CHAPTER 1

A PREVIEW

1. The role of natural resources in the functioning of an economic system has received intermittent attention from economists. The classical economists of the nineteenth century were very much concerned with this issue: both Malthus and Ricardo saw in a country's land the key to many characteristics of its economy. However, in the considerable developments of economic theory that have occurred in the twentieth century, there has been little explicit mention of natural resources. These differences are perhaps not surprising. In the eighteenth and nineteenth centuries, the ownership and productivity of land were evidently of great importance in determining the distribution of income, and the timing and location of the industrial revolution in the United Kingdom were clearly influenced by the exhaustion of certain traditional resource supplies and the availability of alternatives. To nineteenth-century man, it would therefore have seemed unthinkable that one could explain the dynamics of an economy, or analyse the processes of production and exchange, without giving special attention to the role of natural resources.

The economic theorists of the twentieth century have, however, proceeded on the basis of just such an omission, at least until recently: in the works that have exercised a dominant influence on the evolution of economic theory in the last half century—Hicks's *Value and Capital*, Samuelson's *Foundations of Economic Analysis* and the developments of the Arrow–Debreu model—there are few explicit references to natural resources. And indeed one could read the whole of the very extensive literature of the 1950s and 1960s on economic growth in the long run without ever realizing that the availability of natural resources (other than labour) might be a determinant of growth potential. The lack of direct reference to resources in this literature presumably reflects the fact that for the first two-thirds of the twentieth century, resource constraints were not important for most industrialized nations: these either possessed their own resource supplies, which they regarded as adequate, or

felt that they could be confident of importing resources in unlimited amounts from developing countries, initially because in many cases they controlled these countries as part of the colonial system, and subsequently because, although independent, the supplying countries remained politically quiescent, with foreign exchange needs so great that they could be counted on to supply unlimited quantities of their principal (and often only) exports.

The wheel has now turned full circle: in the last quarter of the twentieth century, no general text on economics will be complete without a reference to resource depletion. There are many reasons for this abrupt change: some authors would argue that it reflects a shift in the balance of political power between developed and developing countries, and others that it reflects a change in the economic balance in resource markets—a change which will no doubt bring in its wake changes in many traditional political balances. We examine one of the most notable exemplars of this phenomenon—the oil market—in some detail in Chapter 15. The revival of interest in the economic aspects of resource-depletion has been accompanied by some rather widely publicized claims that the tools of economic analysis as forged over the last half century fail to provide an adequate intellectual basis for tackling the problems that arise: we need, or so it is said, newer, more glamorous, more capital-intensive tools such as systems analysis. We hope that our book will disprove this point. It is true that the tools of economic analysis cannot solve all the problems in this area, but this could of course be said of any field of enquiry. However, the important point is that, although economic theory as elaborated in recent years contains very few explicit references to the role of natural resources, it does, occasionally with modification and extensions, provide a very productive framework within which one can analyse many of the questions of current concern—questions such as 'Will the free play of market forces lead to a use of resources that is in any sense rational? Is there a case for government intervention, or even extensive national planning, in relation to activities impinging on resource-use? What are the particular problems in planning such activities?'

Interest in these issues was also stimulated by the appearance of Forrester's book *World Dynamics* and by the subsequent publications of the Club of Rome. These provoked two vocal reactions, neither of which seems entirely appropriate, given the state of our knowledge. There are those who, being persuaded by the numbers in the world models, are convinced that doom lies in wait at the end

of the century—unless we act. But when this action is detailed as cutting industrial production and asking developing countries to forgo industrialization, initial sympathy with this concern for the human plight is greatly diminished. We do not profess to know if doom lurks around the corner (for many people round the globe, it is perhaps this side of the corner), but it is clear that the economics of the world models is, to say the least, questionable. There are many central issues concerning the nature of production with exhaustible resources and the role of the price mechanism, which are totally overlooked. Subsequent chapters examine these in some detail.

Partly in response to this apocalyptic vision is the other reaction to the exhaustible resource problem. This is that there is really no problem. As resources become scarce, their prices will rise, and this encourages entrepreneurs to search for cheaper substitutes. Of course there is uncertainty about the success of this search, but the point is that the market generates signals and incentives which ensure that discovery and substitution are carried out at an appropriate intensity. This too is an overly simplistic view, neglecting many major complications connected with the behaviour of markets under conditions of uncertainty and endogenous information. These are also issues that we shall subject to careful scrutiny. Indeed, we now turn to a preview of these and other relevant issues.

2. There are many economically important commodities that could be described as natural resources—land, oil, coal, ores, precious stones, fish populations, areas of scenic beauty, and so on. Our attention in this book is directed not at all of these, but only at those that might be described as exhaustible resources. A resource is exhaustible if it is possible to find a pattern of use which makes its supply dwindle to zero. Obviously oil, coal and ores are exhaustible resources, in that the world's total endowments of these, though large, are certainly finite. Typically the amount available at any given cost increases with the cost, and in some cases may become very large indeed at sufficiently high costs—as in the case of the extraction of minerals from sea water. A fish population is also an exhaustible resource. Although it can potentially reproduce itself or even expand, very intensive fishing can certainly reduce it to zero. Perhaps fertile land is also an exhaustible resource in this sense: if it is over-cropped and badly maintained, soil erosion may reduce it to a wasteland—as happened several millennia ago in parts of what is now the Sahara desert. At certain stages of our analysis,

it will prove convenient to distinguish between these two classes of exhaustible resources: we shall do this by referring to the former (oil, minerals, etc.) as strictly exhaustible resources and to the latter (fish populations, possibly land) as renewable resources.

The analytical problems that arise when one starts to ask questions about the depletion of exhaustible resources are extremely wide ranging, and involve many facets of economic theory. Thus, in many cases important issues hinge upon the nature of property rights in the resource. It is often difficult to establish such rights, yet their absence may lead to excessively rapid depletion. This point is exemplified by the case of fish populations: it has long been recognized that unrestricted access by competing fishermen leads to considerable externalities between them (the more one catches, the less is available to others), and hence to a private marginal product in excess of the social, and an over-allocation of resources to fishing. There is also the point that if each boat, or fleet, believes that its competitors will not operate a policy designed to conserve fish stocks for future years, then there is no incentive for it to pursue such a policy itself: for conservation would mean reducing its present catch below the maximum attainable, which in the conditions posited would simply lead to an increase in competitors' catches. Hence whether market forces produce a 'sensible' use pattern for fish populations will depend substantially on the institutional structure within which those forces are constrained. We analyse this kind of issue at some length in Chapters 3 and 5. Oil fields can provide another example of the same problem: if competing companies sink wells into the same oil-bearing rock formation, then there are again externalities between them, which may again reduce the incentives to conserve the stock. Certain states in the USA have passed legislation which is essentially designed to restrict the kinds of property rights that can exist in oil fields, with a view to ensuring that all such externalities are internalized.

Analysing the dynamics of an economy with exhaustible resources requires that one give considerable attention to the nature of the set of consumption paths open to such a system. This in turn requires very careful consideration of the technology of resource use. An intuitively appealing conclusion, and one which is clearly implicit in the various world models of Forrester, Meadows and others, is that if a resource is in some sense 'essential' and is available only in a finite amount, then on all feasible paths consumption must necessarily decline to zero. We shall show that, plausible though this

view seems, it may be false. Capital-resource substitution (or 'stock-flow substitution' in the terminology of some of the conservationist literature) may be sufficient to overcome the 'drag' imposed by an essential and exhaustible resource.

Another puzzle whose resolution also hinges upon a careful analysis of the technology of resource use is that of the relationship between economic and thermodynamic concepts of efficiency in the use of resources, particularly energy resources. This has been the source of some confusion in the last few years—probably unnecessarily so, as there are several relatively simple points that can be made about this relationship. All of these essentially technological issues are considered in Chapter 7.

The efficiency with which a market system allocates exhaustible resources between competing uses at different dates is probably the most important single aspect one might wish to analyse. We may be more concerned to achieve a sensible allocation of our oil stocks between present uses and those a generation hence than we are to achieve such a balance for our present stocks of consumer durables; perhaps the reason is that we expect to be able to make more of the latter at future dates if the need arises. Obtaining the correct intertemporal balance does seem to be the crux of the 'problem of exhaustible resources' as usually viewed by the public and by policy makers. Asking whether the market system will strike such a balance takes us into the domain of intertemporal welfare economics. Again, the answer depends very much on the institutional structure of the market system. Certainly one can devise market structures which will get the balance right, but they are very complicated and rather different from the ones we actually have. Specifically, one element of the sufficient conditions for a market system to produce an optimal allocation of exhaustible resources over time is that it should contain a complete set of forward markets, i.e. that there should exist markets on which it is possible to buy and sell the right to have the resource delivered at any future date. Although actual market systems do contain some forward markets, and those that exist are typically for homogeneous non-produced goods such as resources, this complete condition is certainly not met, and theoretical arguments would tend to suggest that as a consequence resource markets may be unstable, and will almost certainly display 'market bias', in the sense of depleting the resource at a rate different from an optimal rate. It is obviously important to try to establish the nature of this discrepancy, and to consider the impact

on it of various policies open to governments. These include stabilization measures analogous to the schemes already used for certain agricultural commodities, and a range of fiscal instruments such as profits taxes, depletion allowances, and many others.

The non-existence of a sufficiently comprehensive set of markets is one reason for the existence of market bias; another is of course the more traditional problem of imperfect competition. This requires very careful analysis in an intertemporal setting. It has, for example, been argued that 'monopoly is the conservationist's best friend' because by raising the price of a resource and reducing its supply, it will ensure that the resource is depleted less rapidly than otherwise. We shall see in Chapter 11 that matters are a little more complex, though this simple argument is not entirely misleading. Of course, to be thorough, one has to consider forms of imperfect competition other than pure monopoly, and this as always introduces great complexity and a multitude of possible outcomes. All of these issues are taken up in the central part of the book, and especially in Chapters 4, 6, 8 and 11.

The importance of the time dimension in the present problem suggests very naturally questions about the *efficiency* of allocation over time; but one is at least equally interested in the question of intertemporal equity. If the present generation uses up the whole of the remaining stock of a resource, their successors may be impoverished because of this, Such a situation could be efficient, but many would regard it as grossly unfair. Anyone familiar with basic welfare economics will realize that efficient outcomes need not be equitable, and vice versa. Problems of equity arise in a particularly acute form in the present intertemporal context because those most likely to suffer from an inequitable outcome are those not at present available to press their case. Basic to the problem is a complete inequality in the extent to which the generations affected by a policy are capable of putting their case to those making the decisions. Hence, in analysing these issues, and in attempting to decide how, ideally, depletion should be arranged, we need to clarify our ideas about fairness between generations, and to spell out in detail the implications of these ideas. This forms the subject matter of Chapters 9 and 10.

Uncertainty provides a further complication that is an essential ingredient in any convincing formulation of our problem. It is not unique in this respect; most economic problems, if stated accurately, involve an element of uncertainty. However, as uncertainty is

typically compounded by increasing distance into the future, and we have already seen that our analysis must take into account considerations related to the relatively distant future, it is clear that uncertainty will loom particularly large. The balance that our economic system has to strike is between relatively clear-cut present needs, and some rather unclear future needs. The uncertainty about the future has many causes. Partly it stems from an inevitable inability to predict people's tastes and needs. But more specific to the particular problem in hand is uncertainty about future resource stocks and about future technology. The former arises because resource stocks are rarely known with certainty; there have been few periods in the last half century when there have not been important discoveries of many resources. Hence when deciding how fast to use up a resource, we have to realize that our estimates of its availability may increase or decrease over time, in an unpredictable manner. Evidence for the importance of this is provided by the fact that between 1953 and 1972, the world's proven oil reserves rose by a factor of 5·7, while oil consumption rose by a factor of 4. Of course, the evolution of known reserves is certainly not exogenous, but is a response to the allocation of effort to prospecting and development—itself a function of many factors, including expectations about future prices, the tax treatment of exploration expenses and the system used to allocate exploration rights amongst competing firms. Typically this is some form of competitive bidding, but there are many variations possible within this general framework. We discuss some of these issues in Chapters 12 and 14.

The importance of uncertainty about future technology should be self-evident: as a resource becomes scarce and its price rises, efforts to develop substitutes or to find processes which can function without it, or with only minimal amounts, are intensified. Oil again provides an example. One has only to consider the upsurge of research on alternative energy sources following the 1973 Arab oil embargo and the sharp price rises. Naturally, the choice of a depletion policy should depend upon the likelihood of success in these ventures, so that important elements of uncertainty have once again to be confronted directly. These issues are considered at length in the context of a market economy in Chapter 13, and within the framework of a planned economy in Chapters 14 and 16.

3. The foregoing paragraphs have described, admittedly in rather summary form, a sample of the issues we hope to raise in the follow-

ing chapters. We would not claim to be examining all of the questions that arise in connection with exhaustible resources. We are deliberately concentrating on a range of theoretical issues concerning the performance of the mechanisms by which these resources may be allocated. While many of the empirical questions relating to the likely availability of extra resource supplies or to the chances of technological changes of a major type have been adequately, though perhaps not definitively, studied, there is need for a theoretical framework within which this data can be evaluated. We hope that the arguments of this book go some way towards constructing that framework.

There is another important class of questions that we shall also consider: these are questions relating to what one might describe as the political economy of resource depletion. This is in itself a complex set of issues with many dimensions. Amongst these are strategic issues relating to security; many governments place great importance on being able to control their supplies of resources, a tendency that has been greatly reinforced by turbulent events in the oil market in 1973. This aspect of the political economy of the problem is amenable to our analytical approach; the emphasis on security of supply as an objective of policy could be regarded as a rational response to uncertainty by risk averse governments. One could see it as an attempt to minimize the greatest economic damage that a hostile trading partner could inflict, or to minimize the bargaining power of such a partner. It is analogous to what game theorists know as the 'maximin' strategy in a game of conflict.

Several strands of this complex of problems are concerned with the international distribution of income. Ownership of a large fraction of the world's stock of a resource gives a country, or group of countries if they collaborate, very substantial monopoly power which they may exploit to effect a considerable transfer of income to themselves. This in turn influences relative rates of development, diplomatic relations between buyers and sellers, and the political and military standing of the sellers. One need look no further than the Organization of Petroleum Exporting Countries for illustrations of all these points; and there seems to be little doubt that similar organizations for other resources will follow in the future. The rate at which stocks of a resource are depleted does, of course, influence the chances of such a cartel being formed.

The point is that as stocks are depleted, those remaining tend to become concentrated in a decreasing number of countries, and in

general the smaller the number of countries involved, the easier it will be to organize a really effective cartel. The reduction in numbers makes communication and organization easier, and increases the chances of finding that degree of political homogeneity without which successful collaboration is highly unlikely. These chances are further heightened by the fact that the first stocks to be depleted are usually those nearest to the consumers, i.e. those in the developed consumer countries. And these are just the countries likely to use their power to break a cartel. The history of OPEC again provides an interesting example of these points: although formed in the early 1960s, its bargaining power remained minimal until consuming countries became seriously worried about long-term supply problems, and was given a considerable boost by the rapid passage of the USA from self-sufficiency in oil to substantial dependence on imports in the early 1970s. (This process is examined in some detail in Chapter 15.)

These and related issues could clearly be pursued at much greater length, and in due course they will be. However, we hope that we have at present said enough to whet the reader's appetite for the more formal and precise analysis of these issues that begins in the next chapter.

4. We wish to end this introductory review by making quite explicit a methodological point which is at least strongly implicit in what follows, but which nevertheless merits distinct and emphatic statement. In much of the succeeding analysis, we make a substantial number of simplifying assumptions, and consequently work with relatively simple models, typically involving no more than four or five variables. The methodological point is that this is not a choice that is forced on us by a desire to maintain comprehensibility by a broad audience. It is a deliberate choice based on the belief—confirmed by the common experience of many members of our profession—that for the purposes of developing a deep and intuitive understanding of the complexities of an economic system, it is best to abstract dramatically and consider only a skeletal representation of the key factors and their interactions. Obviously, which are key factors and which are subsidiary, is in the first instance a matter of judgement, to be verified or rejected by empirical studies. What one aims at in constructing an economic model, whose purpose is the development of understanding at a basic conceptual level (as opposed for example to the prediction of the values to be assumed

by a particular set of variables at a future date), is to strip away detail and in the process sacrifice precision, in order to grasp at general principles which would be obscured but by no means invalidated by the inclusion of detail. What one aims at in other words is the construction of a framework which is simple enough to reveal the principles at work but whose basic structure is robust to the kinds of additions and extensions generally needed to implement the analysis in any particular situation. Such an approach is very much in the spirit of a tradition of economic analysis, running from Adam Smith through Keynes to the present, but is sometimes found a little surprising by those inexperienced in the field. It is primarily for this reason that it has seemed to us to merit explicit notice.