Pearce and Turner
Chapter 2 • THE CIRCULAR ECONOMY

## 2.1 NARROW AND HOLISTIC VIEWS OF ECONOMIES AND ENVIRONMENTS

Undergraduate economics textbooks now pay some attention to issues of environmental economics. But, typically, this attention is confined to supplying an `add on' chapter illustrating how the theory in the rest of the book can be applied to environmental issues. The danger in this approach is that it obscures the fundamental ways in which the consideration of environmental matters affects our economic thinking.

Figure 2.1 shows a stylised picture of economy and environment interactions. At this stage, the diagram is deliberately vague - we make it more meaningful on p. 35. The upper square, or `matrix', shows the economy. We consider shortly what might enter into this matrix, but the point for the moment is that economics textbooks are primarily concerned with that matrix only. For example, economics will be concerned with the way in which the various component parts of the economy interact - how consumer demand affects steel output, how the production of automobiles affects the demand for steel, how the overall size of the economy can be expanded, and so on. The lower square shows the environment. This consists of all in situ resources - energy sources, fisheries, land, the capacity of the environment to assimilate waste products, and so on. Clearly, there are interactions within this matrix as well. Water supply affects fisheries, forests affect water supply and soil quality, the supply of prey affects the number of predators, and so on. Just as within the economy matrix the relationships studied are between economic entities, so within the environment matrix the entities studied appear

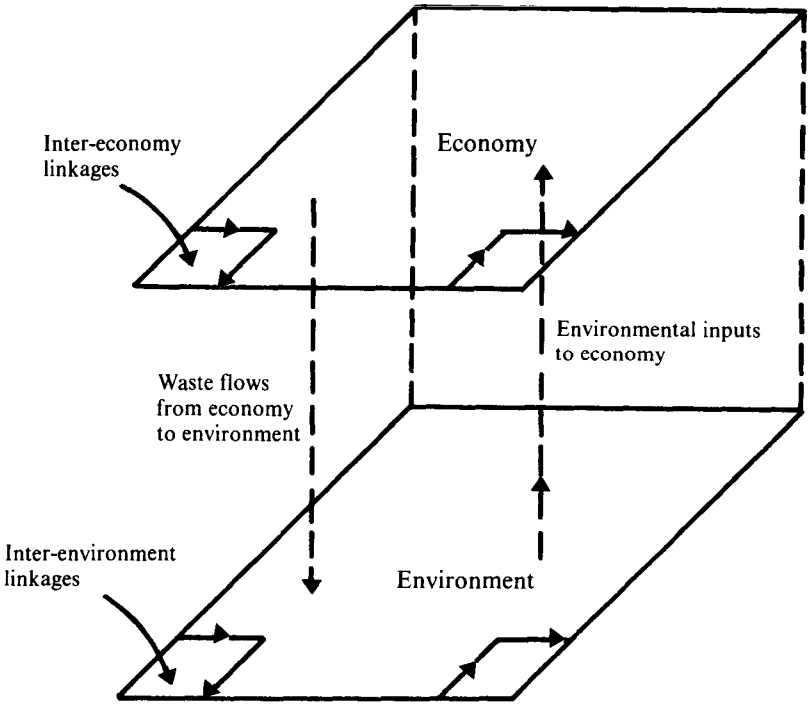



Figure 2.1 General environment-economy interaction.

to have no economic dimension.

Environmental economics is concerned with both matrices in Figure 2.1. Moreover, it concentrates on the interactions between the matrices - how the demand for steel affects the demand for water, how changing the size of the economy ('economic growth) affects the functions of the environment, and so on. Environmental economics thus tends to be more holistic than economics as traditionally construed - it takes a wider, more all-encompassing view of the workings of an economy.

Because it is more holistic there is a temptation to think that environmental economics is somewhat `better' than economics as it is traditionally taught. This has led some people to think of environmental economics as an `alternative' economics, as something that is somehow in competition with the main body of economic doctrine. This is a muddled view. In this textbook we show how we can use the main body of economic thought to derive important propositions about the linkages between the economy and the environment. Rather than looking for some `different' economics, we are seeking to expand the horizons of economic thought. This does not mean that there cannot be an `alternative' economics, but such an economics would have to alter the paradigms of the central body of modern economic thought. Chapter 1 has discussed such alternative paradigms. The view taken here, however, is that we have a great deal to learn from our horizon-expanding application of modern economics, and that the search for `alternatives' is premature. Moreover, we would argue that many of the concerns of those who are motivated to find alternative ways of thinking can be accommodated within the paradigms used in this text.

Modern neoclassical economics is far from faultless, however. We attempt to show what we believe to be true and what we believe to be false in the many critiques available.

## 2.2 THE ENVIRONMENT-ECONOMY INTERACTION

We now need to make Figure 2.1 more meaningful since we did not specify formally what interactions take place within economies, within environments and between economies and environments. We begin with the economy and then expand the picture to include environments. Figure 2.2 pictures the economy as a set of relationships between inputs and outputs. The diagram looks a little complicated but it is fairly easy to follow. It is a big box, or matrix, made up of a series of smaller boxes or matrices. Notice that two of the categories on the vertical axis - commodities and industries - also appear on the horizontal axis.

We need to define the terms used. A `commodity' is anything that is processed, exchanged and produced in the economy - a factory is a commodity, so is a machine, so is a TV set or take-away meal. Coal in the ground is not a commodity because it has not been processed nor yet subjected to any exchange within the economy. Industries have a familiar meaning; they are simply the institutions that undertake economic activity in the form of production or providing a service. Figure 2.2 also contains an entry for `primary'

inputs. This refers to labour and capital, but not to land which we treat separately when Figure 2.2 is developed further. `Final demand' refers to the set of demands in the economy by final consumers, e.g. households. These demands are assumed to be determined by factors outside the model - they are said to be `exogenous'. The numbers in each small matrix simply remind us that each matrix has a number of component parts - for example there are M industries, N commodities, G final demands, and so on. For our purposes we need not worry further with these numbers.

| | Commodities 1,2.....N | Industries 1.....M | Final demand 1.....G | Totals |
|---|---|---|---|---|
| Commodities 1 2 ⋮ N | | A | D | F |
| Industries 1 ⋮ M | B | | | G |
| Primary inputs 1 ⋮ P | | C | E | H |
| Totals | K | L | M | J |

**Figure 2.2** An input–output table without environment.

The relevant matrices have been labelled. Matrix A shows the input of commodities to industries. So, for a given industry, say steel, this matrix will tell us how much is required of each other commodity used in the production of steel. Matrix B shows the output of each commodity by each industry. Matrix C shows how much each industry spends on primary inputs - labour and capital. Matrix D shows the final demand for commodities, i.e. how much of each commodity is required to meet each type of final demand. Matrix E shows the expenditure on each primary input according to each category of final demand.

This leaves us with the column and row titled `totals'. These are not actually matrices in the sense we have been using. For example, box F shows the total demand for

commodities and this is made up of industrial demand for commodities (matrix A) and final demand for commodities (matrix D). But it will appear as a single list of demands classified by the N commodities. This list is known as a'vector'. So, it might appear as x units of commodity 1, y units of commodity 2, z units of commodity 3, and so on. Box G shows the total outputs of each industry. It too is a vector. Vector H shows the total expenditure on primary inputs and is found by summing the elements in C and E. Vector K is the total output of commodities, vector L shows total inputs to industry, and vector M shows total expenditure on all inputs by category of final demand. The last box is J and that shows the total expenditure on all commodities and all primary inputs. It is neither a vector nor a matrix but a single
number – a 'scalar'.

What use is a construct like Figure 2.2? First, we need to observe that it is a particular form of an input-output table. By showing the interactions within an economy, input-output tables have considerable potential value for planning purposes. If, for example, the government decides to expand final demand by inflating the economy, it is helpful to know what this will mean for the demand for labour, the demand for steel, the demand for coal and so on. Second, in ways which are beyond the scope of our interest here, it is possible to modify input-output tables in such a way that we can estimate the price impacts of changing certain key features in the economy. If we decide to raise energy prices, for example, we can show the impact on the costs of energy-using industries. This might not seem to require an input-output table. For example, if steel uses X tonnes of oil and we raise the price of oil it must surely be the case that the cost of producing steel rises by X times the increased price of oil. But we have overlooked the fact that there are other inputs to making steel, e.g. coke, which also require energy, so its price will rise too. Input-output, or 1-0 analysis, helps us trace these second-order effects. It is even possible to say by how much the living costs of the average family will rise, and so on.

But our interest is in the environment. Enough has been said to hint at the uses that the 1-0 approach might have in this context. If it were possible to introduce environmental functions into the picture then we could see how much each economic change would impact on the environment. Figure 2.3 expands Figure 2.2 in order to show this. Basically, we take Figure 2.2, and add on an extra row and an extra column. The extra row is `environmental commodities'. This refers to all natural resources - classified here as land, air and water. In land we include natural commodities such as coal and oil, fish and forests. The environmental commodity flow will basically show us how the environment supplies inputs to the economy. The column that is added is the same - land, water and air - but this time it will show us how these resources act as receiving media for the waste products that flow from the economy. Later, we will elaborate on some important relationships between the environment as input and the environment as receiver of waste (p. 36).

| | Commodities | Industries | Final demand | Total | Waste discharge to environment |
|---|---|---|---|---|---|
| Commodities | | A | D | F | N |
| Industries | B | | | G | O |
| Primary inputs | | C | E | H | |
| Totals | K | L | M | J | P |
| Environmental commodities | Q | R | | S | |

**Figure 2.3** An extended input–output table with environmental commodities.

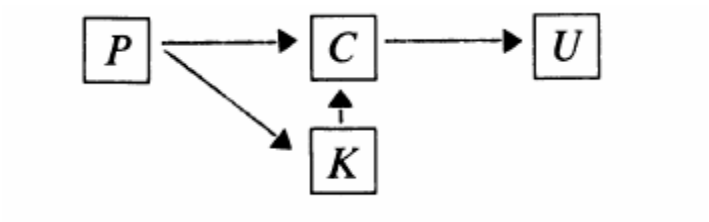
We now have some extra boxes to explain. One thing to note is that all our economy boxes in Figure 2.2 were in money terms - that is, if we actually constructed such a table it would show us, for example, the money value of steel as an input to £1 or $1 of automobile output. Although major advances have been made in putting money values on some of the functions of environments, in terms of Figure 2.3, it must be recognised that the new row and column will be in physical terms, i.e. tonnes of sulphur oxide, tonnes of coal, etc. Matrix N now shows the amount of waste discharged as a result of the final demand for commodities measured in box F. Matrix 0 shows the discharge of waste products by each industry. Box P will be a vector and will show the total amount of waste discharged by the economy, classified by type of waste. Matrix Q shows the inputs of environmental commodities to economic commodities - e.g. how much water is used, how much land is used, and so on. Matrix R shows the inputs of environmental commodities to industries and box S will show the total input of environmental commodities to industrial and final demand.

Effectively, what Figure 2.3 does is to formalise the general relationships introduced in Figure 2.1. If it were possible to quantify the various relationships between environmental commodities and the economy, then we would have a clearer idea of how economy and environment interact. Some efforts have been made to do exactly this and treatment here has followed that of Victor (1972) which showed how the interactions occur in the Canadian economy. However, our purpose in introducing the idea of input-output analysis is rather different. How far one can quantify the interlinkages in detail is not our concern, although it should be evident that advances in this area could be very

fruitful. The basic aim has been to show that economy and environment are linked in various ways and that, in principle at least, it is possible to model these linkages by extending a piece of analysis - input-output - that was initially developed for purposes quite unrelated to the environment. It also permits us to reflect on just what the environment does for the economy.

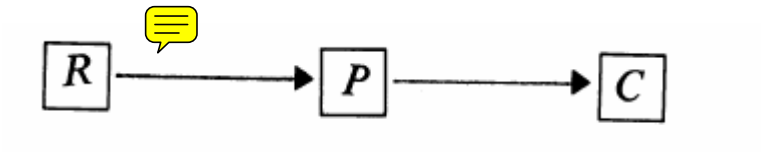
## 2.3 THE CIRCULAR ECONOMY

The previous discussion highlights some important implications of the environment-economy interaction for our conception of how economies work. If we ignore the environment then the economy appears to be a linear system. Production, P, is aimed at producing consumer goods, C, and capital goods, K. In turn, capital goods produce consumption in the future. The purpose of consumption is
to create `utility', U, or welfare.




Leaving out U and K, for convenience, we can immediately add in the flow of natural resources, R, to give a more complete picture.

Resources are an input to the economic system, just as we saw in Section 2.2. Adding resource still produces a linear system:

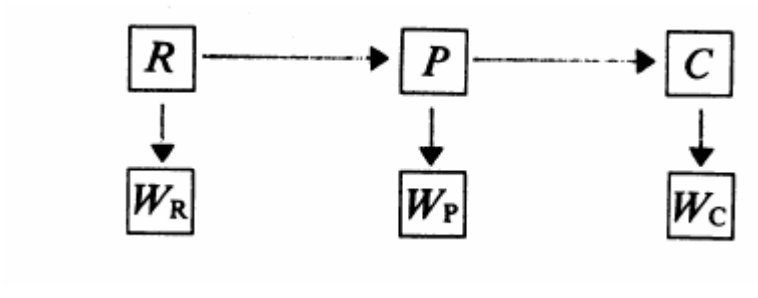



This system, however, captures the first function of natural environments, namely, to provide resource inputs to the productive system.

The picture is still incomplete because it says nothing about waste products. A moment's reflection will show that natural environments are the ultimate repositories of waste products: carbon dioxide and sulphur dioxide go into the atmosphere, industrial and municipal sewage goes into rivers and the sea, solid waste goes to landfill, chlorofluorocarbons go to the stratosphere, and so on. Waste comes from the economic system but we should not be led into believing that natural systems do not have their own waste. Trees dispose of their leaves, for example. This is waste. The basic difference between natural and economic systems, however, is that natural systems tend to recycle their waste. The leaves decompose and are converted into an organic fertiliser for plants and for the very tree creating the waste in the first place. Economies have no such in-built

tendency to recycle. It seems fair therefore to concentrate on wastes from the economy in extending our picture of economy-environment interaction.

Waste arises at each stage of the production process. The processing of resources creates waste, as with overburden tips at coal mines; production creates waste in the form of industrial effluent and air pollution and solid waste; final consumers create waste by generating sewage, litter, and municipal refuse. So, we might take the linear system and expand it a little further:




Now, as it happens there is an interesting relationship between R and the sum of the waste flows generated in any period of time. If we forget for the moment about production going to create capital stock, then the amount of waste in any period is equal to the amount of natural resources used up. That is

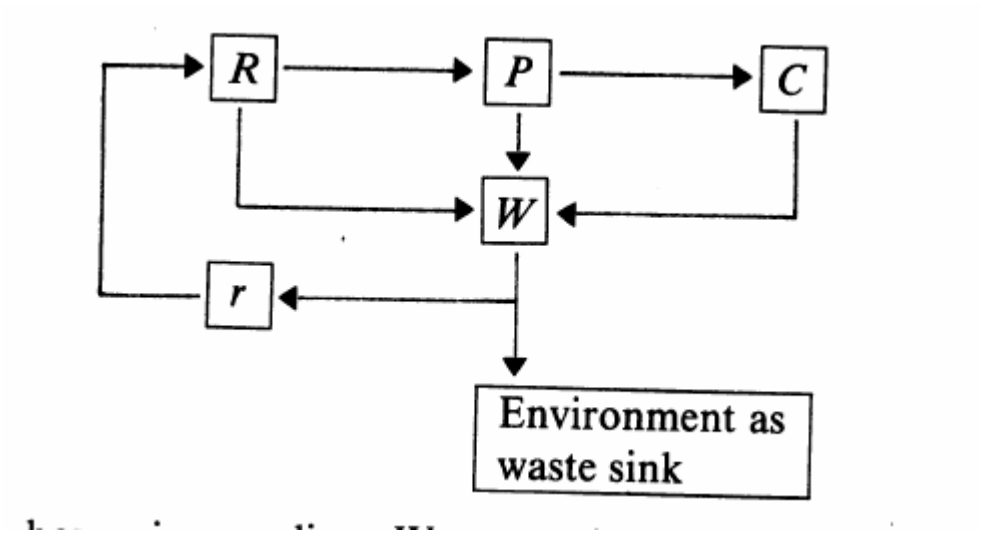
R= W= WR+ Wr+ We

The reason for this equivalence is the First Law of Thermodynamics. This law essentially states that we cannot create or destroy energy and matter. Whatever we use up by way of resources must end up somewhere in the environmental system. It cannot be destroyed. It can be converted and dissipated. For example, coal consumption in any year must be equal to the amount of waste gases and solids produced by coal combustion. Some of it will appear as slag, some as carbon dioxide and so on. This equivalence is not a hard and fast one once we consider capital formation, for then some of the resource flows become `embodied' in capital equipment. But, at the same time, capital equipment constructed in past periods will be wearing out, so it will appear as a waste flow. In any given period, then, we shall have a more complicated relationship between R and W.

The relevance of the First Law of Thermodynamics was given prominence in one of the most celebrated and justly famous essays of the twentieth century. `The economics of the coming spaceship Earth' was written in 1966 by Kenneth Boulding. Boulding's conception was of planet Earth as a `spaceship'. If we think of a spaceship going on a long journey it will have only one external source of energy - solar energy. It will have a stock of resources depending on whatever was put aboard before take-off. But as that stock is reduced, so the expected lives of the spacemen are reduced unless, of course, they can find ways to recycle water and materials and generate their own food. The spaceship is, of course, Earth and Boulding's essay was pointing to the need to contemplate Earth as a closed economic system: one in which the economy and environment are not characterised by linear interlinkages, but by a circular relationship.

Everything is an input into everything else. Simply saying that the end purpose of the economy is to create utility, and to organise the economy accordingly, is to ignore the fact that, ultimately anyway, a closed system sets limits, or boundaries, to what can be done by way of achieving that utility.

The linear system can now be converted to a circular system in light of Boulding's contribution. We now have



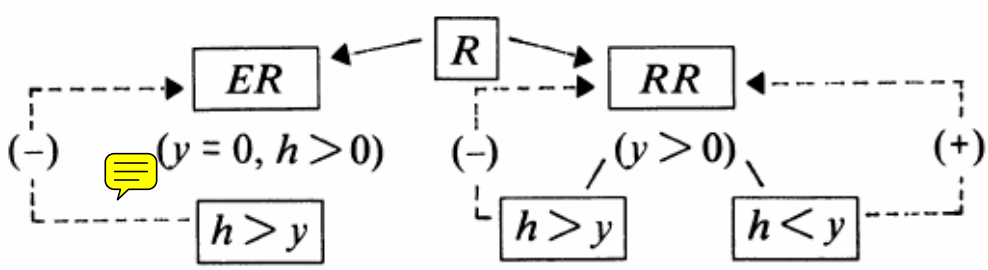

The box r is recycling. We can take some of the waste, W, and convert it back to resources. We are all familiar with bottle banks for recycling glass bottles. The lead in junked car batteries is generally recycled. Many other metals are recycled. Some waste paper returns to be pulped for making further paper, and so on. But a great deal of waste, indeed the majority of it, is not recycled. As the diagram shows, it goes into the environment.

Why is not all waste recycled? It is here that the Second Law of Thermodynamics becomes relevant. Boulding drew attention to the second law, but another economist, Nicholas Georgescu-Roegen, has been the most prolific and forceful advocate of the second law's relevance to economics. In terms of the circular flow diagram above there is a basic reason for the lack of recycling, apart, that is, from missed opportunities. The materials that get used in the economy tend to be used entropically - they get dissipated within the economic system. Of the many hundreds of components in a car it is possible to recycle only a few of them - maybe the aluminium in some parts, the steel in the car body, lead from the batteries. The wood and plastics are generally impossible to extract without the expenditure of such large sums of money that it would not make any sense. In other cases it is not technically feasible to recycle. Think of the lead in leaded gasoline. It cannot be captured from the car exhaust and returned to the economic system. Moreover there is a whole category of resources that cannot be recycled - energy resources. Even if we capture the carbon dioxide from burning fossil fuels, it does not create another fuel. We can capture some of the sulphur oxides and recycle the sulphur, but we cannot recycle energy. Entropy therefore places a physical obstacle, another `boundary', in the

way of redesigning the economy as a closed and sustainable system.

Now consider what happens to that proportion of the waste flow that we cannot recycle. It goes into the environment. The environment has a capability to take wastes and to convert them back into harmless or ecologically useful products. This is the environment's assimilative capacity and it is the second major economic function of natural environments. So long as we dispose of waste in quantities (and qualities) that are commensurate with the environment's assimilative capacity, the circular economic system will function just like a natural system, although, of course, it will still draw down the stocks of any natural resources that do not renew themselves ('exhaustible' resources). The system will therefore still have a finite life determined by the availability of the exhaustible natural resources and other considerations we shall shortly introduce. But if we dispose of wastes in such a way that we damage the capability of the natural environment to absorb waste, then the economic function of the environment as waste sink will be impaired. Essentially, we will have converted what could have been a renewable resource into an exhaustible one. The assimilative capacity of the environment is thus a resource which is finite. So long as we keep within its bounds, the environment will assimilate waste and essentially return the waste to the economic system.

The resources box, R, in the diagram can be expanded to account for two types of natural resource. Exhaustible resources (ER) cannot renew themselves and include such resources as coal, oil, and minerals. Renewable resources (RR) have the capacity to renew themselves. A forest produces a'sustainable yield', so that if we cut X cubic metres of timber in any year, the stock of trees will stay the same as long as the trees have grown by X cubic metres. The same is true of fish. Some resources are mixes of renewable and exhaustibles - soil would be one example. Some renewable resources are very slow-growing, some are fast-growing. Clearly, if we harvest a renewable resource at a rate faster than the rate at which it grows, the stock will be reduced. In this way a renewable resource can be `mined', treated like an exhaustible resource. If we wish to sustain renewable resources we must be careful to harvest them at a rate no greater than their natural regenerative capacity. The resource subsector now appears as:




where y refers to the yield of the resource, and h to the rate at which it is harvested (extracted, exploited). The plus sign tells us that if h < y the resource stock grows, and if h > y the stock falls (the minus sign).

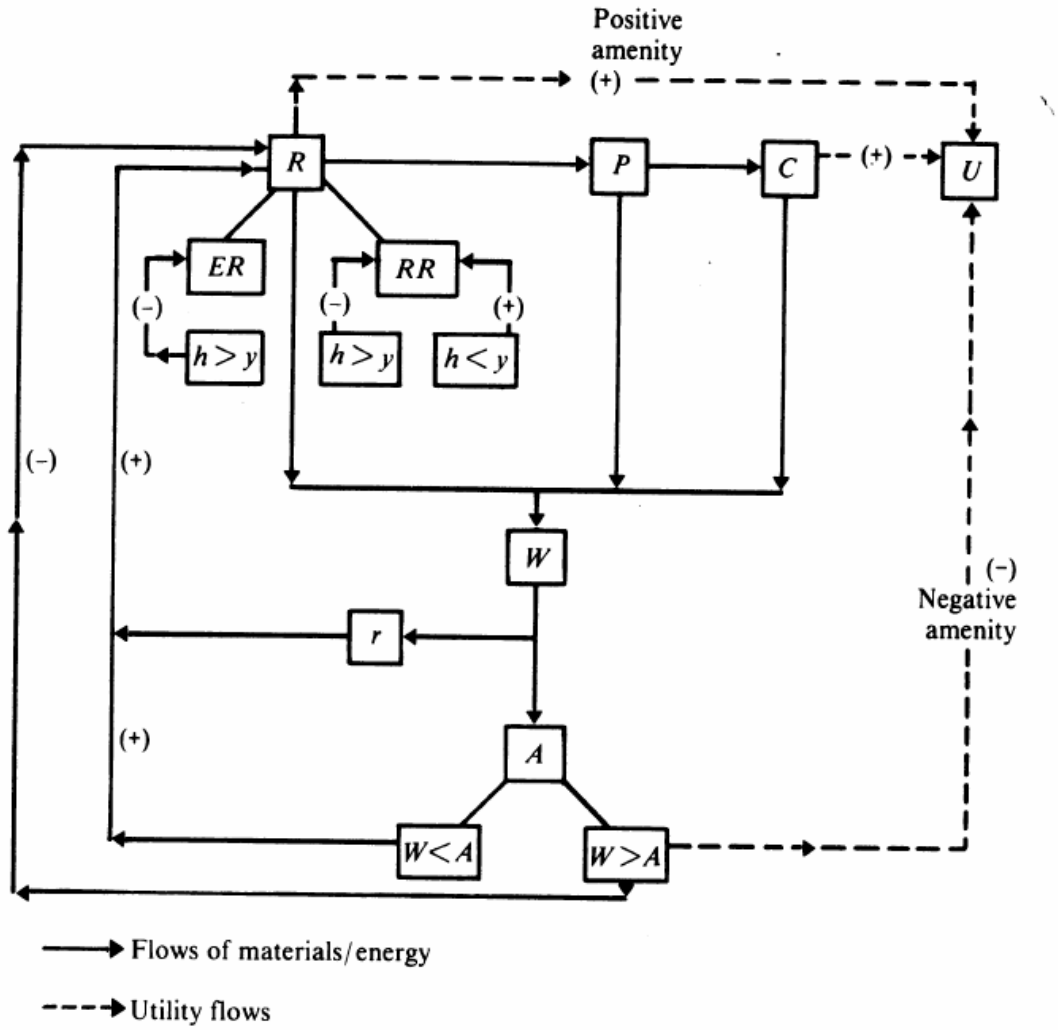



**Figure 2.4** The circular economy.

We are now in a position to complete our picture of the circular economy. Instead of being an open, linear system, it is closed and circular. The laws of thermodynamics ensure that this must be so. In Figure 2.4 we show the full picture. We have added back in the flow of consumption to utility. The reason for this is to highlight the third function of the environment - it supplies utility directly in the form of aesthetic enjoyment and spiritual comfort, whether it is the pleasure of a fine view or the deeper feelings about nature we find in the poetry of Wordsworth. Notice that if we dispose of wastes, W, in excess of the assimilative capacity, A, of the environment, we shall damage this third function. Polluted rivers detract from this economic function.

By looking at this circular flow, sometimes called a materials balance model, we have been able to identify clearly three economic functions of the environment - as resource supplier, as waste assimilator, and as a direct source of utility. They are economic functions because they all have a positive economic value: if we bought and sold these functions in the market-place they would all have positive prices. The dangers arise from the mistreatment of natural environments because we do not recognise the positive prices

for these economic functions. This is not the fault of economics or economists (although it is often made out to be in the environmental literature). Indeed, environmental economists have been at considerable pain to point out these economic functions and to demonstrate their positive price. Nor is it intrinsic to modern economics that these economic functions should be ignored. Ignorance of economic functions lies elsewhere in the personal and social aims of individuals, groups, communities, pressure groups and politicians. But there is a problem with the perception of economic systems to which we now turn.

## 2.4 EXISTENCE THEOREMS

The three economic functions, resource supply, waste assimilation and aesthetic commodity, can be regarded as components of one general function of natural environments - the function of life support. Some sort of existence might be imaginable without most natural resources, though not without all of them. But for the foreseeable future we need to survive and, more so, we need them to fulfil human values. The problem we face is that the design of economies - whether free market, planned, or mixed - offers us no guarantee that the life support functions of natural environments will persist. Modern economics spends quite a lot of time trying to determine whether equilibria within the economic system exist - for example, whether we can have equilibria between supply and demand in money markets, goods markets, and labour markets and whether there is some set of market-clearing prices which will secure all these equilibria.

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.