Steady-State Economics

Concepts, Questions, Policies

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This lecture first discusses the pre-analytic vision of steady-state economics, along with its basic magnitudes, idea of efficiency, and relations to the traditional concepts of income and capital. Next it addresses some analytical questions suggested by the steady-state vision. Finally, it discusses some policy issues of moving toward a steady-state economy.

The Pre-Analytic Vision and Basic Concepts of Steady-State Economics

The pre-analytic vision from which steady-state economics emerges is that the economy, in its physical dimensions, is an open subsystem of a finite, non-growing and materially closed total system — the earth-ecosystem or biosphere. An "open" system is one with a "digestive tract," i.e., that takes matter and energy from the environment in low-entropy form (raw materials), and returns it to the environment in high-entropy form (waste). A "closed" system is one in which only energy flows through, while matter circulates within the system. Whatever flows through a system, entering as input and exiting as output, is called "throughput." Just as an organism maintains its physical structure by a metabolic flow and is connected to the environment at both ends of its digestive tract, so too an economy requires a throughput, which must to some degree both deplete and pollute the environment. A steady-state economy is one whose throughput remains constant at a level that neither depletes the environment beyond its regenerative capacity, nor pollutes it beyond its absorptive capacity.

Growth of the subsystem is further limited by the complementary relation between manmade and natural capital.[2] If the two forms of capital were good substitutes, then natural capital could be totally replaced by manmade, and the only limit to expansion of manmade capital would be finitude of the containing system. But in fact manmade capital loses its value without a complement of natural capital. What good are fishing boats without populations of fish? Saw mills without forests? And even if we could convert the whole ocean into a catfish pond we would still need the natural capital of solar energy, photosynthetic organisms, nutrient recyclers, etc.

The pre-analytic vision underlying standard economics is that the economy is an isolated system: a circular flow of exchange value between firms and households. This vision is useless for studying the relation of the economy to the environment. It is as if a biologist's vision of an animal contained only a circulatory system, but no digestive tract.

As long as the scale of the economy was very small relative to the ecosystem, one could abstract from the throughput since no apparent sacrifice was involved in increasing it. The economy has now grown to a scale such that this is no longer reasonable. We have also failed to make the elementary distinction between growth (physical increase in size resulting from accretion or assimilation of materials), and development (realization of potentialities, evolution to a fuller, better, or different state). Quantitative and qualitative changes follow different laws. Conflating the two, as we currently do in our measure of economic activity, GNP, has led to much confusion.

The pre-analytic vision which supports most economic analysis is that the economy is the total system and is unconstrained in its growth by anything. Nature may be finite, but it is just a sector of the economy, for which other sectors can substitute, without limiting overall growth in any important

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way. If the economy is seen as an isolated system then there is no environment to constrain its continual growth. But if we see it as a subsystem of a larger, but finite and non-growing ecosystem, then obviously its growth is limited. The economy may develop qualitatively without growing quantitatively, just as the planet Earth does, but it cannot continue to grow — i.e., beyond some point it must approximate a steady state in its physical dimensions. Sustainable development is development without growth — a physically steady-state economy that may develop greater capacity to satisfy human wants by increasing the efficiency of resource use, but not by increasing the resource throughput.

In addition to throughput there are two other magnitudes that are basic: stock and service. Stock is the capital accumulation, manmade and natural, as well as durable consumer goods, that yields a flow of services. Services are satisfactions of wants yielded by the stock. The throughput is the entropic or metabolic physical flow that maintains the stock. Stock is an intermediate magnitude that on the one hand yields services, and on the other requires throughput for its maintenance and replacement. Service is benefit; throughput is related to cost. For any given level of stock, throughput should be minimized and service maximized. In an empty world increasing throughput implies no sacrifice of ecosystem services, but in a full world it does. The ultimate cost is the sacrifice of ecosystem services required by using the natural capital stock as a source of throughput rather than as a source of direct ecosystem services. Throughput begins with depletion and ends with pollution, both of which are costs in a full world. Therefore it makes sense to minimize throughput for any given level of stock. If we recognize that the economy grows by converting ever more of the ecosystem (natural capital) into economy (manmade capital), then we see that the benefit of that expansion is the extra services from manmade capital and the cost is the loss of service from reduced natural capital.

The efficiency with which we use the world to satisfy our wants depends on the amount of service we get per unit of manmade capital, and the amount of service we sacrifice per unit of natural capital lost as a result of its conversion into manmade capital. This *overall ecological-economic efficiency is the ratio:*

$$\frac{\text{MMK services gained}}{\text{NK services sacrificed}}$$

where MMK is man made capital and NK is natural capital. In an empty world there is no noticeable sacrifice of NK services required by increases in MMK, so the denominator is irrelevant. In a full world any increase in MMK comes at a noticeable reduction in NK and its services.

This efficiency ratio can be "unfolded" into four components by means of the identity below.[3] Each term represents a dimension of efficiency that might be improved by increased investment in knowledge or technique.

Ratio (1) is the **service efficiency** of the manmade capital stock. It depends on several things. First, the technical design efficiency of the product itself. Second, the economic efficiency of resource allocation among the different product uses in conformity with individual preferences and ability to pay. Third, the distributive efficiency among individuals. The first two are straightforward and in conformity with standard economics, but the third requires explanation. Usually distribution is separated from efficiency by the Pareto condition that utility cannot be compared across individuals, and it does make sense to believe that total social utility increases when resources are redistributed from the low marginal utility uses of the rich to the high marginal uses of the poor. One can reject the total egalitarianism implicit in carrying this idea to its logical extreme while agreeing with Joan Robinson that it is possible to allow too much of the good juice of utility to evaporate from commodities by allowing them to be unequally distributed. In a full world investments in distributive efficiency can no longer be ruled out of bounds. Economists have studied allocative efficiency via the price mechanism, in great detail. Further refinements from deeper study of this dimension of ratio (1) will probably be less productive than the study of technical and distributive dimensions, or of the other three efficiency ratios.

Ratio (2) reflects the **maintenance efficiency** or durability of the manmade capital stock. While ratio (1) measures the service intensity per unit of time of

$$\frac{\text{MMK services gained}}{\text{NK services sacrificed}} = \underset{(1)}{\frac{\text{MMK services gained}}{\text{MMK stock}}} \times \underset{(2)}{\frac{\text{MMK stock}}{\text{throughput}}} \times \underset{(3)}{\frac{\text{throughput}}{\text{NK stock}}} \times \underset{(4)}{\frac{\text{NK stock}}{\text{NK services sacrificed}}}$$

the manmade stock, ratio (2) measures the number of units of time over which the stock yields that service. Ratio (2) is the durability of the stock, or the "residence time" of a unit of resource throughput as a part of the manmade capital stock. A slower rate of throughput, *ceteris paribus* ["other things being equal"], means reduced depletion and pollution. Maintenance efficiency is increased by designing commodities to be durable, repairable, and recyclable. Or by designing patterns of living that make certain commodities less necessary to begin with. Eliminating planned obsolescence and excessive model changes would improve this ratio. As Kenneth Boulding has long argued, we must learn to focus on the service of the capital stock as the benefit, and treat the flow of new production as a cost made necessary by the regrettable tendency of the stock to become worn out or used up. A longer life expectancy for the stock means less production is needed, which in turn reduces the throughput which reduces depletion and pollution.

Ratio (3) is the **growth efficiency** of natural capital in yielding an increment available for offtake as throughput. It is determined by the biological growth rate of the population or ecosystem being exploited. For example, pine trees grow faster than mahogany, so in uses where either will do, pine is more efficient. Generally nature presents a menu of different species growing at different rates. If we are able to design our technologies and consumption patterns to depend on the faster growing species, that will be more efficient, *ceteris paribus*.

With the advent of genetic engineering there will be more attempts to speed up growth rates of exploited species (e.g., bovine growth hormone). The green revolution involves an attempt to speed up growth rates of wheat and rice. Since an increase in biological growth rate frequently comes at the expense of stability, resilience, resistance to disease or predators, it may be that attempts to speed up reproductive rates will often end up costing more than they are worth. It is for now surely better for humans to slow down our own biological growth rate than to attempt to speed up the growth rates of all the species we depend upon. Nevertheless, we can to some degree adapt our pattern of consumption to depend more on naturally faster growing species, where possible.

For sustained-yield exploitation ratio (3) will vary with the size of the population maintained, according to the familiar inverted-U-shaped function. For any chosen combination of population size and yield ratio (3) would remain constant over time under sustained yield management. Maximum sustained yield would of course maximize this dimension of efficiency over the long run (if harvesting costs are constant). In the short run this ratio can be driven very high by the non-sustainable practice of exceeding renewable rates of harvest and thereby converting permanent stock into one-time throughput. This appears as an increase in growth efficiency due to our absurd accounting practice of counting natural capital depletion as current income.[4]

Ratio (4) measures the amount of natural capital stock that can be exploited for throughput (either as source or sink), per unit of other natural services sacrificed. For example, if we exploit a forest to get maximum sustainable yield of timber (or maximum absorption of CO^2), then we will to some degree sacrifice other natural services of the forest such as wildlife habitat, erosion control, and water catchment. We want to minimize the loss of other ecosystem services per unit of natural capital managed with the objective of yielding a single service — usually that of generating raw material throughput. Ratio (4) might be called ecosystem service efficiency reflecting the minimization of loss of other ecosystem services when a population or ecosystem is exploited primarily for throughput extraction or absorption.[5]

The world is complicated and no simple identity can capture everything. However, these four dimensions of ecological-economic efficiency may be helpful in devising ways to invest indirectly in natural capital. As NK is converted into MMK we want at each step to maximize the service from the increment of MMK and to minimize the loss of ecosystem service from the decrement of NK. But at some point, even if carried out efficiently, this process of conversion of NK into MMK will itself reach an economic limit, an optimal scale of the economic subsystem beyond which further expansion would increase ecological costs faster than production benefits. This optimal scale is defined by the usual economic criterion of equating marginal costs and benefits. This criterion assumes that marginal benefits decline and that marginal costs increase, both in a continuous fashion. It is reasonable to think that marginal benefits decline because humans are sufficiently rational to satisfy their most pressing wants first. But the assumption that marginal costs (sacrificed ecosystem services) increase in a continuous fashion is problematic. As the human niche has expanded the stresses on the ecosystem have increased, but there has been no rational ordering by human or providential intelligence to ensure that the least important ecosystem services are always sacrificed first. We appear to be sacrificing some vital services rather early. This is another way of saying that ratio (4), ecological service efficiency, has been ignored. If we begin to pay attention to that dimension of efficiency then we may expect human rationality to begin to order the sacrifice of ecosystem services from least to most damaging, and thus justify the economists' usual assumption of gradually rising marginal costs. That would make the optimal scale of the human niche more definable.

The present lack of rational sequencing of ecosystem costs is due both to nonrecognition of the problem and to ignorance of ecosystem functioning. Prudence in the face of large uncertainties about ecosystem costs should lead us to be very conservative about risking any further expansion. But even with complete certainty and a least-cost sequence of environmental costs, there would still be an optimal scale beyond it would be anti-economic to grow.

Even within the confines of more traditional concepts a similar conclusion can be reached. Exceeding carrying capacity in either source or sink functions leads to a loss of that function in the future. This loss represents depreciation of natural capital, which, like depreciation of manmade capital, is a reduction in productive capacity, and must be deducted as a cost from gross income to arrive at net income. Renewable natural capital is thus treated as a productive machine whose maintenance costs must be covered by the process of production. Of course, some natural capital is nonrenewable and its depletion is best considered as disinvestment of already "produced" inventories, rather than as a reduction of future capacity to produce. Consequently the depletion of nonrenewable inventories (resource reserves) should not even be counted in gross income, much less in net income. But since it usually is mistakenly included in gross income we must at least subtract it in moving to net income, as we do with depreciation of renewable natural capital. In Balance of Payment Accounts it is worth noting that this reclassification of receipts from exploitation and export of nonrenewables from current account to capital account will convert many balance of trade surpluses into deficits.

Maintaining capital intact is fundamental to the very definition of income. This requirement should be applied to natural capital as well as to man made. Steady- state economics does this in physical terms by maintaining critical natural capital intact (rejecting the substitution of manmade for natural capital beyond some point). The scale of the economic subsystem cannot grow beyond the size that can be supported by a renewable throughput, or "natural income" that is yielded continuously by natural capital that is maintained intact. Logically this would preclude any use of nonrenewable resources, since, by definition, they cannot be maintained intact in any physical sense. Yet to leave such wealth in the ground never to benefit anyone is absurd. Consequently, steady-state economics advocates their exploitation, but subject to the following rule of "quasi-sustainability" – deplete nonrenewables at a rate equal to the rate at which a renewable substitute is developed (and of course at a rate that is within sink constraints as well). This would involve investing a portion of the rents from nonrenewable resource extraction in the development of the renewable substitute.

III Analytical First Steps: Three Questions Raised by the Steady-State Paradigm

If we accept the pre-analytic vision of the economy as subsystem of a finite and nongrowing total system, then the first three questions for analysis that spring to mind are:

(1) How big is the economy relative to the ecosystem?

(2) How big can it become before its maintenance demands volumes of throughput that overwhelm and destroy the regenerative and assimilative capacities of the environment?

(3) How big should economy be – i.e., what is the scale of the economic subsystem that optimizes value, either for humans alone, or for the biosphere as a whole?

These questions have not, and indeed could not, occur within a discipline founded on the paradigm of the economy as an isolated system – the circular flow.

Before attempting to answer these questions, it is worth pausing to ask why standard economists are so reluctant to adopt the open subsystem vision? After all, it is obviously more congruent with physical reality and more relevant to the new pattern of scarcity induced by growth itself – i.e., the shift from an "empty world" to a "full world." A large part of the answer has been given by Thomas Kuhn, who explains the reason for our extreme reluctance to admit the obvious fact of limits to growth. Growth has been our answer to poverty. If we cannot continue to grow, and we still want to eliminate poverty, then we must face up to sharing and to population control. There is a third alternative: increasing throughput productivity, which, as has already been emphasized, is development rather than growth. That development without growth, however desirable, would be sufficient to overcome poverty at today's level, with no help from increased sharing and population control, stretches the faith of even the most devout technical optimist. Pretending that growth can continue thus serves to keep politically difficult issues at bay, or at least out of sight.

Returning to the three questions:

How big *is* the human subsystem relative to the total ecosystem? Probably the best single index of relative size is the percentage appropriation by human beings of the net primary product of photosynthesis. This is on the order of 25% for the globe as a whole, and 40% for the land-based ecosystems.[6] These figures reflect both direct appropriation, as in food and fibre used by humans, and indirect appropriation by reducing the photosynthetic capacity of an ecosystem as a result of human interventions, such as desertification, paving over, etc.

How big can the human economy be relative to the total ecosystem? Taking the lower figure of 25% it is clear that two more doublings will give 100%. So we can take a factor of four as an outside limit to the scale increase of the human economy. The current doubling time is about 40 years, so the outside limit would be encountered in roughly one average lifetime. It is very much an outside limit because it is doubtful that humans are capable of managing the entire biosphere in a way that would permit survival. Indeed there is plenty of evidence that the present scale is already unsustainable in the long run. These calculations are in sharp contradiction with the Brundtland Report's vision of sustainable development as requiring an expansion of the world economy by a factor of five to ten. Thus Brundtland says a greater than five-fold expansion is necessary, our calculation shows that less than four-fold is possible.

How big should the economy be relative to the ecosystem? What is its optimal scale? This is the big question for steady-state or ecological economics. One definition of optimal scale is purely anthropocentric: grow until the marginal benefits to humans of further growth just equal the marginal costs. Other species are valued only instrumentally according to their capacity to satisfy human wants. Assuming that wants bear some relation to needs, this would be a great advance over current practice that hardly recognizes even instrumental value of nonhuman species. The other concept of optimum would be biocentric, attributing intrinsic as well as instrumental value to other species, by virtue of their being sentient creatures capable of enjoying their own lives. The biocentric optimum size of the human niche would be smaller than the anthropocentric optimum. The one characteristic that either optimum must have, in the judgment of most people, is that it be sustainable. There are many sustainable scales, only one of which is optimal. But for now just achieving sustainability is a sufficient challenge, in that it will require a reduction in the human scale unprecedented in modern times. Since scale is the product of population times per capita resource use, it would appear that both of these factors need to be reduced.

To avoid possible confusion it should be emphasized that the scale issue under discussion refers to macroeconomics – the scale of the aggregate economy relative to the ecosystem. In microeconomics the issue of optimal scale is omnipresent – indeed microeconomics is about little else than defining the optimal scale or level of an activity, be it production or consumption, by some variant of the MB=MC rule [marginal benefit equals marginal cost]. All the more strange that the most fundamental concept of microeconomics should be totally absent from macroeconomics!!

IV Policy First Steps: Moving to A Steady-State Economy

It is important to distinguish three independent optima or policy goals that require three independent policy instruments for their attainment. These are: optimal allocation (the goal of efficiency served by the instrument of relative prices); optimal distribution (the goal of fairness served by the instruments of income and wealth redistribution); and optimal scale (the goal of sustainability served by a currently non- existent policy instrument of throughput control – i.e., a policy that limits population and/or per capita resource use). The distinction between allocation and distribution is a basic and well-accepted part of standard economics. No one argues that the costs of injustice should be internalized into prices as a part of the efficiency problem. Justice is one thing, efficiency is another, and economists take great pains to keep them separate. Yet many seem to think that the cost of excessive scale can and should be internalized into prices and that there is no fundamental distinction between optimal allocation and optimal scale. This is a confusion. Scale is the product of population times per capita resource use. Population can double or be cut in half and the market will still optimally allocate resources among their alternative uses and attain a "Pareto optimum" [i.e., a situation in which no one can be made better off without making someone else worse off]. Resource consumption per capita could double as a result of fortuitous discoveries, or plummet as a result of natural disaster or simple depletion, and in all cases the market would attain an optimal allocation of whatever resources were available. A changed scale will lead to a changed set of prices (different Pareto optimum), just as a changed distribution leads to a changed set of prices (different Pareto optimum). Relative price adjustments effect the best possible adaptation to whatever circumstances of distribution and scale are given. Prices help us to make the best of a given situation, but that "given" situation may be becoming ever more unjust or unsustainable over time.

To clarify the distinction, suppose a situation in which the scale of the economy was so small that the efficient prices for water and air were zero. Population doubles and so does per capita resource use so that the total throughput has increased by a factor of four. It now turns out that the efficient prices for air and water are no longer zero, but some positive numbers, perhaps large. But large or small they are the efficient prices and we are at a Pareto optimum. In both cases prices are right. Does it not still make sense for someone to ask: are we better off or worse off now that we have to pay for air and water, compared to back when they were free goods? Do the benefits of the larger scale outweigh the costs? Might we not have increased costs more than benefits in growing to this larger scale? That is a perfectly obvious and sensible question, and economists cannot answer it.

The central policy issue is to limit scale – preferably at the optimal level, of course, but for a start any sustainable level will do. Since the present scale is beyond all sustainable levels we must reduce scale, and to begin reducing scale we must first stop it from growing larger.

The impact on the environment comes from the scale of throughput that can be decomposed into three factors:

$$T=P \times Y/P \times T/Y$$

where T = throughput; P = population; and Y = national income. In other words, environmental impact (T), equals population (P), times affluence (Y/P or per capita income), times technology (T/Y, or throughput intensity of income).

Since an x% change in any of the three factors will give an x% change in the product, it follows that in an arithmetic sense all three factors are of equal importance. Nevertheless, it makes sense to ask in any concrete situation which factor is most likely to permit an x% change. As a very broad generalization one could say that the South has the most room for an improvement in P (reducing population growth rates); the North has the most room for improvement in Y/P (reducing per capita consumption); and the formerly communist East has the most room for an improvement in T/Y (reducing the throughput intensity of technology). But again, all countries need to pay attention to all three factors.

Nevertheless, many economists tell us that technology will solve the problem, with no need to reduce population or affluence. For the world as a whole, some orders of magnitude are instructive in indicating just how much faith in technology is required to accept this proposition. P is projected to double in roughly the next 40 years. Per capita GNP in the high-income countries is on the order of 23 times higher than for the low- and middle-income countries (i.e., 23 = $18,330/$800, from Table A.2, *World Development Report* 1991). If the goal is for the poor to catch up with the rich, and there is no further increase in the average per capita income of the rich countries over the next 40 years, then to avoid greater impact on the environment than today, technology would have to improve by a factor of about 2 x 23 = 46. Is it feasible to increase the efficiency of our total use of the environment by 46 times? The Brundtland Report called for increasing the size of the economy by a factor of five to ten. They did not say how much of that they hoped to get from an improvement in technology (development), and how much would come from throughput increase (growth). Suppose unrealistically that the full factor of ten increase could come entirely from efficiency improvement. That would still leave a factor of 4.6 to be made up by a decrease in population or affluence, just to keep throughput constant at the present already unsustainable level. Alternatively, we could experience a 4.6- fold increase in throughput with population and affluence remaining the same. And this whole calculation assumes that the rich countries do not increase their per capita income beyond the 1989 figure of $18,330 during the 40 years that it takes for population to double. So far the rich have shown no willingness to stand still while the poor catch up. And the standard doctrine is that the rich should grow more, to provide markets for the poor.

It may be that a factor of 23 difference between the rich and the poor-plus-middle is an overstatement in view of the fact that poorer countries have a relatively large nonmonetized sector compared to the rich. Also, since there is a sectoral shift away from resource-intensive activities beyond some point as economic expansion continues, a 23-fold increase in GNP would entail a less than 23-fold increase in throughput. But even reducing the rich/poor ratio from 23 to 10 in the light of these considerations still leaves us with a factor of 2 x 10 = 20 increase in resource productivity required to keep throughput constant.

How likely is such an increase? Keep in mind that the large increases in "productivity" experienced historically have been in capital, land or labor productivity – not in resource productivity. In fact one reason for the historical increase in labor, capital and land productivities has been the large increase in resource throughput. In agriculture, for example, the productivity of capital, labor, and an acre of land have all increased thanks to a tremendous increase in the resource throughput (fertilizer, pesticides, water, energy to run machinery). Productivity per unit of throughput has actually fallen as its volume increased in order to raise the productivity of the complementary factors. Certainly the recent historical record offers no trend of increasing resource productivity to fuel the optimists' pipe dreams. The only basis for any optimism at all on this score is that, precisely because we have been so negligent of resource productivity, there is now, as a result, considerable room for improvement. But nothing like a factor of 46, or even of 20, is visible on the horizon. And just as we sacrificed resource productivity to maximize labour and capital productivity in the past, so now the maximization of resource productivity will require some sacrifice of labor and capital productivity. The latter will be difficult because labor and capital are stronger social classes than are landlords or resource owners. With the unlamented demise of the landlord there is no longer a social class whose income is tied to resource productivity. The government must take on this role and raise the price, productivity, and income derived from resources. Resource rents would no longer accrue as unearned income to a privileged class, but as public revenue.

Indeed there are many reasons to shift taxes away from income and on to consumption. Many economists advocate a value added tax. From our perspective it would be better not to tax value added, but rather to tax that to which the value is added, namely the resource throughput. We should tax what we want less of (depletion, pollution, i.e., throughput), not what we want more of (income, or value added). Some argue that you have to tax value added rather than resources because resources represent such a small percentage of GNP, while value added is a large percentage. But this simply means that to raise the same revenue we must tax throughput at a much higher rate than we would tax value added. No problem. Furthermore, the tax on throughput need not be "ad valorem." The only thing to worry about is not taxing our tax base out of existence. We can hardly tax throughput out of existence since it is a physical necessity. And if we succeed in reducing it somewhat through taxation, that is all to the good. But we can tax a great deal of income (value added) out of existence, and that is regrettable.

In conclusion, since technical improvement in resource efficiency by a factor of 20 to 40 is very unlikely, we can be sure that we will have to have recourse to reductions in population and affluence if we are to avoid wholesale environmental degradation. Of course, technical improvements should be pushed as far as possible, in the ways indicated by the economic/ecologic efficiency identity discussed in section II. But we should be under no illusions about the sufficiency of technical fixes to meet the problem. Indeed, until we accept the discipline of the steady state for total resource throughput (population times per capita resource use), there will be very little incentive for technology to increase any of the four ratios that determine overall ecological-economic efficiency. •