fall—it is low-entropy or available (still useful) matter / energy. This is the second law of thermodynamics: entropy (or "used-up-ness") increases in an isolated system. The hourglass analogy is particularly apt since entropy is time's arrow in the physical world.

The analogy can be extended by considering the sand in the upper chamber to be the stock of low-entropy energy in the sun. Solar energy arrives to earth as a flow whose amount is governed by the constricted middle of the hourglass, which limits the rate at which sand falls, the rate at which solar energy flows to earth. Suppose that over ancient geologic ages some of the falling sand had gotten stuck against the inner surface of the bottom chamber, but at the top of the bottom chamber, before it had fallen all the way. This becomes a terrestrial dowry of low-entropy matter / energy, a stock that we can use up at a rate of our own choosing. We use it by drilling holes into its surface through which the trapped sand can fall to the bottom of the lower chamber. This terrestrial source of low-entropy matter / energy can be used at a rate of our own choosing, unlike the energy of the sun, which arrives at a fixed flow rate. We cannot "mine" the sun to use tomorrow's sunlight today, but we can mine terrestrial deposits and, in a sense, use up tomorrow's petroleum today.

There is thus an important asymmetry between our two sources of low entropy. The solar source is stock-abundant, but flow-limited. The terrestrial source is stock-limited, but flow-abundant (temporarily). Peasant societies lived off the abundant solar flow; industrial societies have come to depend on enormous supplements from the limited terrestrial stocks.

Reversing this dependence will be an enormous evolutionary shift. Georgescu-Roegen argued that evolution has in the past consisted of slow adaptations of our "endosomatic organs" (heart, lungs, etc.), which run on solar energy. But the present path of evolution has shifted to rapid adaptations of our "exosomatic organs" (cars, airplanes, etc.), which depend on terrestrial low entropy. The uneven ownership of exosomatic organs and of the terrestrial stocks of low entropy from which they are made, compared to the egalitarian distribution of ownership of endosomatic capital, is for Georgescu-Roegen the root of social conflict in industrial societies.

One more thing. Unlike a real hourglass, this one cannot be turned upside down! Its central feature is what Georgescu-Roegen called the "metabolic flow," the entropic throughput of matter / energy by which the economy depends on its environment. This dependence is completely abstracted from in the neoclassical economist's starting point, the circular flow of exchange value.

Chapter 1

Moving to a Steady-State Economy

Sustainable development, I argue, necessarily means a radical shift from a growth economy and all it entails to a steady-state economy, certainly in the North, and eventually in the South as well. My first task has to be to elaborate the case for that theoretical and practical shift in worldview. What are the main theoretical and moral anomalies of the growth economy, and how are they resolved by the steady state? And what are the practical failures of the growth economy, viewed as forced first steps toward a steady state?

It is necessary to define what is meant by the terms "steady-state economy" (SSE) and "growth economy." Growth, as here used, refers to an increase in the physical scale of the matter/energy throughput that sustains the economic activities of production and consumption of commodities. In an SSE the aggregate throughput is constant, though its allocation among competing uses is free to vary in response to the market. Since there is of course no production and consumption of matter/energy itself in a physical sense, the throughput is really a process in which low-entropy raw materials are transformed into commodities and then, eventually, into high-entropy wastes. Throughput begins with depletion and ends with pollution. Growth is quantitative increase in the physical scale of throughput. Qualitative improvement in the use made of a given scale of throughput, resulting either from improved technical knowledge or from a deeper understanding of purpose, is called "development." An SSE therefore can develop, but cannot grow, just as the planet earth, of which it is a subsystem, can develop without growing.

The steady state is by no means static. There is continuous renewal by death and birth, depreciation and production, as well as qualitative improvement in the stocks of both people and artifacts. By this definition, strictly speaking, even the stocks of artifacts or people may occasionally grow temporarily as a result of technical progress that increases the durability and repairability (longevity) of artifacts. The same maintenance flow can support a larger stock if the stock becomes longer-lived. The stock may also decrease, however, if resource quality declines at a faster rate than increases in durability-enhancing technology.

The other crucial feature in the definition of an SSE is that the constant level of throughput must be ecologically sustainable for a long future for a population living at a standard or per capita resource use that is sufficient for a good life. Note that an SSE is not defined in terms of gross national product. It is not to be thought of as "zero growth in GNP."

Ecological sustainability of the throughput is not guaranteed by market forces. The market cannot by itself register the cost of its own increasing scale relative to the ecosystem. Market prices measure the scarcity of individual resources relative to each other. Prices do not measure the absolute scarcity of resources in general, of environmental low entropy. The best we can hope for from a perfect market is a Pareto-optimal allocation of resources (i.e., a situation in which no one can be made better off without making someone else worse off). Such an allocation can be achieved at any scale of resource throughput, including unsustainable scales, just as it can be achieved with any distribution of income, including unjust ones. The latter proposition is well known, the former less so, but equally true. Ecological criteria of sustainability, like ethical criteria of justice, are not served by markets. Markets singlemindedly aim to serve allocative efficiency. Optimal *allocation* is one thing; optimal *scale* is something else.

Economists are always preoccupied with maximizing something: profits, rent, present value, consumers' surplus, and so on. What is maximized in the SSE? Basically the maximand is life, measured in cumulative person-years ever to be lived at a standard of resource use sufficient for a good life. This certainly does not imply maximizing population growth, as advocated by Julian Simon (1981), because too many people simultaneously alive, especially high-consuming people, will be forced to consume ecological "capital" and thereby lower the carrying capacity of the environment and the cumulative total of future lives. Although the maximand is human lives, the SSE would go a long way toward maximizing cumulative life for all species by imposing the constraint of a constant throughput at a sustainable level, thereby halting the growing takeover of habitats of other species, as well as slowing the rate of drawdown of geological capital otherwise available to future generations.

I do not wish to put too fine a point on the notion that the steady state maximizes cumulative life over time for all species, but it certainly would do better in this regard than the present value-maximizing growth economy, which drives to extinction any valuable species whose biological growth rate is less than the expected rate of interest, as long as capture costs are not too high (Clark 1976).

Of course many deep issues are raised in this definition of the SSE that, in the interests of brevity, are only touched on here. The meanings of "sufficient for a good life" and 'sustainable for a long future" have to be left vague. But any economic system must give implicit answers to these dialectical questions, even when it refuses to face them explicitly. For example, the growth economy implicitly says that there is no such thing as sufficiency because more is always better, and that a twenty-year future is quite long enough if the discount rate is 10%. Many would prefer explicit vagueness to such implicit precision.

Moving from Growthmania to the Steady State in Thought: Theoretical and Moral Anomalies of the Growth Paradigm That Are Resolved by the Steady State

The growth economy runs into two kinds of fundamental limits: the biophysical and the ethicosocial. Although they are by no means totally independent, it is worthwhile to distinguish between them.

Biophysical Limits to Growth The biophysical limits to growth arise from three interrelated conditions: finitude, entropy, and ecological interdependence. The economy, in its physical dimensions, is an open subsystem of our finite and closed ecosystem, which is both the supplier of its low-entropy raw materials and the recipient of its high-entropy wastes. The growth of the economic subsystem is limited by the fixed size of the host ecosystem, by its dependence on the ecosystem as a source of low-entropy inputs and as a sink for high-entropy wastes, and by the complex ecological connections that are more easily disrupted as the scale of the economic subsystem (the throughput) grows relative to the total ecosystem. Moreover, these three basic limits interact. Finitude would not be so limiting if everything could be recycled, but entropy prevents complete recycling. Entropy would not be so limiting if environmental sources and sinks were infinite, but both are finite. That both are finite, plus the entropy law, means that the ordered structures of the economic subsystem are maintained at the expense of creating a more-than-offsetting amount of disorder in the rest of the system. If it is largely the sun that pays the disorder costs, the entropic costs of throughput, as it is with traditional peasant economies, then we need not worry. But if these entropic costs (depletion and pollution) are mainly inflicted on the terrestrial environment, as in a modern industrial economy, then they interfere with complex ecological life-support services rendered to the economy by nature. The loss of these services should surely be counted as a cost of growth, to be weighed against benefits at the margin. But our national accounts emphatically do not do this.

Standard growth economics ignores finitude, entropy, and ecological interdependence because the concept of throughput is absent from its preanalytic vision, which is that of an isolated circular flow of exchange value (see figure 2, page 47), as can be verified by examining the first few chapters of any basic textbook

(Daly 1985; Georgescu-Roegen 1971). The physical dimension of commodities and factors is at best totally abstracted from (left out altogether) and at worst assumed to flow in a circle, just like exchange value. It is as if one were to study physiology solely in terms of the circulatory system without ever mentioning the digestive tract. The dependence of the organism on its environment would not be evident. The absence of the concept of throughput in the economists' vision means that the economy carries on no exchange with its environment. It is, by implication, a self-sustaining isolated system, a giant perpetual motion machine. The focus on exchange value in the macroeconomic circular flow also abstracts from use value and any idea of purpose other than maximization of the circular flow of exchange value.

But everyone, including economists, knows perfectly well that the economy takes in raw material from the environment and gives back waste. So why is this undisputed fact ignored in the circular flow paradigm? Economists are interested in scarcity. What is not scarce is abstracted from. Environmental sources and sinks were considered infinite relative to the demands of the economy, which was more or less the case during the formative years of economic theory. Therefore it was not an unreasonable abstraction. But it is highly unreasonable to continue omitting the concept of throughput after the scale of the economy has grown to the point where sources and sinks for the throughput are obviously scarce, even if this new absolute scarcity does not register in relative prices. The current practice of ad hoc introduction of "externalities" to take account of the effects of the growing scale of throughput that do not fit the circular flow model is akin to the use of "epicycles" to explain the departures of astronomical observations from the theoretical circular motion of heavenly bodies.

Nevertheless, many economists hang on to the infinite-resources assumption in one way or another, because otherwise they would have to admit that economic growth faces limits, and that is "unthinkable." The usual ploy is to appeal to the infinite possibilities of technology and resource substitution (ingenuity) as a dynamic force that can continuously outrun depletion and pollution. This counterargument is flawed in many respects. First, technology and infinite substitution mean only that one form of low-entropy matter/energy is substituted for another, within a finite and diminishing set of low-entropy sources. Such substitution is often very advantageous, but we never substitute high-entropy wastes for low-entropy resources in net terms. Second, the claim is frequently made that reproducible capital is a near-perfect substitute for resources. But this assumes that capital can be produced independently of resources, which is absurd. Furthermore, it flies in the teeth of the obvious complementarity of capital and resources in production. The capital stock is an agent for transforming the resource flow from raw material into a product (Georgescu-Roegen 1971). More capital does not substitute for less resources, except on a very restricted margin. You cannot make the same house by substituting more saws for less wood.

The growth advocates are left with one basic argument: resource and environmental limits have not halted growth in the past and therefore will not do so in the future. But such logic proves too much, namely, that nothing new can ever happen. A famous general survived a hundred battles without a scratch, and that was still true when he was blown up.

Earl Cook offered some insightful criticism of this faith in limitless ingenuity in one of his last articles (Cook 1982). The appeal of the limitless-ingenuity argument, he contended, lies not in the scientific grounding of its premises nor in the cogency of its logic but rather in the fact that

> the concept of limits to growth threatens vested interests and power structures; even worse, it threatens value structures in which lives have been invested. . . . Abandonment of belief in perpetual motion was a major step toward recognition of the true human condition. It is significant that "mainstream" economists never abandoned that belief and do not accept the relevance to the economic process of the Second Law of Thermodynamics; their position as high priests of the market economy would become untenable did they do so. [Cook 1982, p. 198]

Indeed it would. Therefore, much ingenuity is devoted to "proving" that ingenuity is unlimited. Julian Simon, George Gilder, Herman Kahn, and Ronald Reagan trumpeted this theme above all others. Every technical accomplishment, no matter how ultimately insignificant, is celebrated as one more victory in an infinite series of future victories of technology over nature. The Greeks called this hubris. The Hebrews were warned to "beware of saying in your heart, 'My own strength and the might of my own hand won this power for me' " (Deut. 8:17). But such wisdom is drowned out in the drumbeat of the see-no-evil "optimism" of growthmania. All the more necessary is it then to repeat Earl Cook's trenchant remark that "without the enormous amount of work done by nature in concentrating flows of energy and stocks of resources, human ingenuity would be onanistic. What does it matter that human ingenuity may be limitless, when matter and energy are governed by other rules than is information?" (Cook 1982, p. 194).

Ethicosocial Limits Even when growth is, with enough ingenuity, still possible, ethicosocial limits may render it undesirable. Four ethicosocial propositions limiting the desirability of growth are briefly considered below.

1. *The desirability of growth financed by the drawdown of geological capital is limited by the cost imposed on future generations.* In standard economics the balancing of future against present costs and benefits is done by discounting. A time

discount rate is a numerical way of expressing the value judgment that beyond a certain point the future is not worth anything to presently living people. The higher the discount rate, the sooner that point is reached. The value of the future to future people does not count in the standard approach.

Perhaps a more discriminating, though less numerical, principle for balancing the present and the future would be that the basic needs of the present should always take precedence over the basic needs of the future but that the basic needs of the future should take precedence over the extravagant luxury of the present.

2. *The desirability of growth financed by takeover of habitat is limited by the extinction or reduction in number of sentient subhuman species whose habitat disappears.* Economic growth requires space for growing stocks of artifacts and people and for expanding sources of raw material and sinks for waste material. Other species also require space, their "place in the sun." The instrumental value of other species to us, the life-support services they provide, was touched on in the discussion of biophysical limits above. Another limit derives from the intrinsic value of other species, that is, counting them as sentient, though probably not self-conscious, beings which experience pleasure and pain and whose experienced "utility" should be counted positively in welfare economics, even though it does not give rise to maximizing market behavior.

The intrinsic value of subhuman species should exert some limit on habitat takeover in addition to the limit arising from instrumental value. But it is extremely difficult to say how much (Birch and Cobb 1981). Clarification of this limit is a major philosophical task, but if we wait for a definitive answer before imposing any limits on takeover, then the question will be rendered moot by extinctions which are now occurring at an extremely rapid rate relative to past ages (Ehrlich and Ehrlich 1981).

3. *The desirability of aggregate growth is limited by its self-canceling effects on welfare.* Keynes (1930) argued that absolute wants (those we feel independently of the condition of others) are not insatiable. Relative wants (those we feel only because their satisfaction makes us feel superior to others) are indeed insatiable, for, as Keynes put it, "The higher the general level, the higher still are they." Or, as J. S. Mill expressed it, "Men do not desire to be rich, but to be richer than other men." At the current margin of production in rich countries it is very likely that welfare increments (increments in well-being) are largely a function of changes in relative income (insofar as they depend on income at all). Since the struggle for relative shares is a zero-sum game, it is clear that aggregate growth cannot increase aggregate welfare. To the extent that welfare depends on relative position, growth is unable to increase welfare in the aggregate. It is subject to the same kind of self-canceling trap that we find in the arms race.

Because of this self-canceling effect of relative position, aggregate growth is less productive of human welfare than we heretofore thought. Consequently, other competing goals should rise relative to growth in the scale of social priorities (Abramowitz 1979). Future generations, subhuman species, commnity, and whatever else has been sacrificed in the name of growth should henceforth be sacrificed less simply because growth is less productive of general happiness than used to be the case when marginal income was dedicated mainly to the satisfaction of absolute rather than relative wants.

4. *The desirability of aggregate growth is limited by the corrosive effects on moral standards resulting from the very attitudes that foster growth, such as glorification of self-interest and a scientistic-technocratic worldview.* On the demand side of commodity markets, growth is stimulated by greed and acquisitiveness, intensified beyond the "natural" endowment from original sin by the multibillion-dollar advertising industry. On the supply side, technocratic scientism proclaims the possibility of limitless expansion and preaches a reductionistic, mechanistic philosophy which, in spite of its success as a research program, has serious shortcomings as a worldview. As a research program it very effectively furthers power and control, but as a worldview it leaves no room for purpose, much less for any distinction between good and bad purposes. "Anything goes" is a convenient moral slogan for the growth economy because it implies that anything also sells. To the extent that growth has a well-defined purpose, then it is limited by the satisfaction of that purpose. Expanding power and shrinking purpose lead to uncontrolled growth for its own sake, which is wrecking the moral and social order just as surely as it is wrecking the ecological order (Hirsch 1976).

The situation of economic thought today can be summarized by a somewhat farfetched but apt analogy. Neoclassical economics, like classical physics, is relevant to a special case that assumes that we are far from limits—far from the limiting speed of light or the limiting smallness of an elementary particle in physics—and far from the biophysical limits of the earth's carrying capacity and the ethicosocial limits of satiety in economics. Just as in physics, so in economics: the classical theories do not work well in regions close to limits. A more general theory is needed to embrace both normal and limiting cases. In economics this need becomes greater with time because the ethic of growth itself guarantees that the close-to-the-limits case becomes more and more the norm. The nearer the economy is to limits, the less can we accept the practical judgment most economists make, namely, that "a change in economic welfare implies a change in total welfare in the same direction if not in the same degree" (Abramowitz 1979). Rather, we must learn to define and explicitly count the other component of total welfare that growth inhibits and erodes when it presses against limits.

Moving from Growthmania to the Steady State in Practice: Failures of Growth as Forced First Steps Toward a Steady-State Economy

No doubt the biggest growth failure is the continuing arms race, where growth has led to less security rather than more and has raised the stakes from loss of individual lives to loss of life itself in wholesale ecocide. Excessive population growth, toxic wastes, acid rain, climate modification, devastation of rain forests, and the loss of ecosystem services resulting from these aggressions against the environment represent case studies in growth failure. Seeing them as first steps toward a steady-state economy requires the conscious willing of a hopeful attitude.

All the growth failures mentioned above are failures of the growth economy to respect the biophysical limits of its host. I would like also to consider some symptoms of growthmania within the economy itself. Three examples will be considered: money fetishism and the paper economy, faulty national accounts and the treachery of quantified success indexes, and the ambivalent "information economy."

Money Fetishism and the Paper Economy Money fetishism is a particular case of what Alfred North Whitehead called "the fallacy of misplaced concreteness," which consists in reasoning at one level of abstraction but applying the conclusions of that reasoning to a different level of abstraction. It argues that, since abstract exchange value flows in a circle, so do the physical commodities constituting real GNP. Or, since money in the bank can grow forever at compound interest, so can real wealth, and so can welfare. Whatever is true for the abstract symbol of wealth is assumed to hold for concrete wealth itself.

Money fetishism is alive and well in a world in which banks in wealthy countries make loans to poor countries and then, when the debtor countries cannot make the repayment, simply make new loans to enable the payment of interest on old loans, thereby avoiding taking a loss on a bad debt. Using new loans to pay interest on old loans is worse than a Ponzi scheme, but the exponential snowballing of debt is expected to be offset by a snowballing of real growth in debtor countries. The international debt impasse is a clear symptom of the basic disease of growthmania. Too many accumulations of money are seeking ways to grow exponentially in a world in which the physical scale of the economy is already so large relative to the ecosystem that there is not much room left for growth of anything that has a physical dimension.

Marx, and Aristotle before him, pointed out that the danger of money fetishism arises as a society progressively shifts its focus from use value to exchange value, under the pressure of increasingly complex division of labor and exchange. The sequence is sketched below in four steps, using Marx's shorthand notation for labels.

1. *C-C′*. One commodity (*C*) is directly traded for a different commodity (*C′*). The exchange values of the two commodities are by definition equal, but each trader gains an increased use value. This is simple *barter*. No money exists, so there can be no money fetishism.

2. *C-M-C′*. *Simple commodity circulation* begins and ends with a use value embodied in a commodity. Money (*M*) is merely a convenient medium of exchange. The object of exchange remains the acquisition of an increased use value. *C′* represents a greater use value to the trader, but *C′* is still a use value, limited by its specific use or purpose. One has, say, a greater need for a hammer than a knife but has no need for two hammers, much less for fifty. The incentive to accumulate use values is very limited.

3. *M-C-M′*. As simple commodity circulation gave way to *capitalist circulation*, the sequence shifted. It now begins with money capital and ends with money capital. The commodity or use value is now an intermediary step in bringing about the expansion of exchange value by some amount of profit, $\Delta M = M' - M$. Exchange value has no specific use or physical dimension to impose concrete limits. One dollar of exchange value is not as good as two, and fifty dollars is better yet, and a million is much better, etc. Unlike concrete use values, which spoil or deteriorate when hoarded, abstract exchange value can accumulate indefinitely without spoilage or storage costs. In fact, exchange value can grow by itself at compound interest. But as Frederick Soddy (Daly 1980) pointed out, "You cannot permanently pit an absurd human convention [compound interest] against a law of nature [entropic decay]."[1] "Permanently," however, is not the same as "in the meantime," during which we have, at the micro level, bypassed the absurdity of accumulating use values by accumulating exchange value and holding it as a lien against future use values. But unless future use value, or real wealth, has grown as fast as accumulations of exchange value have grown, then at the end of some time period there will be a devaluation of exchange value by inflation or some other form of debt repudiation. At the macro level limits will reassert themselves, even when ignored at the micro level, where the quest for exchange value accumulation has become the driving force.

4. *M-M′*. We can extend Marx's stages one more step to the *paper economy*, in which, for many transactions, concrete commodities "disappear" even as an intermediary step in the expansion of exchange value. Manipulations of symbols according to arbitrary and changing tax rules, accounting conventions, depreciation, mergers, public relations imagery, advertising, litigation, and so on, all result in a positive ΔM for some, but no increase in social wealth, and hence an equal negative ΔM for others. Such "paper entrepreneurialism" and "rent-seeking" activities seem to be absorbing more and more business talent. Echoes of Frederick Soddy are audi-

ble in the statement of Robert Reich (1983, p. 153) that "the set of symbols developed to represent real assets has lost the link with any actual productive activity. Finance has progressively evolved into a sector all its own, only loosely connected to industry." Unlike Soddy, however, Reich does not appreciate the role played by biophysical limits in redirecting efforts from manipulating resistant matter and energy toward manipulating pliant symbols. He thinks that, as more flexible and information-intensive production processes replace traditional mass production, somehow financial symbols and physical realities will again become congruent. But it may be that as physical resources become harder to acquire, as evidenced by falling energy rates of return on investment (Cleveland et al. 1984), the incentive to bypass the physical world by moving from *M-C-M'* to *M-M'* becomes ever greater. We may then keep growing on paper, but not in reality. This illusion is fostered by our national accounting conventions. It could be that we are moving toward a nongrowing economy a bit faster than we think. If the cost of toxic waste dumps were subtracted from the value product of the chemical industry, we might discover that we have already attained zero growth in value from that sector of the economy.

Faulty National Accounting and the Treachery of Quantified Success Indicators Our national accounts are designed in such a way that they cannot reflect the costs of growth, except by perversely counting the resulting defensive expenditures as further growth. It is by now a commonplace to point out that GNP does not reveal whether we are living off income or capital, off interest or principal. Depletion of fossil fuels, minerals, forests, and soils is capital consumption, yet such unsustainable consumption is treated no differently from sustainable yield production (true income) in GNP. But not only do we decumulate positive capital (wealth), we also accumulate negative capital (illth) in the form of toxic-waste deposits and nuclear dumps. To speak so insouciantly of "economic growth" whenever produced goods accumulate, when at the same time natural wealth is being diminished and man-made illth is increasing represents, to say the least, an enormous prejudgment about the relative size of these changes (Hueting 1980). Only on the assumption that environmental sources and sinks are infinite does such a procedure make sense.

Another problem with national accounts is that they do not reflect the "informal" or "underground" economy. Estimates of the size of the underground economy in the United States range from around 4% to around 30% of GNP, depending on the technique of estimation (Tanzi 1983). The underground economy has apparently grown in recent times, probably as a result of higher taxes, growing unemployment, and frustration with the increasing complexity and arbitrariness of the paper economy. Like household production, of which they are extensions, none of these informal productive activities are registered in GNP. Their growth represents an adaptation to the failure of traditional economic growth to provide employment and security. As an adaptation to growth failure in the GNP

sector, the underground economy may represent a forced first step toward an SSE. But not everything about the underground economy is good. Many of its activities (drugs, prostitution) are illegal, and much of its basic motivation is tax evasion, although in today's world there may well be some noble reasons for not paying taxes.

The act of measurement always involves some interaction and interference with the reality being measured. This generalized Heisenberg principle is especially relevant in economics, where the measurement of a success index on which rewards are based, or taxes calculated, nearly always has perverse repercussions on the reality being measured. Consider, for example, the case of management by quantified objectives applied to a tuberculosis hospital, as related to me by a physician. It is well known that TB patients cough less as they get better. So the number of coughs per day was taken as a quantitative measure of the patient's improvement. Small microphones were attached to the patients' beds, and their coughs were duly recorded and tabulated. The staff quickly perceived that they were being evaluated in inverse proportion to the number of times their patients coughed. Coughing steadily declined as doses of codeine were more frequently prescribed. Relaxed patients cough less. Unfortunately the patients got worse, precisely because they were not coughing up and spitting out the congestion. The cough index was abandoned.

The cough index totally subverted the activity it was designed to measure because people served the abstract quantitative index instead of the concrete qualitative goal of health. Perversities induced by quantitative goal setting are pervasive in the literature on Soviet planning: set the production quota for cloth in linear feet, and the bolt gets narrower; set it in square feet, and the cloth gets thinner; set it by weight, and it gets too thick. But one need not go as far away as the Soviet Union to find examples. The phenomenon is ubiquitous. In universities a professor is rewarded according to number of publications. Consequently the length of articles is becoming shorter as we approach the minimum publishable unit of research. At the same time the frequency of coauthors has increased. More and more people are collaborating on shorter and shorter papers. What is being maximized is not discovery and dissemination of coherent knowledge but the number of publications on which one's name appears.

The purpose of these examples of the treachery of quantified success indexes is to suggest that, like them, GNP is not only a passive mismeasure but also an actively distorting influence on the very reality that it aims only to reflect. GNP is an index of throughput, not welfare. Throughput is positively correlated with welfare in a world of infinite sources and sinks, but in a finite world with fully employed carrying capacity, throughput is a *cost*. To design national policies to maximize GNP is just not smart. It is practically equivalent to maximizing depletion and pollution.

The usual reply to these well-known criticisms of GNP is, "So it's not perfect, but it's all we have. What would you put in its place?" It is assumed that we *must* have some numerical index. But why? Might we not be better off without the GNP statistic, even with nothing to "put in its place"? Were not the TB patients better off without the cough index, when physicians and administrators had to rely on "soft" qualitative judgment? The world before 1940 got along well enough without calculating GNP. Perhaps we could come up with a better system of national accounts, but abandoning GNP need not be postponed until then. Politically we are not likely to abandon the GNP statistic any time soon. But in the meantime we can start thinking of it as "gross national cost."

The Ambivalent "Information Economy" The much-touted "information economy" is often presented as a strategy for escaping biophysical limits. Its modern devotees proclaim that "whereas matter and energy decay according to the laws of entropy . . . information is . . . immortal." And, further, "The universe itself is made of information—matter and energy are only simple forms of it" (Turner 1984). Such half-truths forget that information does not exist apart from physical brains, books, and computers, and, further, that brains require the support of bodies, books require library buildings, computers run on electricity, etc. At worst the information economy is seen as a computer-based explosion of the symbol manipulations of the paper economy. More occult powers are attributed to information and its handler, the computer, by the silicon gnostics of today than any primitive shaman ever dared claim for his favorite talisman. And this in spite of the enormous legitimate importance of the computer, which needs no exaggeration.

Other notions of the information economy are by no means nonsensical. When the term refers to qualitative improvements in products to make them more serviceable, longer-lasting, more repairable, and better-looking (Hawken 1983), then we have what was earlier referred to as "development." To think of qualitative improvement as the embodiment of more information in a product is not unreasonable.

But the best question to ask about the information economy is that posed by T. S. Eliot in "Choruses from 'The Rock' ":

> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information?

Why stop with an information economy? Why not a knowledge economy? Why not a wisdom economy?

Knowledge is structured, organized information rendered intelligible and understandable. It is hard to imagine embodying a bit of isolated information (in the sense of communications theory) in a product. What is required for qualitative improvement of products is knowledge—an understanding of the purpose of the item, the nature of the materials, and the alternative designs that are permitted within the restrictions of purpose and nature of the materials. Probably

many writers on the subject use the term "information" synonymously with "knowledge," and what they have in mind is really already a "knowledge economy." The important step is to go to a "wisdom economy."

Wisdom involves a knowledge of techniques plus an understanding of purposes and their relative importance, along with an appreciation of the limits to which technique and purpose are subject. To distinguish a real limit from a temporary bottleneck, and a fundamental purpose from a velleity, requires wise judgment. Growthmania cannot be checked without wise judgment. Since events are forcing us to think in terms of an information economy, it is perhaps not too much to hope that we will follow that thrust all the way to a wisdom economy, one design feature of which, I submit, will be that of a dynamic steady state.

The main characteristics of such a wisdom economy were adumbrated by Earl Cook (1982) in his list of nine "Beliefs of a Neomalthusian," and I will conclude by listing them:

1. "Materials and energy balances constrain production."

2. "Affluence has been a much more fecund mother of invention than has necessity." That is, science and technology require an economic surplus to support them, and a few extra but poor geniuses provided by rapid population growth will not help.

3. "Real wealth is by technology out of nature," or, as William Petty would have said, technology may be the father of wealth, but nature is the mother.

4. "The appropriate human objective is the maximization of psychic income by conversion of natural resources to useful commodities and by the use of those commodities as efficiently as possible," and "the appropriate measure of efficiency in the conversion of resources to psychic income is the human life-hour, with the calculus extended to the yet unborn."

5. "Physical laws are not subject to repeal by men," and of all the laws of economics the law of diminishing returns is closest to a physical law.

6. "The industrial revolution can be defined as that period of human history when basic resources, especially nonhuman energy, grew cheaper and more abundant."

7. "The industrial revolution so defined is ending."

8. "There are compelling reasons to expect natural resources to become more expensive."

9. "Resource problems vary so much from country to country that careless geographic and commodity aggregation may confuse rather than clarify." That is, "it serves no useful purpose to combine the biomass of Amazonia with that of the Sahel to calculate a per capita availability of firewood."

Earl Cook would have been the last person to offer these nine points as a complete blueprint for a wisdom economy. But I think that he got us off to a good start.

Chapter 2

Elements of Environmental Macroeconomics

I have argued in Chapter 1 that the growth economy is an unsustainable goal at the present historical moment, and that we need to shift our vision and practice to a different model—the sustainable or steady-state economy. But economists are a stubborn and resourceful lot, and economics as a discipline provides an array of arguments and techniques that can be used to avoid a rethinking of the fundamental model.

In recent years environmental concerns have been taken up by traditional economists, and their general theme of "internalization of externalities" certainly has its place. However, as a general solution to environmental problems it is proving inadequate. The increasing frequency of appeal to externalities is the clearest possible evidence that more and more relevant facts do not fit within the existing theoretical framework. When increasingly vital facts, including the very capacity of the earth to support life, have to be treated as "externalities," then it is past time to change the basic framework of our thinking so that we can treat these critical issues internally and centrally. In this chapter we will take a look at some of the environmentally relevant contributions of traditional economics (mainly from microeconomics), as well as discuss the traditional absence of any environmental contribution from macroeconomics. Steps toward an environmental macroeconomics are suggested.

Environmental economics, as it is taught in universities and practiced in government agencies and development banks, is overwhelmingly *micro*economics. The theoretical focus is on prices, and the big issue is how to internalize external environmental costs to arrive at prices that reflect full social marginal opportunity costs. Once prices are right, the environmental problem is "solved"—there is no macroeconomic dimension. Cost-benefit analysis in its various permutations is the major tool for estimating full-cost prices. So in practice as well as theory we remain within the domain of microeconomics. There are, of course, good reasons for environmental economics to be closely tied to microeconomics and it is not my intention to argue against that connection. Rather, I ask if there is not a neglected connection between the environment and macroeconomics.

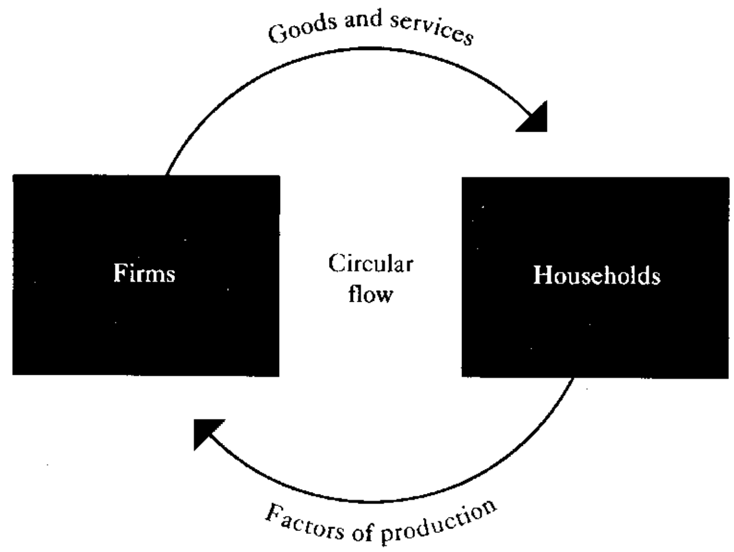
A search through the indexes of three leading textbooks in macroeconomics[1] reveals no entries under any of the following subjects: *environment, natural resources, pollution, depletion*. One of the three does have an entry under "resources," but the discussion refers only to labor and capital, which, along with efficiency, are listed as the causes of growth in GNP. Natural resources are not mentioned. Evidently GNP growth is thought to be independent of natural resources. Is it really the case, as prominent textbook writers seem to think, that macroeconomics has nothing to do with the environment? What historically has impeded the development of an environmental macroeconomics? If there is no such thing as environmental macroeconomics, should there be? Do parts of it already exist? What needs to be added? What policy implications are visible?[2]

The reason that environmental macroeconomics is an empty box lies in what Thomas Kuhn calls a paradigm, and what Joseph Schumpeter more descriptively called a preanalytic vision (Schumpeter 1954). As Schumpeter emphasized, analysis has to start somewhere—there has to be something to analyze. That something is given by a preanalytic cognitive act that Schumpeter called "Vision." One might say that such a vision is what the "right brain" supplies to the "left brain" for analysis. Whatever is omitted from the preanalytic vision cannot be recaptured by subsequent analysis. Schumpeter is worth quoting at length on this point:

> In practice we all start our own research from the work of our predecessors, that is, we hardly ever start from scratch. But suppose we did start from scratch, what are the steps we should have to take? Obviously, in order to be able to posit to ourselves any problems at all, we should first have to visualize a distinct set of coherent phenomena as a worthwhile object of our analytic effort. In other words, analytic effort is of necessity preceded by a preanalytic cognitive act that supplies the raw material for the analytic effort. In this book, this preanalytic cognitive act will be called Vision. It is interesting to note that vision of this kind not only must precede historically the emergence of analytic effort in any field, but also may reenter the history of every established science each time somebody teaches us to *see* things in a light of which the source is not to be found in the facts, methods, and results of the pre-existing state of the science. [p. 41]

The vision of modern economics in general, and especially of macroeconomics, is the familiar circular flow diagram (see figure 2). The macroeconomy

Figure 2. *The economy as an isolated system*



is seen as an isolated system (i.e., as having no exchanges of matter or energy with its environment) in which exchange value circulates between firms and households in a closed loop. What is "flowing in a circle" is variously referred to as production or consumption, but these have physical dimensions. The circular flow does not refer to materials recycling, which in any case could not be a completely closed loop and of course would require energy, which cannot be recycled at all. What is truly flowing in a circle can only be abstract exchange value—exchange value abstracted from the physical dimensions of the goods and factors that are being exchanged. Since an isolated system of abstract exchange value flowing in a circle has no dependence on an environment, there can be no problem of natural resource depletion, nor environmental pollution, nor any dependence of the macroeconomy on natural services, or indeed on anything at all outside itself (Daly 1985). Since analysis cannot supply what the preanalytic vision omits, it is only to be expected that macroeconomics texts would be silent on environment, natural resources, depletion and pollution.

Things are no better when we turn to the advanced chapters at the end of most macroeconomics texts, where the topic is growth theory. True to the preanalytic vision the aggregate production is written as $Y = f(K,L)$, i.e., output is a function of capital and labor stocks. Resource flows (R) do not even enter! Nor is any waste output flow noted. And if occasionally R is stuck in the function along with K and L it makes little difference since the production function is almost always a multiplicative form, such as Cobb-Douglas, in which R can approach zero with Y constant if only we increase K or L in a compensatory fashion. Resources are seen as "necessary" for production, but the amount required can be as little as one likes!

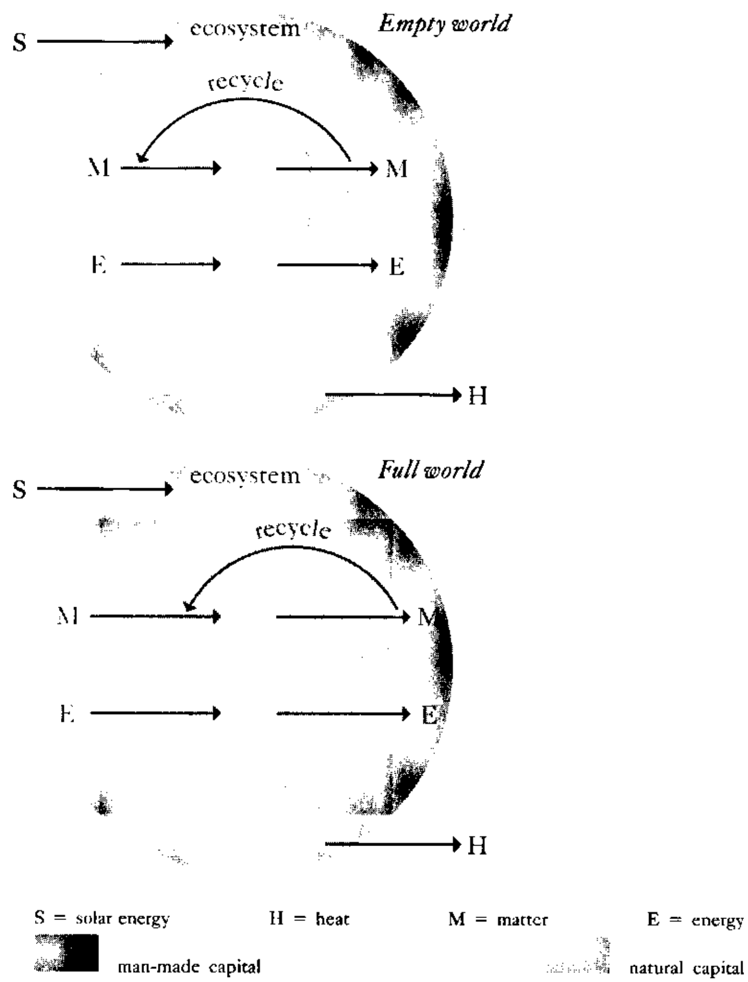
What is needed is not ever more refined analysis of a faulty vision, but a new vision. This does not mean that everything built on the old vision will necessarily have to be scrapped, but fundamental changes are likely when the preanalytic vision is altered. The necessary change in vision is to picture the macroeconomy as an open subsystem of the finite natural ecosystem (environment), and not as an isolated circular flow of abstract exchange value, unconstrained by mass balance, entropy and finitude (see figure 3). The circular flow of exchange value is a useful abstraction for some purposes. It highlights issues of aggregate demand, unemployment, and inflation that were of interest to Keynes in his analysis of the Great Depression. But it casts an impenetrable shadow on all physical relationships between the macroeconomy and the environment. For Keynes, this shadow was not very important, but for us it is. Just as, for Keynes, Say's law and the impossibility of a general glut cast an impenetrable shadow over the problem of the Great Depression, so now the very Keynesian categories that were revolutionary in their time are obstructing the analysis of the major problem of our time—namely, what is the proper scale of the macroeconomy relative to the ecosystem?

Once the macroeconomy is seen as an open subsystem, rather than an isolated system, the issue of its relation to its parent system (the environment) cannot be avoided. The obvious question is, How big should the subsystem be relative to the overall system?

The Environmental Macroeconomics of Optimal Scale

Just as the micro unit of the economy (firm or household) operates as part of a larger system (the aggregate or macroeconomy), so the aggregate economy is likewise a part of a larger system, the natural ecosystem. The macroeconomy is an open subsystem of the ecosystem and is totally dependent upon it, both as a source for inputs of low-entropy matter/energy and as a sink for outputs of high-entropy matter/energy. *The physical exchanges crossing the boundary between the total ecological system and the economic subsystem constitute the subject matter of environmental macroeconomics.* These flows are considered in terms of their scale or total volume relative to the ecosystem, not in terms of the price of one component of the total flow relative to another. Just as standard macroeconomics focuses on the volume of transactions rather than the relative prices of different items traded, so environmental macroeconomics focuses on the volume of exchanges that cross the boundary between sys-

Figure 3. *The economy as an open subsystem of the ecosystem*



Since the ecosystem remains constant in scale as the economy grows, it is inevitable that over time the economy becomes larger *relative* to the containing ecosystem. This transition from an "empty world" to a "full world" is depicted in figure 3. The point is that the evolution of the human economy has passed from an era in which man-made capital was the limiting factor in economic development to an era in which remaining natural capital is the limiting factor. This theme is developed in Part 2.

tem and subsystem, rather than the pricing and allocation of each part of the total flow within the human economy or even within the nonhuman part of the ecosystem.

The term "scale" is shorthand for "the physical scale or size of the human presence in the ecosystem, as measured by population times per capita resource use." Optimal *allocation* of a given scale of resource flow within the economy is one thing (a microeconomic problem). Optimal *scale* of the whole economy relative to the ecosystem is an entirely different problem (a macro-macro problem). The micro allocation problem is analagous to allocating optimally a given amount of weight in a boat. But once the best relative location of weight has been determined, there is still the question of the absolute amount of weight the boat should carry. This absolute optimal scale of load is recognized in the maritime institution of the Plimsoll line. When the watermark hits the Plimsoll line the boat is full, it has reached its safe *carrying capacity.* Of course, if the weight is badly allocated, the water line will touch the Plimsoll mark sooner. But eventually as the absolute load is increased, the watermark will reach the Plimsoll line even for a boat whose load is optimally allocated. Optimally loaded boats will still sink under too much weight—even though they may sink optimally! It should be clear that optimal allocation and optimal scale are quite distinct problems. The major task of environmental macroeconomics is to design an economic institution analogous to the Plimsoll mark—to keep the weight, the absolute scale, of the economy from sinking our biospheric ark.[3]

The market, of course, functions only within the economic subsystem, where it does only one thing: it solves the allocation problem by providing the necessary information and incentive. It does that one thing very well. What it does not do is solve the problems of optimal scale and of optimal distribution. The market's inability to solve the problem of just distribution is widely recognized, but its similar inability to solve the problem of optimal or even sustainable scale is not as widely appreciated.[4]

An example of the confusion that can result from the nonrecognition of the independence of the scale issue from the question of allocation is provided by the following dilemma.[5] Which puts more pressure on the environment, a high or a low discount rate? The usual answer is that a high discount rate is worse for the environment because it speeds the rate of depletion of nonrenewable resources and shortens the turnover and fallow periods in the exploitation of renewables. It shifts the allocation of capital and labor towards projects that exploit natural resources more intensively but it restricts the total number of projects undertaken. A low discount rate will permit more projects to be undertaken even while encouraging less intensive resource use for each project. The allocation effect of a high discount rate is to increase throughput, but the scale effect is to lower throughput. Which effect is stronger is hard to say, although one suspects that over the long run the scale effect will dominate. The resolution to the dilemma is to recognize that two independent policy goals require two independent policy instruments. We cannot serve both optimal scale and optimal allocation with the single policy instrument of the discount rate (Tinbergen 1952). The discount rate should be allowed to solve the allocation problem, within the confines of a solution to the scale problem provided by a presently nonexistent policy instrument, which we may for now call an "economic Plimsoll line," that limits the scale of the throughput.

Economists have recognized the independence of the goals of efficient allocation and just distribution and are in general agreement that it is better to let prices serve efficiency, and to serve equity with income redistribution policies. Proper scale is a third, independent policy goal and requires a third policy instrument. This latter point has not yet been accepted by economists, but its logic is parallel to the logic underlying the separation of allocation and distribution. In pricing factors of production and distributing profits the market does, of course, influence the distribution of income. Providing incentive requires some ability to alter the distribution of income in the interests of efficiency. The point is that the market's criterion for distributing income is to provide an incentive for efficient allocation, not to attain justice. And in any case, historical conditions of property ownership are major determinants of income distribution and have little to do with either efficiency or justice. These two values can conflict, and the market does not automatically resolve this conflict. The point to be added is that there are not just two, but three, values in conflict: allocation (efficiency), distribution (justice), and scale (sustainability).

Microeconomics has not discovered in the price system any built-in tendency to grow only up to the scale of aggregate resource use that is optimal (or even merely sustainable) in its demands on the biosphere. *Optimal scale, like distributive justice, full employment, or price level stability, is a macroeconomic goal.* And it is a goal that is likely to conflict with the other macroeconomic goals. The traditional solution to unemployment is growth in production, which means a larger scale. Frequently the solution to inflation is also thought to be growth in real output, and a larger scale. And most of all, the issue of distributive justice is "finessed" by the claim that aggregate growth will do more for the poor than redistributive measures. Conventional macroeconomic goals tend to conflict, and certainly optimal scale will conflict with any goal that requires further growth once the optimum has been reached.

Scale has a maximum limit defined either by the regenerative or absorptive capacity of the ecosystem, whichever is less. However, the maximum scale is not likely to be the optimal scale. Two concepts of optimal scale can be distinguished, both formalisms at this stage, but important for clarity.

1. *The anthropocentric optimum.* The rule is to expand scale (i.e., grow) to the point at which the marginal benefit to human beings of additional man-made physical capital is just equal to the marginal cost to human beings of sac-

rificed natural capital. All nonhuman species and their habitats are valued only instrumentally according to their capacity to satisfy human wants. Their intrinsic value (capacity to enjoy their own lives) is assumed to be zero.

2. *The biocentric optimum.* Other species and their habitats are preserved beyond the point necessary to avoid ecological collapse or cumulative decline, and beyond the point of maximum instrumental convenience, out of a recognition that other species have intrinsic value independent of their instrumental value to human beings. The biocentric optimal scale of the human niche would therefore be smaller than the anthropocentric optimum.

The definition of sustainable development does not specify which concept of optimum scale to use. It is consistent with any scale that is not above the maximum. Sustainability is probably the characteristic of optimal scale on which there is most consensus. It is a necessary, but not sufficient, condition for optimal scale.

Policy Outruns Theory: Tradeable Permits as a Forced Separation of Allocation, Distribution, and Scale

The tradeable pollution permits scheme, explained below, is a beautiful example of the independence and proper relationship among allocation, distribution, and scale. Consider step by step what this policy requires in practice.

First we must create a limited number of rights to pollute. The aggregate or total amount of pollution corresponding to these rights is determined to be within the absorptive capacity of the airshed or watershed in question. That is to say, the scale impact is limited to a level judged to be ecologically sustainable—an economic Plimsoll line must be drawn as the very first step. Far from ignoring scale, this policy requires that the issue of sustainable or optimal scale be settled at the beginning. It may be done on the basis of a carrying capacity estimate, a safe minimum standards estimate, or a cost-benefit study, but some limit to total pollution must be set.

Second, the limited number of rights corresponding to the chosen scale must be distributed initially to different people. Perhaps equally to citizens, or to firms, or perhaps collectively as public property then to be auctioned or sold by the government to individuals. But there must be an initial distribution before there can be any allocation and reallocation by trading.

Only in third place, after having made social decisions regarding an ecologically sustainable scale and an ethically just distribution, are we in a position

to allow reallocation among individuals through markets in the interests of efficiency. A separation between allocation and scale requires that the total quantity of permits be fixed, but that the price at which the permits trade be free to vary. If the total quantity were determined by a willingness-to-pay study that also gave a shadow price as well as an aggregate quantity, then the neoclassical economist who wants to avoid separating allocation and scale must insist that trading take place at the calculated shadow price. Otherwise there will be a separation between allocation and scale. In practice, the price is always free to vary, clearly indicating that the pragmatic, operational solution has been to separate allocation and scale.

It is clear that scale is not determined by prices, but by a social decision reflecting ecological limits. Distribution is not determined by prices, but by a social decision reflecting a just distribution of the newly created assets. Subject to these social decisions, individualistic trading in the market is then able to allocate the scarce rights efficiently. For some reason economists have analyzed the tradeable pollution permits scheme almost entirely in relation to the command and control allocative schemes. They have indeed shown it to be superior to command and control in terms of allocative efficiency. But with all the emphasis on allocation the critical role of scale went unnoticed, and the role of distribution, while certainly noticed, was not sufficiently emphasized. Tradeable permits have been considered the individualistic "free market" solution, without emphasizing that this market is free only after having been firmly and collectively fixed within scale and distributive limits.

The greens (environmentalists), too, have shown considerable misunderstanding of this scheme, condemning it as "giving away licenses to pollute." The point is that this scheme limits the total scale of pollution, need not give away anything but can sell the rights for public revenue, yet allows reallocation among individuals in the interest of efficiency. Some greens complain that under this scheme the rich have an advantage. The rich *always* have an advantage, but does this scheme increase or decrease the preexisting advantage of the rich? It could do either, it all depends on the initial distribution of ownership of the new assets, and not on the fact that they are tradeable.

The usual way for economists to deal with the scale issue, when forced to think about it at all, is to try to subsume it under allocation, claiming that if we just get prices right there will be no scale problem. Of course, when the scale of the economy was small, then the right price for nonscarce environmental services was zero. Economists reason that when these services become scarce it is simply necessary to find the right positive price and everything will be efficiently allocated. It is true that pricing newly scarce resources is necessary to solve the allocation problem. The mistake is to assume that it therefore solves the scale problem as well. A small scale with a lot of zero prices for environmental services is quite a different state of the world from a large scale with a lot of positive prices for those previously free environmental services. In both cases "prices are right" and allocation is efficient. But it still makes sense to ask whether people are better off in the first or second case. The difference is a matter of scale.

The neoclassical economist would reply that such a question is easily answered. If the larger scale exists, it was obviously chosen by individuals in numerous micro decisions in which they were willing to pay the marginal environmental costs of growing to the larger scale because they judged them to be less than the marginal benefits. Of course, the individuals' judgment could be biased by "externalities," but "right prices" means that these have all been internalized in prices.

The price of a commodity reflects the value of the next-best alternative commodity to which the factors embodied in the commodity in question could have been allocated. In practice, nature is excluded from the world of commodities whose opportunity costs are measured by market prices. Prices do not balance marginal ecosystem services sacrificed against marginal social benefit of a larger population or greater per capita resource use (i.e., larger scale). This balance requires calculation and imposition of shadow prices that value the *in natura* use of all resources in terms commensurate with the customary pecuniary exchange valuation of commodities. This view requires heroic assumptions about our knowledge of the external costs resulting from ecosystem disruption, and how these costs are imputed to the micro decisions that gave rise to them. The ecosystem is under no obligation to respond to increasing stress by sacrificing its services in order of their increasing importance to us, conveniently giving economists a "well-behaved" marginal cost function. Discontinuities, threshholds, and complex webs of interdependence make a mockery of the idea that we can nicely balance smoothly increasing ecosystem costs with the diminishing marginal utility of production at the macro level. The notion that systemic vital costs of collective behavior (greenhouse effect, ozone depletion) are best dealt with by pretending that every individual could and should, on the basis of assumed perfect knowledge, decide his or her own willingness to pay to avoid the loss of such services, is not an idea that comes easily to the unprejudiced mind. It requires years of indoctrination in "methodological individualism."

The distribution and scale questions, like the allocation question, are *economic* in that they involve costs and benefits. But the dimensions in which costs and benefits are defined are different in the three cases. Allocative prices are not even relevant to estimating the costs and benefits of scale expansion, just as they are not relevant to estimating the costs and benefits of a step towards a more equal distribution of income or wealth. We have three independent optima requiring three independent policy instruments. In each case an optimum is formally defined by the equality of rising costs and falling benefits at the margin. But the definitions and measures of costs and benefits in each of the three cases are different because the problems being solved are different. The relative price of shoes and bicycles is instrumental in allocating resources efficiently between shoes and bicycles, but is clearly not instrumental for deciding the proper range of inequality in wealth or income, nor for deciding how many people consuming how much per capita of natural resources is sustainable.

Distribution and scale involve relationships with the poor, the future, and other species that are fundamentally social in nature rather than individual. *Homo economicus* as the self-contained atom of methodological individualism, or as the pure social being of collectivist theory, are both severe abstractions. Our concrete experience is that of "persons in community." We are individual persons, but our very individual identity is defined by the quality of our social relations. Our relations are not just external, they are also internal, that is, the nature of the related entities (ourselves in this case) changes when relations among them changes. We are related not only by a nexus of individual willingnesses to pay for different things, but also by relations of trusteeship for the poor, the future, and other species. The attempt to abstract from these concrete relations of trusteeship and reduce everything to a question of individual willingness to pay is a distortion of our concrete experience as persons in community, an example of A. N. Whitehead's "fallacy of misplaced concreteness."[6]

The prices that measure the opportunity costs of reallocation are unrelated to measures of the opportunity costs of redistribution or of a change in scale. Any tradeoff among the three goals (e.g., an improvement in distribution in exchange for a worsening in scale or allocation, or more unequal distribution in exchange for sharper incentives seen as instrumental to more efficient allocation) involves an ethical judgment about the quality of our social relations rather than a willingness-to-pay calculation. The contrary view, that this choice among basic social goals and the quality of social relations that help to define us as persons should be made on the basis of individual willingness to pay, just as the tradeoff between chewing gum and shoelaces is made, seems to be dominant in economics today and is part of the retrograde modern reduction of all ethical choice to the level of personal tastes weighted by income.

It is instructive to consider the historical attempt of the Scholastic economists to subsume distribution under allocation (or more likely they were subsuming allocation under distribution—at any rate they did not make the distinction). This was the famous "just price" doctrine of the Middle Ages, which has been totally rejected in economic theory, although it stubbornly survives in the politics of minimum wages, farm price supports, water, and electric power subsidies, and so on. However, we do not as a general rule try to internalize the external cost of distributive injustice into market prices. We reject the attempt to correct market prices for their unwanted effects on income distribution. Economists nowadays keep allocation and distribution quite separate, and argue for letting prices serve only efficiency, while serving justice with the separate policy of transfers of wealth through taxes and social programs. This follows Tinbergen's dictum of equality of policy goals and instruments. The point is that just as we cannot subsume distribution under allocation, neither can we subsume scale under allocation.

Although the usual attempt is to subsume scale under allocation, a few economists have recently implicitly subsumed it under distribution.[7] The argument is that excessive scale erodes carrying capacity and inflicts a cost on future generations. Since future generations are different people, this is a matter of distribution, not allocation. A sustainable scale is nothing other than an intergenerational distribution of the resource base that is fair to the future. This argument is raised against economists who subsume scale under allocation by arguing that intertemporal allocation via discounting the future is the rational (efficient) way to deal with provision for the future. The intergenerational discounting argument is circular because the discount rate, like other prices, is determined on the basis of some given distribution (intergenerational distribution of the resource base in this instance). To then use the discount rate to determine that same distribution between generations is circular. You have to have the distribution to get the discount rate, yet the discounting approach wants to use the discount rate to determine the intergenerational distribution—which is mistakenly called an intergenerational "allocation."

I think that this critique of discounting is correct. But it should not be thought of as a way to subsume the scale problem entirely under the distribution problem. Although justice with respect to the future is certainly an important motivation behind sustainability as a goal, and excessive scale can indeed mean a loss of sustainability, that does not exhaust the question of optimal scale. Scale can become too large from the point of view of the present, even if it remains possible to pass on the too-large economy to the future forever. For example, we could take over the habitat of most other species, driving all nonessential species to extinction, and by careful self-discipline impose on ourselves a rigorous and costly management to compensate for the displaced self-managing natural systems. Scale could be too large even if sustainable. For this reason scale cannot be totally subsumed under distribution, although it must be admitted that scale issues do overlap with one part of distribution, the intergenerational part, to a considerable degree.

Although discussed in terms of pollution, the logic of tradeable permits extends to controlling depletion as well. It can be applied regionally, nationally, and even internationally, as with carbon emission permits to limit the greenhouse effect. It can even be applied to population control as in the tradeable birth quotas suggested by Kenneth Boulding (1964). In fact, to my knowledge, Boulding's was the first clear exposition of the logic of the scheme, although applied to the least likely area of acceptance politically. The tradeable permits idea is truly a paradigm for many sensible policies, as well as by now a fact of experience that should be allowed to alter economic theory. Specifically, theory should recognize scale, along with allocation and distribution, as a fundamental part of the economic problem. If operationality (the congruence of abstract concepts with policy instruments) is a criterion for judging theories, then the theoretical separation of scale and allocation advocated here is superior to the neoclassical approach of lumping them together, because the latter requires nonoperational assumptions to save appearances of methodological individualism, while the former is already being accepted in the practical policy of tradeable permits.

How Big Is the Economy?

As long as the human economy was infinitesimal relative to the natural world, then sources and sinks could be considered infinite, and therefore not scarce. And if they are not scarce then they are safely abstracted from economics. There was no need to consider the larger system since it imposed no scarcities. This was a reasonable view at one time, but no longer. As Kenneth Boulding says, when something grows it gets bigger! The economy has gotten bigger, the ecosystem has not. How big has the economy become relative to the ecosystem?

Probably the best index of the scale of the human economy as a part of the biosphere is the percentage of human appropriation of the total world product of photosynthesis. Net primary production (NPP) is the amount of solar energy captured in photosynthesis by primary producers, less the energy used in their own growth and reproduction. NPP is thus the basic food resource for everything on earth not capable of photosynthesis. Vitousek et al. (1986) calculate that 25% of potential global (terrestrial and aquatic) NPP is now appropriated by human beings.[8] If only terrestrial NPP is considered, the fraction rises to 40%. Taking the 25% figure for the entire world, it is apparent that two more doublings of the human scale will give 100%. Since this would mean zero energy left for all nonhuman and nondomesticated species, and since humans cannot survive without the services of ecosystems (which are made up of other species), it is clear that two more doublings of the human scale is an ecological impossibility, although arithmetically possible. Furthermore, the terrestrial figure of 40% is probably more relevant since we are unlikely to increase our take from the oceans very much. Total appropriation of the terrestrial NPP can occur in only a bit over one doubling time. Perhaps it is theoretically possible to increase the earth's total photosynthetic capacity somewhat, but the actual trend of past economic growth is decidedly in the opposite direction.

Assuming a constant level of per capita resource consumption, the doubling time of the human scale would be equal to the doubling time of population, which is on the order of forty years. Of course, economic growth currently aims to increase the average per capita resource consumption and consequently to reduce the doubling time of the scale of the human presence below that implicit in the demographic rate of growth. The greenhouse effect, ozone layer depletion, and acid rain all constitute evidence that we have already gone beyond a prudent Plimsoll line for the scale of the macroeconomy.

Cowboy, Spaceman, or Bull in the China Shop?

If one starts from the vision of the economic process as an open subsystem of a closed finite total system, then the question of how big the subsystem should be relative to the total system is hard to avoid. How then have we managed to avoid it? In two ways: first, by viewing the economic subsystem as infinitesimally small relative to the total system, so that scale becomes irrelevant because it is negligible; second, by viewing the economy as coextensive with the total system. If the economy includes everything, then the issue of scale relative to a total system simply does not arise. These polar extremes correspond to Boulding's colorful distinction between the "cowboy economy" and the "spaceman economy." The cowboy of the infinite plains lives off of a linear throughput from source to sink, with no need to recycle anything. The spaceman in a small capsule lives off of tight material cycles and immediate feedbacks, all under total control and subservient to his needs. For the cowboy, scale is negligible; for the spaceman, scale is total. There is no material environment relative to which scale must be determined; there is no ecosystem, only economy. In each of these polar cases, the only problem is allocation. Scale is irrelevant.

It is only in the middle ground between the cowboy and the spaceman that the issue of scale does not get conflated with allocation. But, as Boulding realized, the middle ground happens to be where we are. Between the cowboy and spaceman economies is a whole range of larger and smaller "bull-in-the-china-shop economies" where scale is a major concern. We are not cowboys because the existing scale of the economy is far from negligible compared to the environment. But neither are we spacemen, because most of the matter/energy transformations of the ecosystem are not subject to human control either by prices or by central planning. In a finite system subject to the conservation of mass, the more that is brought under our economic control, the less remains under the spontaneous control of nature. As our exactions from and insertions back into the ecosystem increase in scale, the qualitative change induced in the ecosystem must also increase, for two reasons. The first is the first law of thermodynamics (conservation of matter/energy). The taking of matter and energy out of the ecosystem must disrupt the functioning of that system even if nothing is done to the matter and energy so removed. Its mere absence must have an effect. Likewise, the mere insertion of matter and energy into an ecosystem must disrupt the system into which it is newly added. This must be the case even without appealing to any qualitative degradation of the matter and energy thus relocated. The second reason is the second law of thermodynamics, which guarantees that the matter/energy exacted is qualitatively different from the matter/energy inserted. Low-entropy raw materials are taken out, high-entropy wastes are returned. This qualitative degradation of the matter/energy throughput, along with the purely quantitative dislocation of the same, induces changes in the ecosystem which to us are surprising and novel because our information and control system (prices) assumes nonscarcity (nondisruptability) of environmental source and sink functions. Economic calculation is about to be overwhelmed by novel, uncertain, and surprising feedbacks from an ecosystem that is excessively stressed by having to support too large an economic subsystem (Perrings 1987).

How big should the subsystem be relative to the total ecosystem? Certainly this, the question of optimal scale, is the big question for environmental macroeconomics. But since it is such a difficult question, and since we cannot go back to the cowboy economy, we have acquired a tendency to want to jump all the way to the spaceman economy and take total control of the spaceship earth. (The September 1989 special issue of *Scientific American* entitled "Managing Planet Earth" is representative of this thrust.) But, as environmentalist David Orr points out, God, Gaia, or Evolution was doing a nice job of managing the earth until the scale of the human population, economy, and technology got out of control. Planetary management implies that it is the planet that is at fault, not human numbers, greed, arrogance, ignorance, stupidity, and evil. We need to manage ourselves more than the planet, and our self-management should be, in Orr's words, "more akin to child-proofing a day-care center than to piloting spaceship earth." The way to child-proof a room is to build the optimal scale playpen within which the child is both free and protected from the excesses of its own freedom. It can enjoy the light and warmth provided by electrical circuits beyond its ken, without running the risk of shorting out those circuits, or itself, by experimenting with the "planetary management technique" of teething on a lamp cord.

Our manifest inability to centrally plan economies should inspire more humility among the planetary managers who would centrally plan the ecosystem. Humility should argue for the strategy of minimizing the need for planetary management by keeping the human scale sufficiently low so as not to disrupt the automatic functioning of our life-support systems, thereby forcing them into the domain of human management. Those who want to take advantage of the "invisible hand" of self-managing ecosystems have to recognize that the invisible hand of the market, while wonderful for allocation, is unable to set limits to the scale of the macroeconomy. Our limited managerial capacities should be devoted to institutionalizing an economic Plimsoll line that limits the macroeconomy to a scale such that the invisible hand can function in both domains to the maximum extent. It is ironic that many free marketeers, by opposing any limit to the scale of the market economy (and therefore to the increase in externalities), are making more and more inevitable the very central planning that they oppose. Even worse is their celebration of the increase in GNP that results as formerly free goods become scarce and receive a price. For allocation it is necessary that newly scarce goods not continue to have a zero price—no one disputes that. The issue is that, for all we know, we might have been better off to remain at the smaller scale at which the newly scarce goods were free and their proper allocative price was still zero. The increase in measured national income and wealth resulting as formerly free goods are turned into scarce goods is more an index of cost than of benefit, as was recognized by the classical economist Lauderdale back in 1819 (Lauderdale 1819; Foy 1989).

A Glittering Anomaly

Optimal scale of a single activity is not a strange concept to economists. Indeed, microeconomics is about little else. An activity is identified, be it producing shoes or consuming ice cream, and a cost function and a benefit function for the activity in question are defined. Good reasons are given for believing that marginal costs increase and marginal benefits decline as the scale of the activity grows. The message of microeconomics is to expand the scale of the activity in question up to the point where marginal costs equal marginal benefits, a condition which defines the optimal scale. All of microeconomics is an extended variation on this theme.

When we move to macroeconomics, however, we never again hear about optimal scale. There is apparently no optimal scale for the macroeconomy. There are no cost and benefit functions defined for growth in scale of the economy as a whole. It just doesn't matter how many people there are, or how much they each consume, as long as the proportions and relative prices are right. But if every micro activity has an optimal scale, then why does not the aggregate of all micro activities have an optimal scale? If I am told in reply that the reason is that the constraint on any one activity is the fixity of all the others and that when all economic activities increase proportionally the restraints cancel out, then I will invite the economist to increase the scale of the carbon cycle and the hydrologic cycle in proportion to the growth of industry and agriculture. I will admit that if the ecosystem can grow indefinitely then so can the aggregate economy. But until the surface of the earth begins to grow at a rate equal to the rate of interest, one should not take this answer too seriously.

The total absence in macroeconomics of the most basic concept of microeconomics is a glittering anomaly, and it is not resolved by appeals to the fallacy of composition. What is true of a part is not necessarily true for the whole, but it can be and usually is unless there is some aggregate identity or self-canceling feedback at work. (As in the classic example of all spectators standing on tiptoe to get a better view and each canceling out the better view of the other, or in the observation that while any single country's exports can be greater than its imports, nevertheless the aggregate of all exports cannot be different than the aggregate of all imports.) But what analogous feedback or identity is there that allows every economic activity to have an optimal scale while the aggregate economy remains indifferent to scale? The indifference to scale of the macroeconomy is due to the preanalytic vision of the economy as an isolated system—the inappropriateness of which has already been discussed.

Chapter 3

Consumption: Value Added, Physical Transformation, and Welfare

At the heart of the current crisis in economic theory and practice is the fact that we are consuming the earth's resource beyond its sustainable capacities of renewal, thus running down that capacity over time—that is, we are consuming natural capital while calling it income. So it is natural that we turn our attention to another set of key topics in economic theory: consumption, value added, and welfare. What insights can we gain from traditional economics? What mistakes must we correct?

While all countries must worry about both population and per capita resource consumption, it is evident that the South needs to focus more on population, and the North more on per capita resource consumption. This fact will likely play a major role in North / South treaties and discussions. Why should the South control its population if the resources saved thereby are merely gobbled up by Northern overconsumption? Why should the North control its overconsumption if the saved resources will merely allow a larger number of poor people to subsist at the same level of misery? Without for a minute minimizing the necessity of population control, it is nevertheless incumbent on the North to get serious about consumption control. These considerations lend a sense of urgency to the reconsideration of the meaning of consumption.

Consumption and Value Added

When we speak of consumption what is it that we think of as being consumed? Alfred Marshall reminded us of the laws of conservation of matter / energy and the consequent impossibility of consuming the material building blocks of which commodities are made: