conditions, i.e. consistent with the assumption that there is predominantly a trade-off between growth and environment.

One possible explanation is that there may be a lack of information which is somehow eased by the introduction of an environmental regulation. Examples are

sometimes quoted of firms which find that they can recycle by-products of a production process, simultaneously saving costs and avoiding environmental damage. Examples have been cited in a recent report by Her Majesty's Inspectorate of Pollution (1995): an investment of £100,000 by one chemical company in Bradford led to an annual saving of £300,000. In a dynamic economy with changing prices and technologies such opportunities will occur. But it is to be expected that such opportunities will be infrequent and relatively minor in relation to a firm's total costs. Firms will take advantage of cost-saving opportunities when they are aware of them, and given the positive publicity which may be generated, will be more keen when there are 'free' ways of improving the environment.

Second, regulations which require firms to take action to reduce the external costs may directly reduce the costs of production of other firms which bear these external costs (Cairncross, 1995). In the absence of an environmental regulation, the other firms may, for instance, have to purify polluted water before it can be used in a production process. It is possible that the cost to the polluting firm of complying with the regulation could be less than the cost to firm suffering from the pollution of purifying its water supply. Thus, here too the environmental regulation can lead to a reduction in total production costs in the economy. This situation will only occur where a high proportion of the external cost which is reduced by a regulation represents a direct financial cost to other firms rather than being a non-priced effect. The balance between these costs is difficult to determine empirically, but it seems likely that most environmental effects include significant non-priced elements so that this situation would be relatively rare. It will be more probable in highly damaged environments, where the net gains from environmental regulations are very high.

Environmental regulation does, without doubt, create market opportunities and this represents a third explanation. As environmental problems are identified and become more critical, pressures develop for higher environmental standards and new regulations are introduced by government. This creates market opportunities for pollution control equipment, for more environmentally sensitive products and for the equipment with which these products can be manufactured (Porter, 1991). Countries or firms which are early to develop the new technology for meeting this environmental concern will not only be ahead in marketing their product, they may also sell the technology to those firms lagging behind. Indeed, the higher costs involved may drive some companies out of certain markets (Cairncross, 1995). It might also be anticipated that in such circumstances, consumers may well be responsive to the promotion of 'green' products, creating new marketing opportunities.

It is common in this context to focus on the relative performance of national economies; arguing that economic growth can be achieved by establishing higher environmental standards rather than lagging behind other economies. For example, Gardiner (Gardiner and Portney, 1994) comments that a failure to anticipate public demand for stronger environmental regulations or opportunities for cost-effective, safe and clean technologies by US industry had the consequence that the manufacture of all water-borne basecoats used in the US for automobile coatings relies substantially on technology developed by European suppliers.

Similarly, he comments that 'US industry is racing to capture the world market for new and emerging technologies' (p.21).

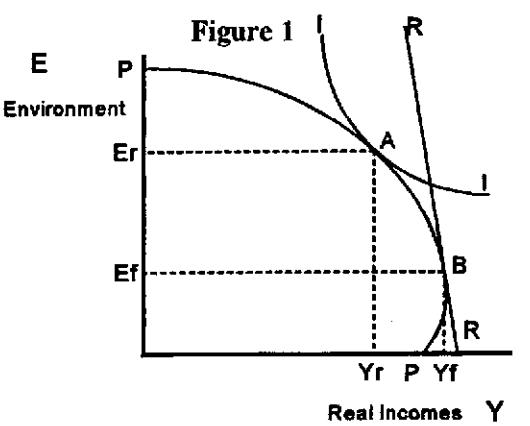
These arguments suggest that it is indeed possible for new environmental constraints to act as a stimulus to economic profitability and growth. But there are also losers. See Walley and Whitehead (1994) for a criticism of Porter's views. The firms and economies which fail to adjust will lose jobs and profits, just as they will do if they fail to offer products which embody other qualities demanded in the market. It is much less clear that there are net gains to be made when looked at across all firms and economies. Of course, individual firms and countries will want to pass on those costs to others.

Pearce (1991) has reviewed studies of the macro-economic impacts of environmental regulations. He found that these studies 'suggest that environmental policy can actually increase employment and incomes, or at least make them no worse.' While some studies, particularly in the United States, have found that environmental regulations do reduce the annual GDP growth rate, others find limited or positive impacts. There are a number of reasons for this. Increases in environmental taxes may be assumed to be offset by reductions in other taxes to maintain fiscal neutrality. Regulations may stimulate the replacement of new technology for old technology. The investments in pollution control equipment and plant modification themselves have the effect of increasing GDP. Reduced environmental damage can contribute to the increase of productivity. Part of the explanation also lies in the limits inherent in the use of GDP as a measure of economic progress (eg. Pearce, 1993).

3. A static framework

Given these arguments, we characterise a trade-off between environment and the real income levels per capita generated from the production of non-environmental goods and services. For convenience we refer to these as real incomes. This is illustrated in Figure 1. Of course, in practice it is not possible to value and aggregate all aspects of the environment in monetary terms, although we do retain the assumption that this is possible conceptually. (See for instance Bateman and Turner (1993), Bateman (1993) and Vatn and Bromley (1995) for discussions of the valuation question and Sagoff (1988) for a wider critique of the economic approach). The relationship also assumes that other factors are held constant. Shafik (1994) hypothesises four determinants of environmental quality in any given country: (i) endowment such as climate and location, (ii) per capita income reflecting the structure of production, urbanization and consumption of private goods and services, (iii) exogenous factors such as technology, and (iv) policies that reflect social decisions about the provision of environmental public goods. In this discussion, we assume that the endowment and exogenous factors are given.

Figure 1



These determine the location of the production possibility frontier, PP in Figure 1. PP represents the range of combinations of environmental qualities and real incomes which could be produced. The role of environment as a production input is one factor determining the location of the production possibility frontier. Following our earlier comment, the production possibility frontier shows declining real income with declining environmental quality where the environmental quality is low. This reflects the higher production costs associated with degraded environments. II represents a community indifference curve reflecting the population's preferences for environment and real incomes. Here, we assume that welfare arises directly from the environment and from the consumption of non-environmental goods and services. There is a complication in this formulation in that environment both influences human welfare directly and represents an input into the production of goods and services. We assume that tastes remain constant for any given level of income. RR represents the price ratio between non-environmental goods and services and priced environmental services. This is drawn as being particularly steep to represent the idea that substantial elements of the environment remain unpriced.

The figure suggests two alternative outcomes. A 'policy-free' approach might be adopted, in which the pattern of economic activity will be determined through the price mechanism with little attention to economic impacts. This leads us to B, with environmental quality Ef and real income level Yf.

Alternatively, the state might introduce some form of environmental policy which would have the effect of internalising the external costs of economic activity. The environmental policy could be introduced at different levels, but an 'optimal policy' approach would in effect shift the price ratio to the point where it was tangential to the production possibility frontier at the point where the indifference curve is tangential, at A. It would be inefficient to introduce more stringent environmental policies than this in a conventional Paretian sense. While it is possible that more stringent policies might be advocated perhaps in the face of extreme uncertainty or due to some alternative assumptions about the rights of future generations, the figure suggests a 'policy zone' around PP, between A and B.

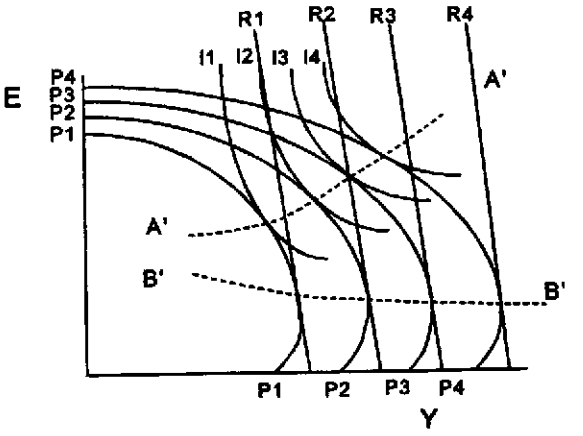
4. Alternative growth paths

In this very simple framework, economic growth can be represented by an outward shift of the production possibility frontier.[2] With respect to the level of real incomes, this is straightforward. An economy expands its capital and manpower and develops technology by means of which it is possible to raise the level of production of non-environmental goods and services or real incomes. It is less clear whether it is possible to raise the level of environmental quality beyond some initial endowment. We will assume here that some improvement is a possibility; that mankind can act in such a way as to raise the quality of the environment, perhaps by making good environmental damage, by landscaping or creating habitat in rural areas or by creating attractive urban environments. But the extent of this is limited in comparison with the potential for raising real income levels. This type of change does imply that it is possible to achieve a greater level of non-environmental consumption for a given level of environmental quality. This would reflect a fall in the environmental impact coefficient

(Jacobs, 1991).

This pattern of economic growth is illustrated in Figure 2, where P1P1 shifts outwards in stages to P4P4. In the absence of environmental policy, the 'policy-free' approach, the economy follows the path B'B'. In this case, environmental quality tends to decline somewhat. In contrast to this, the level of real incomes rises considerably.

Figure 2



The Figure also shows a series of indifference curves (I1 to I4). These are not drawn parallel[3]; rather they represent a relative shift in preferences towards environmental quality as real income levels rise. With parallel indifference curves, economic growth would lead to some increase in environmental quality but to greater relative increases in the level of real incomes. The shift of preferences towards the environment leads to a greater emphasis on improving environmental quality with economic growth. An economy which adopts an 'optimal policy' level of environment policy intervention would follow path A'A'.

Economies will then follow some growth path, reflecting the choice of location on successive production possibility frontiers. In this, the 'policy zone' between the 'policy-free' solution and the 'optimal policy' solution widens represented by the increasing gap between A'A' and B'B' and this might suggest an increasingly heated political debate about environmental policy. The range of environmental policy options widens and pressures grow to use some of the benefits of economic growth in order to attain a higher level of environmental quality.

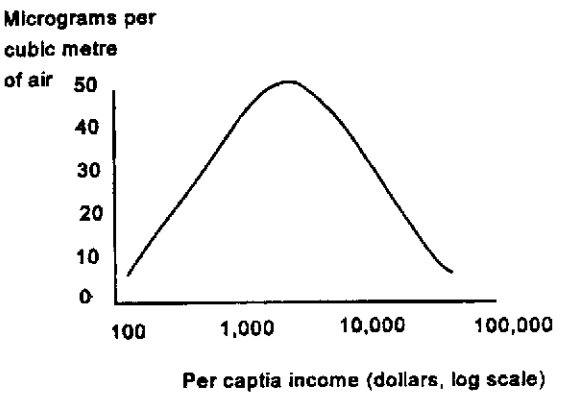
The model also suggests an initial explanation to the debate as to the relationship between economic growth and the environment. In a static framework, we may accept that there is a straightforward trade-off between the two, while in a dynamic framework it is possible to see a complementary relationship: it is possible to achieve both an increase in real incomes and an increase in environmental quality through time. However it will generally be necessary for environmental policies to be introduced which can deliver this.

5. Environmental Kuznets curves

Recent data on some measures of environmental quality and the levels of per capita income suggest a pattern of environmental quality initially declining at low income levels but subsequently rising at higher income levels. Figure 3 from the World Bank (1992) shows the concentrations of sulphur dioxide (SO2) in urban areas of countries at different levels of per capita income. This suggests that at low levels of income, SO2 concentrations tend to rise with increasing income, while at higher incomes they tend to fall as incomes rise. Similar patterns have been found for suspended particulate matter and nitrogen oxides in air, and faecal coliform, dissolved oxygen and

nitrates in water (Seldon and Song, 1994; Grossman, 1995). Dasgupta and Mäler (1994) call this proposed relationship between national income per head and concentration levels of industrial pollutants an environmental Kuznets curve, in reference to the conventional Kuznets curve which demonstrates a similar relationship between real national income per head and income inequality.

Figure 3



We can illustrate the logic behind this relationship from Figure 2. If it is assumed that prior to industrialisation economies start from the position P1 on the environment axis, although it is not well explained in the terms used here, the process of industrialisation implies a path which first moves down to a point within the policy zone on the production possibility frontier involving a reduction of environmental quality. We have already outlined a subsequent stage, at higher income levels, of increasing environmental quality.

Clearly we should be circumspect in generalising from the empirical evidence or from assuming that it will predict the future development paths for existing Less Developed Countries. First, there is a wide range of possible indicators of environmental quality and they do not all show the same relationship with per capita incomes. In fact the World Bank notes two other types of relationship. Some problems decline as incomes increase from the lowest income levels. This applies to sanitation and access to safe water, basic services which are regarded as a priority for investment once the preoccupation with day-to-day survival has been overcome. A third type of relationship does show a continuously rising environmental impact with increasing incomes. Examples are emissions of CO2 and municipal wastes. In these cases, the costs of limiting the impact are relatively high and the environmental impacts may not be regarded as very important. Also, with the case of CO2 at least, the environmental costs are largely passed onto others.

Shafik (1994) has undertaken an econometric analysis of the relationship between environmental quality and per capita incomes. He finds a similar range of relationships, reflecting the relative costs and benefits that individuals and countries attach to environmental changes at different stages of development. Action to improve environmental quality appears less likely where the costs of degradation are borne by people other than those who have influence over political decision-making, particularly the poor and people in other countries. Thus social structure and the state of democracy are also important influences on the choices made in individual countries, affecting the extent to which those suffering from environmental degradation have an effective

voice in the political process. This is illustrated, for example, by the high degree of environmental degradation experienced in the previously centrally planned economies of Eastern Europe and the former Soviet Union.

A second reason for taking care in interpreting the available evidence is that it is possible that the severe nature of the environmental damage currently being experienced in LDCs may act as a constraint on the capacity of these countries to achieve higher income levels in the longer term. Thus for example damage to soils and forests or the creation of derelict land by urban and industrial development, much of which may be effectively irreversible, may impose a very high cost on future development efforts. We return to this point later.

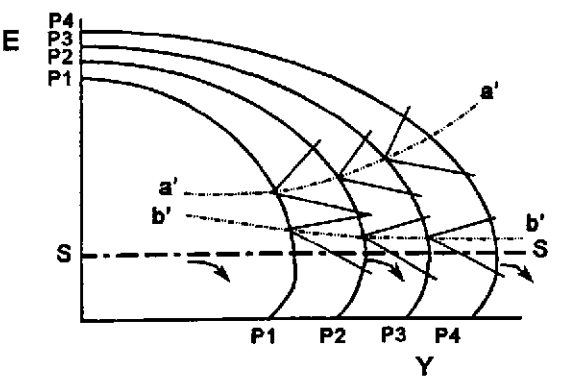
6. Environmental constraints on options for growth

This apparently comforting model abstracts from reality in a whole host of ways. It is not a sound basis for complacency in practice. It is possible to illustrate a little of the complexity involved through some further developments of the framework. Perhaps the most significant simplification arises from the implication that a decision as to where to locate within the policy zone in one period can be made independently of the position selected in previous periods. In practice this is not so. Generally a reduction of environmental quality reduces not only the flow of environmental services within one time period but also the stock of environmental capital. Because this stock may be difficult or impossible to recreate, then a decline in environmental quality in one period would constrain the options available in subsequent periods.

It is also the case that the type of technology available to an economy in any one period will depend upon that developed in previous periods. Different levels of environmental exploitation imply different types of technology. If there are increasing returns to adoption (Arthur, 1989), it will be easier for economies to advance with a similar degree of environmental exploitation rather than to change to some alternative. They are likely to become locked-in to a particular environmental exploitation path. For this reason too, the options available may be constrained by history.

An extreme assumption would be that all environmental damage was irreversible. If this were so, a growth path could only move in a south easterly direction. In the very long term, assuming that it is impossible to maintain an existing level of environmental quality perfectly and indefinitely, there would therefore be an irreversible tendency towards a decline in environmental quality, ultimately reaching some 'zero' position. This assumption is rather too extreme. But it must be accepted that the historical path chosen by an economy does influence both the type of capital and the technology which is developed and that this limits the options available in a future period.

Figure 4



These ideas are illustrated in Figure 4, which shows two possible growth paths: a′a′ and b′b′. The former represents the growth of an 'environmentalist' economy, the latter the growth of a 'materialist' economy. Path a′a′ tracks reasonably closely to the 'optimal' path, following the changing preferences reflected by the indifference curves. Path b′b′, remaining close to the 'policy-free' approach, leads to rising levels of material consumption and monetary incomes, measured in real terms, but given the increasing divergence from the pattern of preference represented by the changing shape of the indifference curves, may or may not achieve improvements in the overall level of welfare. This represents the aspect of the economic growth debate which concerns the extent to which increases in Gross Domestic Product represent real increases in welfare. This debate was particularly active in the 1970s, see especially Mishan (1977) and Beckerman (1974).

The arcs originating from the intercept of the growth paths with the production possibility frontiers indicate the range of locations which can possibly be reached on the subsequent production possibility frontier. In both cases, however, there is an asymmetry in the options available, the element of irreversibility in environmental damage is represented by wider options for a movement along the production possibility curve which involve reductions in environmental quality than there is for options which raise environmental quality.

In Figure 4, the effect of depleting environmental quality acts to reduce the range of options available in subsequent periods. In particular, the materialist economy faces very limited opportunities for raising the level of environmental quality. It is possible to return to a higher environmental standard, but only over a relatively long period. In contrast the environmentalist economy faces a wider range of options.

7. A sustainability constraint

But is it possible to maintain a rising level of real incomes against declining environmental quality indefinitely? The answer must be almost certainly not. The widespread support of the principle of sustainable development, notwithstanding the multiple views of its definition and implications (e.g. Turner, 1993; Toman, 1994; Toman *et al.* 1995), suggest a common assent that some degree of conservation of natural capital is necessary in order to maintain the growth of real incomes, or even to prevent their decline in the long run.

This sustainability constraint might be represented very simply as a base line level of environmental quality, a critical level of natural capital, beyond which real incomes can only fall. This disregards the debate as to the appropriate definition of environmental resources and sustainability (Khalil, 1995) and as to how any specific critical level may be defined in practice, when carrying capacities are not fixed or static (Arrow *et al.* 1995) but it is similar to the principle of 'strong sustainability' (Turner, 1993). Abstracting from these difficulties, the constraint is illustrated by SS in Figure 4. Whether it would be most appropriate to conceive of this as remaining constant with economic growth (as in the figure) or either rising or falling is unclear. The increasing scale of the economy with economic growth might suggest that the constraint could rise, i.e. that a greater level of natural capital was necessary in relation to greater volumes of economic activity. However, there may be possible arguments for all of these patterns.

While the location of the constraint has no implications for the environmentalist economy, it does suggest a potentially severe and even potentially disastrous policy squeeze on the materialistic economy. The narrowing options due to environmental decline, coupled with a sustainability constraint, could leave the economy with very little room for manoeuvre. If we then recognise the practical difficulties faced in attempting to guide real economies within narrow bands, whether they be linked to environmental limits or to the limits of macroeconomic policy, the potential crisis for the economy could be of major proportions.

This illustrates a limitation in the capacity of environmental Kuznets curves to predict development paths. Environmental degradation may constrain the options available to economies so that they are unable to raise environmental standards after they have been lowered, even though higher standards may be demanded by the population at higher real income levels. In more extreme cases, the level of environmental degradation may lead to an irreversible breakdown in life support systems.

8. A global environmental squeeze

The most recent concerns about the overall limits to growth at a global scale tend to focus on the issues of climate change and ozone depletion. The evidence that mankind's current levels and patterns of economic activity are having a measurable impact on global climate and living conditions (e.g. IPCC, 1990) suggests that it will not be feasible to expect that economies will have the same relative freedom to cause environmental impacts in the future that they have had in the past. To the extent that these concerns become translated into international policy of some sort, it implies that economic growth will be required to proceed within narrower environmental constraints. In terms of the framework presented in this paper, this might be conceived as raising the level of the sustainability constraint, to recognise both global and national limits. However, it takes a somewhat different significance in that the constraint was previously conceived as being associated with consequences internal to the economy and it would therefore, at least in principle, be in the national interest to recognise this internal limit. Global concerns arise from environmental changes which mostly impact on other countries. In this respect a higher sustainability constraint would have to be negotiated or imposed on individual countries by a global community.

9. Conclusions

Our purpose is not to suggest that a two-dimensional model drawing on elementary concepts from economics could have implications for the practical management of real economies and environments. It is possible to alter the apparent implications of the framework by realigning the relative positions of the various curves and we have little empirical basis for determining what relationships these curves should have. Rather the aim has been to encapsulate some of the principles and concerns which are expressed about the relationship between economic growth and the environment.

The model starts by illustrating the choices faced between environment and real incomes. This suggests a potentially benign growth path where it is possible to achieve improvements in both simultaneously, even though there is a trade-off between the two in a static, single period context. But a conscious choice has to be made. There is a requirement for an explicit environmental policy if preferences for environmental quality are to be met.

The extension of the model into a sequence of stages representing economic growth demonstrates a possible divergence in the available paths which might be followed. The 'free market' solution increasingly diverges from the preferences of the population. Economies which give greater emphasis to material consumption may find the options available to them increasingly restricted and may eventually face an ultimate squeeze against a sustainability constraint.

Endnotes

1. University of Cambridge, Department of Land Economy. This paper was partly written while the author was visiting the Department of Agricultural Economics at the University of Wisconsin - Madison. I am grateful for the generous provision of facilities and hospitality there.
2. The framework here abstracts from the difficult issues of uncertainty and intergenerational choice. In practice, given our limited understanding of the dynamic interrelationships within the environment, the long term implications of environmental choices, and hence the 'true' level of environmental quality as judged from a long term perspective, must always to some extent remain unclear.
3. More formally this would assume a homothetic preference function.

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