CHAPTER 1

Introduction

1.1 The problem of external effects

From the innocent parable of the bees to the poisonous gas clouds of Bhopal, environmental external effects are evidence of the price system's inability to signal the true significance of the interdependence of human activities undertaken within a common environment. They are the ex-post measures of the environmental effects of activities launched in a state of deliberate or accidental blindness as to their consequences. Although external effects are all-pervasive, it is by no means universally accepted that they constitute a significant "problem" for economic theory. Like the social costs of racism or sexism, external effects are not susceptible to exact estimation precisely because they are outside the price system, and whether one believes them to be significant is often argued to depend on one's ideological predisposition. This book seeks to demonstrate that environmental external effects represent fundamental flaws in the axiomatic structure of the dominant models of the economic system, and that the adoption of an appropriate axiomatic structure changes the properties of those models in an important way. More particularly, it alters both the conceptualization of the environmental management problem and the criteria for developing strategies to deal with it.

The modern theory of external effects stems from two seminal articles in the early 1950s by Meade (1952) and Scitovsky (1954). These articles established that the basis of external effects is the nonindependence of the preference and production functions of economic agents who operate within a common environment, but who do not meet in the marketplace. To Meade, we owe the useful distinction between external effects that are the product of the direct interdependence of producers or consumers, which he called "unpaid factors of production," and those that are the product of indirect interdependence, which he termed "creation of atmosphere." To Scitovsky, we owe the suggestion that time and uncertainty are key ingredients in the generation of external effects. The importance of both the directness of the interdependence of economic processes and the link between time and uncertainty will be recurrent themes in this work.

Ironically, although later authors declared themselves receptive to the explanation of the causes of external effects offered in these two articles, they have typically drawn a rather different set of inferences. Meade's recommended use of Pigouvian taxes and subsidies, and Scitovsky's implicit judgments as to the weighting of social over private rates of time preference in the face of uncertainty, have both fallen foul of the assurgent economic liberalism that underpins the currently dominant environmental strategy – the "market solution." Increasingly, the emphasis is on internalizing external effects through the allocation of property rights. Uncertainty is interpreted as risk, and so reduced to a problem in the theory of probability. The distinction between the time perspective of the collectivity and that of its individual members is trivialized, and the role allowed the collectivity whittled away.

This would cause no difficulty if it were not for the fact that the market solution can be shown to generate only increasing turbulence and uncertainty, a progressive myopia, and a heightened risk of conflict. By exploring the general problem of the time behavior of a jointly determined economy-environment system, this essay shows why. By probing the significance of time in our perceptions of the global system, it demonstrates that the positive discounting of the uncertainty of the future can lead only to greater uncertainty. The market solution exaggerates the very problem it is designed to remedy.

What is ultimately at issue are the properties of an environmental strategy that is duly sensitive to the physical constraints on economic activity, to the existence of uncertainty in the sense of Knight (1921), Shackle (1955), and Georgescu-Roegen (1971), to the limitations of the price system, and to the ethical imperative for being aware of the needs of future generations. This takes us into a very wide-ranging set of debates, initiated as early as 1848 with John Stuart Mill's *Principles,* and touching on problems in the theory of growth, time, uncertainty, welfare, depletion, and pollution. It asks us to rethink the questions raised by the Club of Rome report, *The Limits to Growth,* which were buried in the welter of accusations and counteraccusations that followed its publication in 1972. It asks that we pay closer attention to the extraordinarily suggestive work of Georgescu-Roegen, usually shrugged off by those who prefer to ignore the physical foundations of economic activity. Most important, it asks us to reconsider the fundamental environmental assumptions underpinning our theories of the time behavior of economic systems.

The problem of external effects exists because something has been left out or distorted in the description of the essential elements of reality summarized in the axiomatic structure of our models. Recognition that the problem may be significant is at once recognition that our models may be significantly flawed. Hence, the defensiveness of those who deny the significance of external effects is defensiveness over the "correctness" of the particular world view contained in the axiomatic structure of their models.

All deductive theory is necessarily limited by what may loosely be called the framework within which the arguments are worked out. This framework is given by the axiomatic structure on which the propositions of the theory are established. Since the propositions in deductive theory add nothing to the axioms and merely draw out their implications, the axiomatic structure or framework of the theory establishes the range of possible results. Hence, by selecting one set of axioms over another it is possible to ensure one set of results rather than another. The axioms of a theory in a very real sense contain its conclusions. The results on the existence and uniqueness of equilibrium in the dynamic models of general economic equilibrium turn out to be highly sensitive to the assumptions made about the role of the environment. Yet few assumptions of the general equilibrium models are challenged less frequently than those relating to the environment.

1.2 The environment in economic theory

Consider the identification of the economy and its environment. At the most general level, a human economy may be defined as a physical system of production organized according to a social system of signals. As a first approximation, we may define a physical system of production to be a mutually dependent set of material transformations, or processes, designed to yield a particular set of services. We may define a social system of signals to be a set of mutually consistent indicators recognizable to and guiding the behavior of a particular society. In the idealized market economy of theoretical economics the processes of the physical system are organized according to a very particular system of signals – the price system. In the "primitive" economies and, indeed, in most economies of the real world, the system of signals is invariably a composite of exchange values and a range of cultural or ideological codes of behavior. In all cases, though, it is the system of signals that sets an economy apart from the other systems of social production with which it interacts.

Nor is the economy unique in this respect. All forms of social production comprise a set of processes that, in principle at least, can be defined by the system of signals informing the behavior of the agents operating those processes. In other words, a system of social production contains all those processes controlled by reference to the relevant social signals. Because of the interdependence of systems of social production, however, it follows that one system of signals may overlap another. Indeed, the human economy is founded on activities that depend on the ability of human agents to manage the signals guiding the behavior of agents in other (subordinate) systems of production. if these signals are not controllable, then the outputs flowing from a well-defined combination of inputs may not be predictable. The material transformations that are the point of such activities may not be determinate.

The limit of human control in such circumstances marks the dividing line between the economy and its environment. Hence, if the agents of an economy are able to control all systems of production, no environment will exist. The environment may be said to be completely dominated by that economy. Conversely, if the agents of an economy are unable to control any system of production, that economy may be said to be completely dominated by its environment. In all cases it is notionally possible to describe the global physical system in terms of a referent system of production and its environment. The concept of an environment is thus very general. If we take the set of all the material transformations undertaken in the general system at a given moment in time to be the universal set and denote this by U, and if we define the material transformations of a given (referent) system of production, $O \subset U$, to be a subset of the universal set, then the complement of the referent set, $O^* \subset U$, is the environment of that set. Symmetrically, if O^* is the referent set, O is its environment.

Consider the environmental assumptions generally made in economic theory. It is worth noting at the outset that there is a marked difference between the environmental assumptions common to the majority of theories of the modern capitalist economy and those common to both anthropological theories of primitive economies and physiocratic theories of early-modern economies. The last two generally suppose the economy to be dominated by its environment, the former generally believe that the economy dominates its environment. The assumption of the dominant economy comes in two versions. The first may be called the *weak environmental assumption.* It supposes that an environment exists; that it is not completely dominated by the economy, but that it plays only a benign and passive role. The second may be called the *strong environmental assumption.* It supposes that the economy completely dominates its environment. It is tantamount to an assumption that an environment does not exist.

The weak environmental assumption is of older lineage, as one might expect. It represents a transitional assumption, a compromise between the assumption of a dominant environment made by the Physiocrats, and the assumption of a dominant economy that appears in at least one modern general equilibrium theory. The weak environmental assumption first appeared in the work of the classical political economists, but was not stated with any clarity until Marx's *Capital.* In this work we find the claim that "those things which labour merely separates from immediate connexion with their environment are subjects of labour spontaneously provided by Nature. Such are fish which we catch and take from their element, water, timber which we fell in the virgin forest, and ores which we extract from their veins" (1954, p. 174). They are the *free gifts* of the environment. The production process was, for Marx, a problem of environmental control, in which "man of his own accord starts, regulates, and controls the material reactions between himself and Nature. . . . Thus Nature becomes one of the organs of his activity, one that he annexes to his own bodily organs, adding stature to himself in spite of the Bible" (ibid., pp. 173–5).

The assumption of free gifts is one-half of the weak environmental assumption. The counterpart to the assumption of free gifts was not formally acknowledged until much later, although it is now standard in the dynamic general equilibrium models evolved in the wake of Neumann's classic (1945–6) paper. Not only is it assumed that the economy may expand without limit at the expense of its environment, it is also assumed that the economy can dispose costlessly of unlimited quantities of waste material within its environment. The environment is simultaneously a horn of plenty and a bottomless sink. The weak environmental assumption means both the assumption of free gifts and the assumption of the *free disposal* of wastes. The physical system under the weak environmental assumption may be represented by a description of all processes using or producing commodities, and only those processes. The environment need not be represented since it does not constrain the system except occasionally or incidentally. The mass of the output of the system may either expand or contact, since any matter required for new output may be freely obtained from the environment and any waste may be freely disposed of in the environment.

The strong environmental assumption is a later addition to the literature. It is never made explicitly, and is tenable only under the powerful assumption that the system is static. A system of production under this assumption is, in the words of the title of Sraffa's famous book, a system of *Production of Commodities by Means of Commodities.* All processes are controlled by agents responding to the price system. As we will see, change involving an increase or decrease in the mass of output implies the existence of some source of mass or some waste receptacle other than the economy. Indeed, if a system of production of commodities by means of commodities is rendered dynamic, it can neither expand nor contract. It is only if the system is assumed to be timeless that this does not matter.

In contrast to the strong environmental assumption, the weak environmental assumption allows the claim that a model encompasses all those effects of the interaction of economy and environment that are economically relevant, given the time horizon of the analysis. The environment may induce a degree of uncertainty, but the conventional argument since Debreu (1959) is that this may be accommodated ex ante by pricing for risk. If unforeseen but economically relevant effects do occur, then the argument developed by Coase (1960) is that these so-called external effects may be accommodated ex post through the allocation of property rights, without disturbing the basic assumptions of the resource allocative models. Environmental external effects are treated as an occasional or incidental problem. It is assumed that the environment is generally controllable, but that where the limits of environmental control are exceeded, the resulting of unforeseen costs or benefits accruing to agents in the economy can be negotiated away by the allocation of appropriate property rights.

The selective appeal to reality associated with the axiomatic structure of the dominant economic models is not without its critics. From a deductivist perspective Kornai (1972) has made a swingeing assault on the validity of a science that betrays such a cavalier attitude to the reality it is supposed to explain in the selection of its axiomatic foundations. From an inductivist perspective Leontief (1971) has condemned an approach that deliberately eschews the discipline of empirical verification. On the particular matter of the environmental assumptions of general equilibrium theory, the exclusion of the natural environment has been challenged in the numerous contributions that followed the work of Boulding (1966), Daly (1968), Ayres and Kneese (1969), Georgescu-Roegen (1971), d'Arge (1972), and the Club of Rome (Meadows et al., 1972).

Given the overwhelming empirical evidence that the natural environment does have a major impact on the economy that is not captured by the price system, the raison d'être of such work is readily intelligible. It is remarkable, however, how little effect it has had on economic theorists. This may be because the intellectual problem is much deeper than an awareness of the human propensity to foul the natural environment. Once we begin to conceptualize the behavior of economy-environment systems over time, unprotected by the assumption that the price system contains all the information we need to know, we find not the comfortable order of stable or relatively stable equilibria but a seemingly chaotic drive to change, paralleled only in the recent findings of physicists investigating the time behavior of structures far from equilibrium (cf. Prigogine and Stengers, 1977). More important, we observe little warrant for the simple Smithian faith in the invisible hand that underpins the market solution, and no warrant at all for the argument that forward markets will compel private interests to secure the information that renders the price system complete.

1.3 Toward a constructive theory of economy-environment interactions

The arguments of this essay are developed in discrete stages, with each corresponding to a different level of abstraction. Part I explores the time behavior of indecomposable physical systems bound by the laws of thermodynamics. The fundamental problem here is that alluded to by Meade: the significance of the physical interdependence of processes via some medium or environment. The analysis abstracts from the complications brought about by the social institutions and signaling system of the economy. It is concerned solely with the time behavior of physical systems. The importance of this in the general argument lies in that fact that the economic system, like any other system of production, rests on physical foundations. It must behave in a way that is consistent with physical laws. It is not, as the free gifts and free disposals assumptions would have it, exempt from those laws.

When working with the limited range of variables admitted at a high level of abstraction, it is convenient to draw out the implications of a particular set of assumptions mathematically. Part I develops a formal model to explore the dynamic behavior of a jointly determined economy-environment system that shares certain features with what has become a broad genus of economy-environment models based on the extension of the basic linear input-output model. Cumberland (1966), Daly (1968), Leontief (1970), Victor (1972) and Lipnowski (1976) have all produced models of this type. The most important feature shared with such models is the assumption, first made in the context of a general equilibrium model by Ayres and Kneese (1969), that a closed physical system must satisfy the conservation of mass condition. As Boulding had pointed out to economists in his celebrated 1966 paper, for all practical purposes matter can be neither created nor destroyed. The mass of resources potentially available for exploitation in the global system, or in any isolated part of the global system, is the same now as it was a million years ago.

Although the assumption of the conservation of mass is relaxed at points in this essay to consider the properties of particular subsystems within the general system, it represents the single most important general assumption of the work. Its implications are far from trivial. Interestingly, it is perhaps the least important of these implications that has attracted the most popular attention: the fact that the growth of any technologically stationary economic system will inevitably run that system up against Malthusian limits. By contrast, the most important implication has been almost completely neglected. It is the necessity for any system generating residuals in the process of production to change over time, to evolve from one state to the next as the residuals generated in production are returned to the system in either a controlled or uncontrolled way.

The traditional free gifts and free disposal assumptions deny both implications. If these assumptions are made, it is necessary to consider neither the limits to growth nor the evolutionary nature of the system. It is of some interest, therefore, that the free gifts and free disposal assumptions have been cornerstones in the development of the theory of the time behavior of economic systems. Only by ignoring the physical foundations of economic systems has it been possible to generalize the static equilibrium results of the Walrasian system to the dynamic case: to pretend to the relevance of equilibrium growth in a technologically stationary world. Neumann's (1945–6) model of general equilibrium, for example, proved to be of seminal importance in developing the theory of economic dynamics, yet it was built on an extraordinarily powerful set of assumptions about the ability of an economy to function independently of its environment. Although it was a remarkable tour de force in terms of the theoretical insights it yielded about the equilibrium growth properties of certain types of system, it was not even an approximate description of the environmentally open economies of the real world. The fact that it was subsequently treated as such – particularly by the string of contributions on the "turnpike" (cf. Turnovsky, 1970, and Tsukui and Marakami, 1979) – is evidence of the casual disregard for the validity of the assumptions of equilibrium models so vehemently criticized by Kornai. For theories based on deductive inference to yield practically relevant results (as opposed to abstract ideological goals), the axioms of those theories must correspond to the essential features of the real systems being modeled. Since the results of all equilibrium models of economic behavior are obtained by deductive inference on the axioms or assumptions of the models, they must satisfy these requirements to be taken seriously as explanations of reality. If they do not, these models can have the status of experiments only.

The difficulty with the traditional environmental assumptions is naturally most acute in dynamic models. Since the free gift and free disposal assumptions turn out to fail before the feedback effects of residual disposals in an indecomposable economy environment system, they are unsustainable except where such feedback effects are assumed to be too distant to be relevant. This may be a valid assumption in a static allocation problem (if it is ever legitimate to abstract from time in economic problems), but it cannot be so in any general dynamic model of economic behavior. If we are interested in the development of economic systems over time, we simply cannot ignore the effects of residual disposals other than controlled investment.

Accordingly, while the model developed here shares certain features of the Neumann model, it is not constrained by the same environmental assumptions. Instead, it explores the significance of the conservation of mass condition for the time behavior of jointly determined economy-environment systems without prejudging the ability of one to override the other. Moreover, the system is shown to be time varying. Although it shares the fixed production coefficient assumption of both the Neumann growth model and the input-output environmental models, it does not assume a static technology. Production coefficients are fixed only in the sense that the inherited technology in a given period will be embodied in a set of physical assets that bear a fixed proportion of one another. In a time-varying system those coefficients will change from period to period.

More important, perhaps, the conventional notion that there exists an initially complete book of blueprints from which are drawn the techniques of production applied in all future periods is argued to be untenable. This does not mean that there is no choice of technique, merely that choice of technique is not the only source of technological change. Future allocations in a jointly determined economy-environment system turn out to be unknowable in advance. Each allocation is the unique and unreproducible outcome of the disposal of a set of residuals that is beyond the control of the agents of any one subsystem.

I do not, therefore, begin with commodity production, the near universal starting point for theories resting on either the strong or the weak environmental assumption. I begin with production in general, where this refers to the material transformations undertaken by all agents in the system irrespective of their species. It represents the highest level of abstraction. I do not suggest that any real-world system of production is not specific to the time and place in which it occurs, but that it is useful to consider the elements that different systems of production have in common. In no other way can we see how the material tranformations of one system may limit those of another, regardless of differences in the rules of the game in each.

Part II considers the structure of the price system, and the role of prices in signaling resource scarcity. Once again, the properties of the price system depend on the fact that I seek to describe the time behavior of a jointly determined economy-environment system. To this I add the supposition that the system is subject to contest over both the appropriation of property (in resolution of external effects) and the distribution of returns to property (in sympathy with the classical models). The price system is assumed not only to ration a given set of resources at a given moment in time, but to discriminate between resources that are subject to rights in property and those that are not, and to mediate the conflicting claims to the social product of distinct classes of economic agent. It thus admits a broader set of functions than is common in models built on strictly neoclassical foundations and allows a less restrictive set of outcomes.

In this sense the economy-environment model developed here contrasts with the Ayres and Kneese (1969) model – one of the earliest and most original attempts to examine the implications for general economic equilibrium of the conservation of mass. Since the authors locked themselves into an essentially static allocative (Walras–Cassel) framework in which they assumed the existence of a stable equilibrium, they blinkered themselves against the most significant implication of the conservation of mass: the nonexistence of stable economic equilibria. The powerful equilibrium orientation of the static allocative models in the Walrasian mold makes them, in these circumstances, unhelpful. Indeed, the economic problem addressed – the problem of economic growth in a far-from-equilibrium, time-varying, economy-environment system subject to the conservation of mass – is much closer to that addressed by the classical political economists than by their neoclassical successors. The classical problem was, as Walsh and Gram put it, "the capacity of an economy to reproduce itself and grow" (1980, p. 9). This is very different from the optimal allocation of given resources addressed by Walras. Consequently, although I wish