ECONOMICS OF NATURAL RESOURCES AND THE ENVIRONMENT

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But we seem to have no comparable analysis that demonstrates whether any particular economy is consistent with the natural environments which are necessarily linked to that economy. They are consistent in one sense – economies exist and natural environments exist. What we do not know is what needs to occur for them to *co-exist* in equilibrium. We do not have an *existence theorem* that relates the scale and configuration of an economy to the set of environment–economy interrelationships underlying that economy. Because we have no such theorem, our planning of the workings of economic systems – and 'planning' here includes letting the economy operate with free markets – risks the running down, the depreciation of the natural environment's functions. Economies may survive, and may survive for long periods of time in such states of disequilibrium. But if we are interested in *sustaining* an economy, it becomes important to establish some conditions for the compatibility of economies and their environments. This is an issue that we consider in Chapter 3.

3 · THE SUSTAINABLE ECONOMY

3.1 RULES FOR SUSTAINING CLOSED ECONOMIES

Chapter 2 showed how the 'open' linear economy construct of modern economics textbooks needs to be revised to allow for the economic functions of natural environments and the thermodynamic equivalences between resource extraction and waste discharges. The development of this 'closed' model of the economy-with-environment immediately raised a broad question about the capability of the natural environment to sustain the economy. To sustain something means making it last, to keep it in being and make it endure. Sustaining an economy does not just mean keeping it in existence: it may be comparatively simple to have an enduring economy in which the standard of living declines over time. Few people would disagree with the idea that the economy needs to change over time in order to improve that standard of living. How we define 'standard of living' is a moot point. It clearly cannot be something as single-valued as real income per capita. Equally, we cannot deny the important role that real income plays in improving the happiness of people. We might therefore think of the standard of living as a set or 'vector' of components – the utility from real incomes, education, health status, spiritual well-being, and so on. Some would stress one component more than the other, but precisely how our standard of living objective is interpreted does not matter for the issues in question in this chapter. The issue is, then, *how should we treat natural environments in order that they can play their part in sustaining the economy as a source of improved standard of living?*

Chapter 2 has already suggested some of the guidelines we might use. We observed that the first two functions of the natural environment – resource supplier and waste assimilator – implied certain rules of resource and environmental management if we wished to think of those functions being maintained over lengthy periods of time. These rules were:

1. Always use renewable resources in such a way that the harvest rate (the rate of use) is not greater than the natural regeneration rate.
2. Always keep waste flows to the environment at or below the assimilative capacity of the environment.

Symbolically, the rules are:

(1) $h < y$

(2) $W < A$

If we observe rules (1) and (2) we know that the stock of renewable resources and the stock of assimilative capacity will not fall. Those stocks are therefore available in any future period to sustain the economy still further. Implicit in the rules we have used, therefore, is the idea that *the resource stock should be held constant over time.*

We investigate this idea of holding the resource stock constant in more detail in Section 3.3. For the moment, note some of the many caveats that need to be made even at this stage. First, we have ignored exhaustible resources. In physical terms their stock cannot be held constant unless we use none of them! Second, y and A are not static. We can manage natural resources so as to improve the sustained yield and the waste assimilative capacity: river flow can be augmented, forests can be managed to improve timber yield, pasture and grazing land can be fertilised and seeded, and so on. Third, the rules of environmental management seem to elevate the role of natural resources and the environment's assimilative capacity. The implication is that we somehow cannot manage without them or, at least, we can only manage for some limited (non-sustainable) period of time. It is indeed the case that environmental economics places emphasis on the economic functions of natural environments – the subject would hardly exist if this were not so. But are natural resources essential? This question is considered below.

3.2 COMPLEMENTARITY AND TRADE-OFFS

The rules of environmental management outlined above tend to imply that we should not let the stock of renewable resources and

amount of waste assimilative capacity decline. It is a little more convenient to think of assimilative capacity as one more renewable resource, the resource of waste degradation capability. So, the rules reduce to a basic statement that the stock of renewable resources should not decline over time. Since exhaustible resources must, by definition, be exhausted one day, we need to consider how the management rules can be modified to allow for them. Two ways in which they can be integrated into the rules are as follows:

1. To ensure that as exhaustible resources are depleted, their reduced stock is compensated for by increases in renewable resources.
2. To allow for the fact that a given standard of living can be secured from a *reducing* stock of resources.

The first modification allows for *substitutability* between exhaustible and renewable resources. An example might be the substitution of fossil fuel energy by solar, wind, tidal and wave energy sources. The second modification allows for increased *efficiency* of resource use. It is indeed the case that most advanced economies now use less energy to produce one unit of Gross Domestic Product than they did a hundred years ago.

Clearly, our simple management rules are already becoming more complex. The idea of holding the stock of renewable resources at least constant over time in order to ensure sustainability needs modification to allow for offsetting influences: (a) the need to expand renewable resources to compensate for declining exhaustible resource stocks, and (b) the reduced need for *all* resources to sustain a given standard of living (since the efficiency consideration is likely to apply to renewable resources as well). We have no real way of telling which influence is the more important without detailed empirical investigation.

But there is a further factor which has a major influence on the equation: population growth. A given standard of living may be supportable with less resource inputs over time, but if population grows rapidly the effect of the increased demand for resources can quickly 'swamp' such efficiency gains. Since the world's population is growing very fast, and since there is little prospect of slowing it down by deliberate management, resource depletion is more, rather than less, likely. Notice that we do not need to embrace ideas of 'catastrophe' or 'doomsday' when looking at the consequences of resource depletion. Our interest is in whether improvements in the

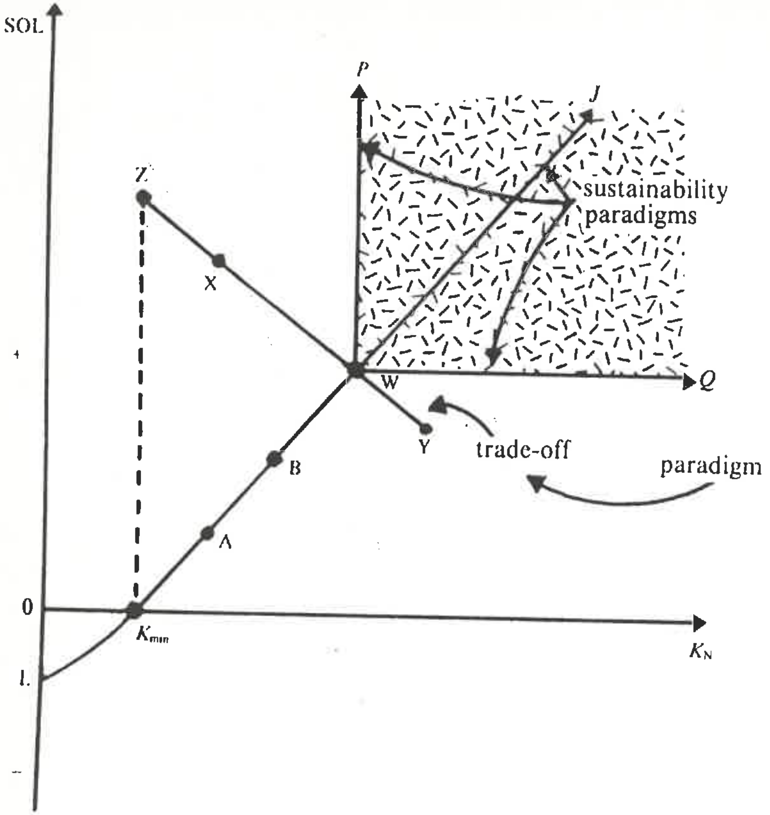

Figure 3.1 Paradigms of environment–standard of living relationships.

average standard of living can be achieved if the stock of natural resources declines.

Figure 3.1 shows how the issue might be characterised. The vertical axis shows the standard of living (SOL) while the horizontal axis shows the stock of environmental resources, or 'natural capital' (K_N). The origin 0 is best interpreted as some positive subsistence standard of living, so that reductions to the negative part of the vertical axis imply serious reductions in livelihoods, nutritional decline, extreme poverty and perhaps starvation at point L; K_{min} corresponds to a minimum level of the natural capital stock necessary to meet the subsistence standard of living. Two extreme views about the relationship between natural capital stock and the SOL can now be illustrated.

The first view suggests that for economies with low levels of K_N, improvements in the SOL can only be achieved by increasing natural capital. Natural capital growth and SOL are to be viewed as *complements*. An illustrative path by which such poor economies can develop, then, is shown by $K_{min}WJ$ which we refer to as a 'sustainability paradigm'. Once the economy has 'taken off' and reaches, say, point W then it might be possible to improve the SOL by operating anywhere in the shaded section *PWQ*, i.e. expanding the natural capital stock or at least keeping it constant. But, while a path of development (raising the SOL) in which natural capital *declines* might be feasible it can only be temporary. Development and environment are complements.

The second view is the more traditional one and is referred to as the 'trade-off' paradigm. What happens here is that the economy is always at a point like W, and development can *only* be secured by surrendering some K_N for improvements in the SOL. The path is something like XWY. If we want more environment, the SOL as defined here must decline. If we want more SOL, natural capital must be reduced. On this view, the same situation occurs at A or B, i.e. the trade-off situation is always relevant.

Within these extremes there is any number of variations. On the assumption that all would agree on the K_{min} concept, the trade-off situation might not be relevant until a point like W has been reached. Then, SOL increases can be achieved by travelling from W to X to Z at which point minimum natural capital stocks are reached again. On this variant, then, environment and development are complements only in the early stages of development. Once take-off is achieved, they become substitutes but with the caveat that they can be traded off against each other only up to a certain limit, and only for certain environmental functions. Thus it is easy to see how environmental *amenity* trades off against development, but the life-support and waste assimilation functions of natural environments are not substitutable. This composite view might be regarded as relevant to modern-day development issues. In the Sahel, for example, it is difficult to envisage development without natural resource augmentation. In the richer nations of the West, development and some environmental services may trade off against each other. The relevance of K_{min}, however, could be significant, as with the effect of trace gases on the ozone layer, the effects of fossil fuel burning on atmospheric carbon dioxide (the 'greenhouse effect'), and so on.

Figure 3.1 is meant to be illustrative only. But is raises the question of how a path like WXZ, in which natural capital declines, is feasible if our interest is in a sustainable economy. We have already suggested one way in which such a path could be consistent with sustainability – increases in the efficiency with which resources are used. The primary source of such changes in efficiency is technological progress. But we should not think of technological change as a 'free good' – it too brings side effects. Fossil fuel burning was a major technological advance, but it has also brought us problems of pollution. We also noted that population growth could adversely affect the chances of moving on to a path like WXZ in Figure 3.1.

One other type of substitution needs to be considered in this context. Economists speak of substituting man-made capital (K_M) – machines, factories, roads – for natural capital. Indeed, traditional economic growth has proceeded on this basis: machines have substituted for animal power, electricity for fuel wood, artificial fertilisers for organic manures, and so on. If this is true natural capital may be inessential for raising the SOL. In terms of Figure 3.1, the path WXZ can be achieved by surrendering K_N for K_M. If the two types of capital were equally productive of increments in SOL we would be indifferent between them, or we might favour K_N for other attributes – its aesthetic qualities for instance – but if K_M can be demonstrated to be more productive, then the choice may favour K_M.

[illegible]

3.3 MAINTAINING THE NATURAL CAPITAL STOCK

The discussion above suggested two reasons why the idea of maintaining the natural capital stock need not, after all, be essential to a sustainable economy: technological change which improves the efficiency of resource use, and the substitution of more productive man-made capital for natural capital. These issues need to be considered further in the context of a more general rationale for conserving and augmenting natural capital.

K_M and K_N substitution / problémák a [illegible]

1) One immediate problem with the distinction between K_M and K_N is that man-made capital is not independent of natural capital. The latter is often needed to make the former. Recall the First Law of Thermodynamics from Chapter 2: this reminded us that to produce anything we must consume some natural resources. The idea of substitution might be rescued if we can demonstrate that the extra productivity in K_M outweighs the extra natural resources that get used up in the production of K_M. At this stage all we can say is that this is not obvious.

2) The second caveat about K_M and K_N substitution is that natural capital fulfils other economic functions. The natural capital we are talking about includes the world's tropical forests, ocean habitats, wetlands and fisheries, atmosphere and stratospheres, and so on. In all cases there are life support functions which are not served by man-made capital. These include climate regulation, watershed protection and the maintenance of the stock of biological resources. To say that K_M is more 'productive' than K_N thus begs the question to some extent, for it is important to deal with the multifunctionality of natural resources, a feature not shared by man-made capital. To this factor we have to add differences in the pollution profile of the two types of capital: using fossil-based electricity is more polluting than using solar energy. Even the once dreamed-of clean and cheap nuclear energy is no longer regarded in the same light.

3) The third caveat is that substitutability may not be relevant to all natural resources. Neoclassical economics tends to work with the idea of fairly smooth substitution between inputs. It is because of this substitution that it is possible, analytically anyway, to obtain results which reduce the emphasis we might wish to place on natural resources. But natural resources are not like other resources in that their many functions include their role in, for example, the maintenance of biogeochemical cycles in the environment and on which mankind depends. Only if we can substitute wholesale for these functions can we sustain the idea of trading off between K_M and K_N.

Technological progress / problémák a [illegible]

Even if the substitutability between types of capital is brought into question, we are left with technological progress as a way of reducing the natural resource input to SOL generation. There can be no question of the importance of this source of increased efficiency. Past visions of the future in which communication does not require resource-intensive travel by automobile, aeroplane or train are now real as information technology advances. The caveats are two-fold. First, new technology is not necessarily less polluting. Second, will technological progress continue for ever, or at least for a very long time? Mankind's inventiveness shows little sign of abating. If anything it has increased in the twentieth century. But the most optimistic view of the role which technology plays in freeing us from dependence on natural resources depends on some almost indefinitely renewable resource which eventually takes over when exhaustible resources have gone. In the literature this is often called the 'backstop technology'. Several technologies have often been cited as backstop technologies: energy from fast-breeder reactors, energy from fusion reactors, energy from converting shale oil. One observation is that fast-breeder technology has been run down in at least one country (the United Kingdom) because of expense and lack of promise. Fusion reactors appear to be no nearer a backstop technology than they were, and grave doubts have been expressed about their environmental cost. The point is not a categorical one. There may indeed be backstop technologies that will free us from natural resources, but they cannot be brought into existence simply by assuming that they are there.

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Sustainability, uncertainty and irreversibility

One of the problems of reaching very definite conclusions about the role which natural environments play in supporting and sustaining economic systems is that we face considerable scientific uncertainty about that role. We do not understand fully how trace gases function in the atmosphere and stratosphere; the chemistry of acid rain is still being developed; the role of ocean currents in climate determination is open to debate, and the ways in which natural forest stands protect soils, rivers and microclimates still need more research. If we could be sure of the benefits of substituting man-made capital for natural capital then the trade-off between them would not be a serious one. But we are not sure of the ways in which environments function, either internally or in terms of their interactions with the economy. Moreover, if we do decide to surrender natural capital there is often a sting in the tail: irreversibility. If we make a mistake, very often we cannot correct it afterwards. Tropical forests cannot be created, feasibly anyway. Desertified land is very difficult to reclaim. Once a species is lost it has gone forever.

The presence of uncertainty and irreversibility together should make us more circumspect about giving up natural capital. As information and understanding increase so the trade-off decision might be made with more certainty about the consequences. Until then, caution should be the order of the day. In terms of Figure 3.1, the trade-off curve ZXWY is flatter: reductions in K_N may achieve only limited sustainable increases in SOL. This issue of valuation of environmental services will occur again several times in this book.

Resilience

/elasticidade

Considerable attention has been paid in recent years to the problems faced by the poorest countries in the world. Invariably they rely on natural resources far more directly than those of us in advanced economies. Fuel usually means fuel wood, water comes directly from surface and ground water sources without treatment, shelter requires wood, food supplies depend on subsistence agriculture and hence on soil quality. The sustainability of these societies depends on the maintenance of the stocks of these natural resources. Yet a stock can be maintained and the society can still be non-sustainable because the margin of flexibility is so low. It may require just a few years of drought, one war, one dramatic crisis, for the society to be set back many years in terms of its development prospects. If resource stocks were bigger there would be a greater margin of flexibility to adjust to these external 'shocks'. Since man-made capital is frequently not available in these societies we cannot argue that man-made capital would ensure as much if not more resilience. It might, but the option is not there. In these circumstances, more natural capital can mean more resilience to shocks and hence a more sustainable society.

Intergenerational equity

Another reason for maintaining the resource stock is to ensure broadly equal access to it by different generations. Intergenerational equity relates to the idea of fairness or justice between different generations. If it is accepted as a social goal – an issue that is discussed in Chapter 14 – then maintaining K_N has added force. Once again, it must be recalled that we can create and destroy K_M, but the possibilities of increasing K_N are less. We can grow more trees, set land aside to revert back to wilderness, restock the oceans. But in many cases the environmental losses incurred are irreversible. Any irreversibility now means the removal of an option for future generations – they cannot secure access to the resource if it has been made extinct.

Rights in nature

No one doubts that humans have rights. But do other sentient beings also have rights? The animal rights movement may not appeal to everyone, but it does advocate rights for sentient beings using arguments that cannot be regarded as silly. But if we accept that animals have rights, ~~one of those rights must~~ be to existence in order to exercise other rights. When we destroy natural capital we are invariably destroying habitat, the environments that wild animals require for their existence. Reducing K_N is thus likely to conflict with animal rights, and this deserves consideration as a further argument for protecting K_N. Chapter 14 explores the issue further.

3.4 THE MEANING OF CONSTANT CAPITAL STOCK

Our discussion so far has suggested that sustainability can be analysed in terms of a requirement to maintain the natural capital stock. This requirement ensures that we observe the 'bounds' set by the functioning of the natural environment in its role of support system for the economy. How far it is possible to relax this requirement depends on what we believe about the degree of substitutability between renewable and exhaustible resources, and between man-made capital and natural capital. It also depends on the behaviour of technological progress in reducing the resource input to a unit gain in the standard of living, and on the effects of population growth in dissipating the capital stock. There can be no hard and fast conclusion here, but the issues must be raised if we are to understand better the thrust of some of the modern environmentalist movement. Moreover, we need to express these arguments about sustainable development in terms of the underlying economic concepts.

We have talked about the requirement that the natural capital stock be constant. We have not explained what this might mean.

There are several interpretations. First, we could say that the capital stock is constant if its physical quantity does not change. But we have no way of adding up the different physical quantities (tonnes of coal, cubic metres of wood, litres of water, etc.). The standard economic approach would be to value each type of resource in money terms and compute the overall aggregate money value. If this could be done, in the same way as we make estimates of the 'national wealth' – i.e. the stock of man-made capital – then we could rephrase the K_N requirement in terms of a constant real value of the stock of natural assets.

Second, we could think in terms of the unit value of the services of K_N. That is, we could look at the prices of natural resources and aim to keep these constant in real terms. Provided we are satisfied that prices reflect absolute scarcity – an issue discussed in Chapter 16 – constant real prices will imply a constant natural capital stock in this modified sense. One obvious problem here is that many resources do not have observable prices. We would need to find implicit or 'shadow' prices in some way.

Third, we could think of a constant value of the resource flows from the natural capital stock. This is different from constant prices because we would allow quantity to decline but the price to rise, keeping value constant.

3.5 EXISTING AND OPTIMAL CAPITAL STOCKS

Conserving the natural capital stock is consistent with several situations. The stock in question might be that which exists at the point of time that decisions are being taken – the existing stock – or it might be the stock that should exist. The latter is clearly correct in terms of the application of neoclassical economics principles to resource issues. Economics would argue that there are costs and benefits of changing the natural capital stock. If it is reduced it will be for some purpose. For example, much tropical forest clearance takes place for agricultural purposes. Wetlands are similarly drained to gain the fertile soil for crop growing. Natural habitats are reduced for housing development, and so on. Thus, each destructive act has benefits in terms of the gains from the use to which the land is put. In the same way, using the atmosphere or the oceans as 'waste sinks' has benefits in that alternative means of disposal are often more

Stock of [illegible]

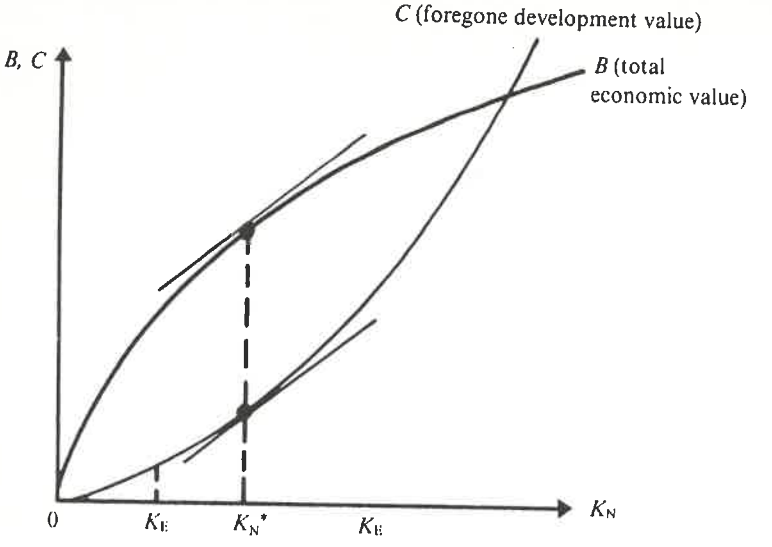

Figure 3.2 The costs and benefits of environmental change. K_N is the natural capital stock. *B* shows the benefits from increasing it, benefits that accrue as use and non-use values. *C* is the cost of increasing the natural capital stock and these stocks are the foregone benefits from using the natural assets for some other purpose. K_N^* is the optimal stock.

[illegible]

expensive. The environment as a waste sink thus reduces production and consumption costs compared to what they would have been. Environmental destruction also has costs since a great many people use natural environments (for wildlife observation, recreation, scientific study, hunting and so on). These 'use benefits' are lost (i.e. there are costs of destruction) if the land is converted for some other purpose. Similarly, one of the benefits of keeping the atmosphere unpolluted is that we avoid the damage that is done by pollution, e.g. better health, and globally, the avoidance of impacts such as global warming through trace-gas emissions. Natural environments do not just have 'use values'. Many people like to think of environments being preserved for their own sake, an 'existence value'. These 'non-use' values need to be added to the use values to get the *total economic value* of the conserved resource or environment (see Chapter 9).

Figure 3.2 depicts the cost–benefit comparison. The stock of natural assets is shown on the horizontal axis and costs and benefits are shown on the vertical axis. The cost curve shows that as the stock of natural capital (K_N) increases there are increasing costs in the form of foregone benefits from *not* conserving the environment. The benefit curve captures the benefits to users and non-users of natural environments. Economic analysis would identify K_N^* as the optimal stock of the environment. If the existing stock is to the right of K_N^* then it will be beneficial in net terms to reduce the stock, i.e. to engage in environmental degradation and destruction. If the existing stock is to the left of K_N^* then improvements in environmental quality are called for.

If our overview of the meaning of sustainable development is correct it appears to be inconsistent with the idea of maintaining optimal stocks of natural assets, or, at least, it will only be consistent if we are to the left of the optimum depicted in Figure 3.2 (since sustainability is consistent with increasing environmental assets) or coincident with it.

① Several observations are in order. First, existing stocks would generally be regarded as being below optimal stocks in many developing countries. For some Sahelian countries they are significantly below the optimum in that desertification and deforestation actually threaten livelihoods. Nor is there evidence that the further reduction of soil quality, tree cover or water supplies will result in some form of surplus which can be re-invested in other, man-made capital assets. To some extent, therefore, deliberations about what precisely constitutes an optimum are redundant in the contexts of these countries.

② The second observation relates to the identification of the 'optimum' in Figure 3.2. To say that capital stocks 'should' be optimal is tautologous. The interesting feature of optimality is how the benefits of augmenting natural capital are calculated. The critical factor here is that the multifunctionality of natural resources needs to be recognised, including the role as integrated life-support systems. Thus, a cost-benefit analysis that compares the 'value' of, say, afforestation with the opportunity cost of land in terms of foregone development values needs more careful execution than might otherwise appear to be the case. How far life-support functions such as contributions to geochemical cycles can be captured by cost-benefit is open to question. In the face of uncertainty and irreversibility, conserving what there is could be a sound risk-averse strategy. Put another way, even in countries where it might appear that we can afford to reduce natural capital stocks further, there are

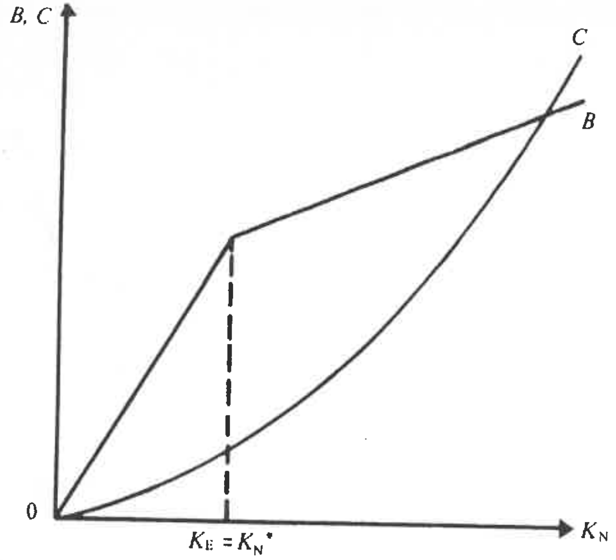

Figure 3.3 Costs and benefits of conservation when the valuation function is kinked. The benefit function of Figure 3.2 is now kinked at the existing stock of natural capital, making the existing and optimal stocks probably coincident.

risks from so doing because of (a) our imperfect understanding of the life-support functions of natural environments, (b) our capability to substitute for those functions even if their loss is reversible in theory, and (c) the fact that losses are often irreversible. There is therefore a rationale in terms of *uncertainty* and *irreversibility* for conserving the existing stock, at least until we have a ~~clearer~~ understanding of what the ~~optimal stock~~ is and how it might be identified.

③ A third observation is that optimality tends to be defined in terms of economic efficiency, whereas conservation of the natural capital stock serves other social goals. That is, Figure 3.2 is helpful as far as it goes, but it does not embrace the 'non-efficiency' benefits of natural capital stocks. These include serving certain distributional goals, both within current generations and between current and future generations. Of course, we have to be sure that these non-efficiency goals cannot be served better by converting natural capital into man-made capital, an issue to which we return.

④ A fourth reason for supposing that existing stocks are important arises from recent research on the use of willingness-to-pay and willingness-to-accept measures of benefit (see Knetsch and Sinden, 1984). A simple conceptual basis for estimating a benefit is to find out what people are willing to pay to secure it. Thus, if we have an environmental asset and there is the possibility of increasing its size, a measure of the economic value of the increase in size will be the sums that people are willing to pay to ensure that the necessary land or other asset is obtained. Whether there is an actual market in the asset or not is of no great relevance. We can still find out what people would pay if only there was a market (see Chapter 10). In the same way, if there is to be a reduction in the size of the asset, we can ask what people are willing to accept to give it up. Economic theory predicts that the difference between these willingness-to-pay and willingness-to-accept measures (the 'equivalent and compensating variation' measures of welfare gain) will not differ significantly. That is, a measure of willingness to pay for a small gain will be approximately equal to the requirement for compensation to give up a small amount of an asset. Empirical work suggests otherwise, with very large discrepancies between willingness to pay and willingness to accept being recorded. Prospect theory offers a rationale for compensation requirements being very much larger. Essentially, what exists is seen as a reference point and attitudes to surrendering some of what is already owned or experienced are quite different to those that come into play when there is the prospect of a gain. Put another way, the valuation function *B* in Figure 3.2 is 'kinked' at the existing stock of assets. The result of modifying Figure 3.2 is shown in Figure 3.3. The existence of the kink means that the optimal level of K_N is likely to be at the point of the kink: existing and optimal natural capital stocks coincide. In terms of the 'constant capital' idea in sustainable development, it implies that a high valuation should be placed on reductions in the existing capital stock, thus supporting the view that conservation of existing stocks itself has a high priority.

Overall, while there is a powerful case in analytical economics for thinking in terms of maintaining optimal rather than existing natural capital stocks as the basic condition for sustainability, there are also sound reasons for conserving at least the existing capital stock. For poor countries dependent upon the natural resource base, optimal stocks will in any event be above the existing stock. In other cases there is a rationale in terms of incomplete information about the benefits of conservation (the failure to appreciate and measure multifunctionality), uncertainty and irreversibility for conserving the existing stock. Additionally, resource conservation serves non-efficiency objectives whereas optimality tends to be defined in terms of efficiency only. Finally, even in terms of efficiency, the existence of a valuation function which is kinked at the existing endowment of natural resources adds emphasis to the conservation of existing stocks.

PART II

THE ECONOMICS OF POLLUTION