CHAPTER 2

The Fundamental Vision

The Whole and the Part

Ecological economics shares many concepts with conventional neoclassical economics. For example, both take as basic the concept of **opportunity cost**, defined as the best alternative that has to be sacrificed when you choose to do something. But ecological economics has a fundamentally different starting point—a different vision at its core of the way the world really is. To put it starkly, conventional economics sees the economy, the entire macroeconomy, as the whole. To the extent that nature or the environment are considered at all, they are thought of as parts or sectors of the macroeconomy—forests, fisheries, grasslands, mines, wells, ecotourist sites, and so on. Ecological economics, by contrast, envisions the macroeconomy as part of a larger enveloping and sustaining Whole—namely, the Earth, its atmosphere, and its ecosystems. The economy is seen as an open subsystem of that larger "Earthsystem." That larger system is finite, nongrowing, and materially closed, although open to solar energy.

Opportunity cost is the best alternative given up when a choice is made. For example, if a farmer cuts down a forest to expand his cropland, and if the consequent loss of timber, firewood, and water purification is the next best use of the land, then the value of timber, firewood, and water purification is the opportunity cost of the expanded cropland.

It is important to understand the distinctions among open, closed, and isolated systems. An **open system** takes in and gives out both matter and energy. The economy is such a system. A **closed system** imports and exports energy only; matter circulates within the system but does not flow through it. The Earth closely approximates a closed system. An **isolated system** is one in which neither matter nor energy enters or exits. It is hard to think of an example of an isolated system, except perhaps the universe as a whole. We say the Earth is approximately a closed system because it does not exchange significant amounts of matter with outer space—an occasional meteor comes in, an occasional rocket never returns, and we have a moon rock in a stained glass window in the National Cathedral. Maybe material exchanges will be greater someday, but so far they are negligible.

However, we do have a significant flow-through or throughput of energy in the form of incoming sunlight and exiting radiant heat. That throughput, like the ecosystem, is also finite and nongrowing. For the Earth, the basic rule is: Energy flows through, material cycles within.

Back to the problem of the whole and the part. Why is it so important? Because if the economy is the whole, then it can expand without limit. It does not displace anything and therefore incurs no opportunity cost—nothing is given up as a result of physical expansion of the macroeconomy into unoccupied space. But if the macroeconomy is a part, then its physical growth encroaches on other parts of the finite and nongrowing whole, exacting a sacrifice of something—an opportunity cost, as economists would call it. In this case, if we choose to expand the economy, the most important natural space or function sacrificed as a result of that expansion is the opportunity cost. The point is that growth has a cost. It is not free, as it would be if we were expanding into a void. The Earth-ecosystem is not a void, it is our sustaining, life-supporting envelope. It is therefore quite conceivable that at some point the further growth of the macroeconomy could cost us more than it is worth. Such growth is known as **uneconomic growth**. This leads to another insight that is fundamental to ecological economics and distinguishes it from conventional economics: Growth can be uneconomic as well as economic. There is an optimal scale of the macroeconomy relative to the ecosystem.[1] How do we know we have not already reached or passed it?

Optimal Scale

The idea of **optimal scale** is not strange to standard economists. It is the very basis of microeconomics. As we increase any activity, be it producing shoes or eating ice cream, we also increase both the costs and the benefits of the activity. For reasons we will investigate later, it is generally the case that after some point, costs rise faster than benefits. Therefore, at some point the extra benefits of growth in the activity will not be worth the extra costs. In economist's jargon, when the **marginal costs** (extra costs) equal the marginal benefits, then the activity has reached its optimal scale.[2] If we grow beyond the optimum, then costs will go up by more

[1]Beyond optimal scale physical expansion becomes uneconomic growth, even if we misleadingly still call it "economic" growth. We use the word "economic" in two senses: (1) of or pertaining to the economy, and (2) yielding net benefits above costs. If the entity we call "the economy" physically grows, then we call that economic growth in sense 1. But growth in sense 1 may be economic or uneconomic in sense 2. Our linguistic habit of using sense 1 often leads us to prejudge the issue in terms of sense 2.

[2]"Marginal" means the last unit; in this case, the last unit of something obtained, produced, or consumed. Marginal cost (benefit) is the cost (benefit) of a very small increase in some activity.

than benefits. Subsequently, growth will make us poorer rather than richer. The basic rule of microeconomics, that optimal scale is reached when marginal cost equals marginal benefit (MC = MB), has aptly been called the "when to stop rule"—that is, when to stop growing. In macroeconomics, curiously, there is no "when to stop rule," nor any concept of the optimal scale of the macroeconomy. The default rule is "grow forever." Indeed, why not grow forever if there is no opportunity cost of growth? And how can there be an opportunity cost to growth of the macroeconomy if it is the whole?

Even if one adopts the basic vision of ecological economics and considers the economy as a subsystem of the ecosystem, there still would be no need to stop growing as long as the subsystem is very small relative to the larger ecosystem. In this "empty-world vision," the environment is not scarce and the opportunity cost to expansion of the economy is insignificant. But continued growth of the physical economy into a finite and nongrowing ecosystem will eventually lead to the "full-world economy" in which the opportunity cost of growth is significant. We are already in such a full-world economy, according to ecological economists.

This basic ecological economics vision is depicted in Figure 2.1. As growth moves us from the empty world to the full world, the welfare from economic services increases while the welfare from ecological services diminishes. For example, as we cut trees to make tables, we add the economic service of the table (holding our plates so we won't have to eat off the floor) and lose the ecological service of the tree in the forest (photosynthesis, securing soil against erosion, providing wildlife habitat, etc.). Traditionally, economists have defined capital as produced means of production, where produced implies "produced by humans." Ecological economists have broadened the definition of capital to include the means of production provided by nature. We define capital as a stock that yields a flow of goods and services into the future. Stocks of manmade capital include our bodies and minds, the artifacts we create, and our social structures. **Natural capital** is a stock that yields a flow of natural services and tangible natural resources. This includes solar energy, land, minerals and fossil fuels, water, living organisms, and the services provided by the interactions of all of these elements in ecological systems.

We have two general sources of welfare: services of manmade capital (dark gray stuff) and services of natural capital (light gray stuff), as represented by the thick arrows pointing to "Welfare" in Figure 2.1. Welfare is placed outside the circle because it is a psychic, not a physical, magnitude (an experience, not a thing). Within the circle, magnitudes are physical. If we object to having a nonphysical magnitude in our basic picture of the economy on the grounds that it is metaphysical and unscientific, then we will have to content ourselves with the view that the economic system is

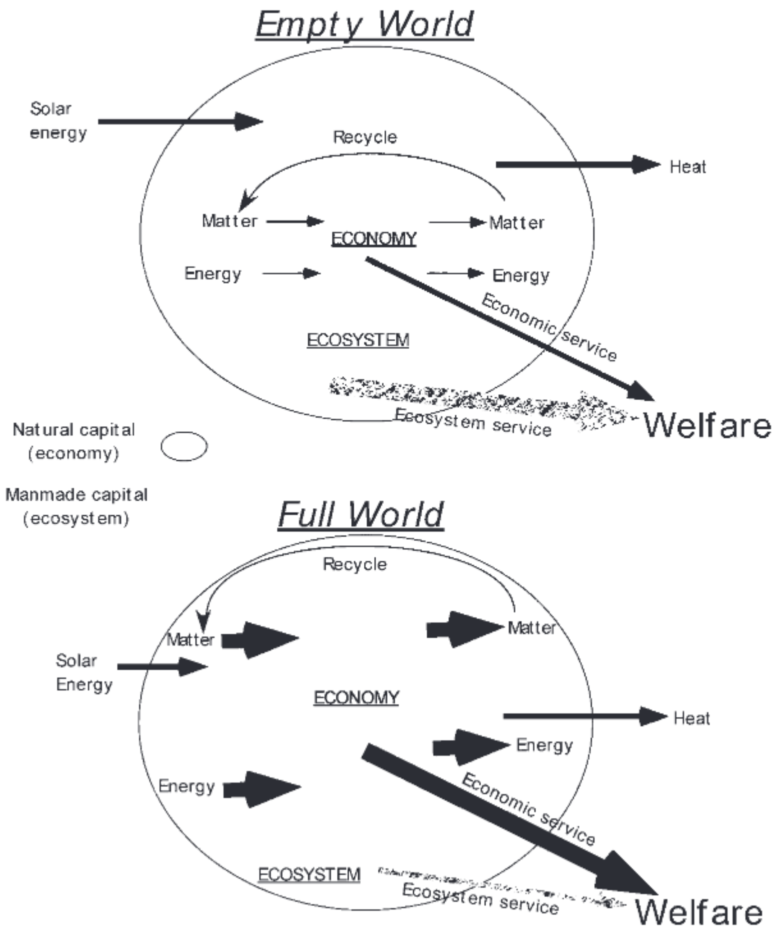

Figure 2.1 • From empty world to full world.

just an idiotic machine for turning resources into waste for no reason. The ultimate *physical* output of the economic process is degraded matter and energy—waste. Neglecting the biophysical basis of economics gives a false picture. But neglecting the psychic basis gives a meaningless picture. Without the concept of welfare or enjoyment of life, the conversion of material resources first into goods (production) and then into waste (consumption) must be seen as an end in itself—a pointless one. Both conventional and ecological economics accept the psychic basis of welfare, but they differ on the extent to which manmade and natural capital contribute to it.

Diminishing Marginal Returns and Uneconomic Growth

As the economy grows, natural capital is physically transformed into manmade capital. More manmade capital results in a greater flow of services from that source. Reduced natural capital results in a smaller flow of services from that source. Moreover, as growth of the economy continues, the services from the economy grow at a decreasing rate. As rational beings, we satisfy our most pressing wants first, hence the law of diminishing marginal utility (to which we will return). As the economy encroaches more and more on the ecosystem, we must give up some ecosystem services. As rational beings, we presumably will sequence our encroachments so that we sacrifice the least important ecosystem services first. This is the best case, the goal. In actuality we fall short of it because we do not understand very well how the ecosystem works, and have only recently begun to think of ecosystem services as scarce. But the consequence of such rational sequencing is a version of the law of increasing marginal cost (to which we will return)—for each further unit of economic expansion, beyond some threshold, we must give up a more important ecosystem service. Marginal costs increase while marginal benefits decrease. At some point increasing marginal costs will equal declining marginal benefits.

Box 2-1 Marginal Utility vs. Marginal Cost

- **Marginal utility:** The marginal utility of something is the additional benefit or satisfaction you derive from obtaining an additional unit of that thing. The **law of diminishing marginal utility** states that the more one has of something, the less satisfaction an additional unit provides. For example, the first slice of pizza on an empty stomach offers considerable satisfaction, but each additional slice provides less satisfaction than the previous one.
- **Marginal cost:** Marginal cost is the additional cost of producing one more unit. The **law of increasing marginal cost** is similar to that of diminishing marginal utility. For each additional ton of wheat harvested, you have to make use of inferior land and workers (you used the best first). Also, once you've used all the land for wheat, adding more labor, fertilizer, and so on is the only way to increase the wheat harvest. But with fixed land, we will have diminishing returns to the variable factors (labor, fertilizer)—more and more laborers and fertilizer will be required for each additional ton of harvest. Diminishing returns is a further reason for increasing marginal costs. Neoclassical economics is constantly comparing increasing marginal costs with declining marginal benefits, looking for their point of intersection that

defines the optimal scale of each microeconomic activity. It does not apply this logic to the macroeconomy, or recognize that it has an optimal scale. Ecological economics insists that the logic of optimal scale is relevant to the entire macroeconomy, as well as to its parts.

This first step in analyzing the core or preanalytic vision of ecological economics can be expressed graphically (Figure 2.2). The basic logic goes back to William Stanley Jevons (1871) and his analysis of labor supply in terms of balancing the marginal utility of wages with the marginal disutility of labor to the worker. Put another way, Jevons asked: When does the effort of working begin to exceed the value of the wage to the worker? Ecological economists ask: When does the cost to all of us of displacing the Earth's ecosystems begin to exceed the value of the extra wealth produced? In Figure 2.2, the marginal utility (MU) curve reflects the dimin-

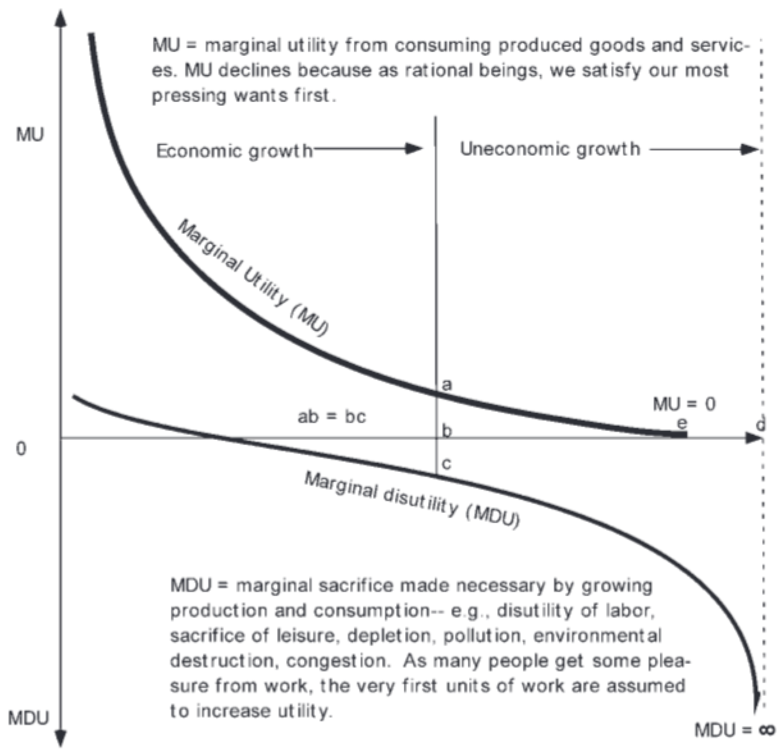

Figure 2.2 • Limits to growth of the macroeconomy. Point b = economic limit or optimal scale, where marginal utility (MU) = marginal disutility (MDU) (maximum net positive utility); e = futility limit, where MU = 0 (consumer satiation); d = catastrophe limit, where MDU = infinity. At point d, we have gone beyond sustainable scale.

ishing marginal utility of additions to the stock of manmade capital. The marginal disutility (MDU) curve reflects the increasing marginal cost of growth (sacrificed natural capital services and disutility of labor), as more natural capital is transformed into manmade capital. The optimal scale of the macroeconomy (economic limit to growth) is at point d, where MU = MDU, or where ab = bc, and net positive utility is a maximum (the area under the MU curve minus the area above the MDU curve).

Two further limits are noted: point e where MU = 0 and further growth is futile even with zero cost; and point d, where an ecological catastrophe is provoked, driving MDU to infinity. For example, some relatively unnecessary chemical pollutant in sufficient amounts might unexpectedly prohibit photosynthesis, rendering plant life incapable of capturing the solar energy upon which all life depends. These "outer limits" need not occur in the order depicted. We could have an ecological disaster before reaching satiation. The diagram shows that growth out to point b is literally economic growth (benefiting us more than it costs), while growth beyond point b is literally uneconomic growth (costing us more than it benefits us). Beyond point b, GNP, "that which seems to be wealth," does indeed become "a gilded index of far-reaching ruin," as John Ruskin predicted over a century ago.[3] The nice thing about point b, the economic limit, is that it occurs first, allowing us to maximize net benefits while stopping us from destroying the capacity of the Earth to support life.

The concepts of optimal scale and uneconomic growth have a universal logic—they apply to the macroeconomy just as much as to microeconomic units.[4] How did we come to forget this in macroeconomics? How did we come to ignore the existence of the MDU curve and the issue of optimal scale of the macroeconomy? We suggest two possibilities. One is the "empty-world vision" that recognizes the concept of uneconomic growth, but claims that we are not yet at that point; neoclassical economists tend to think that MU is still very large, and MDU is still negligible. In this case we can look at the factual evidence to resolve the difference, as will be done later.

The other possibility for explaining the total neglect of the costs of growth is a paradigm difference: The economy is simply not seen as a subsystem of the ecosystem, but rather the reverse—the ecosystem is a subsystem of the economy (Figure 2.3). Here we are discussing different

[3]J. Ruskin, *Unto This Last*, (1862) in Lloyd J. Hubenka, ed., *Four Essays on the First Principles of Political Economy*, Lincoln: University of Nebraska Press, 1967.

[4]It is a mistake to think that microeconomics is about little things and macroeconomics is about big things. Microeconomics means the economics of the part, macroeconomics means the economics of the whole or aggregate. Parts can be big, aggregates can be small. Although MB = MC is a rule of microeconomic analysis, we can apply it to something big, the economic subsystem, as long as the big thing is a part, not the whole.

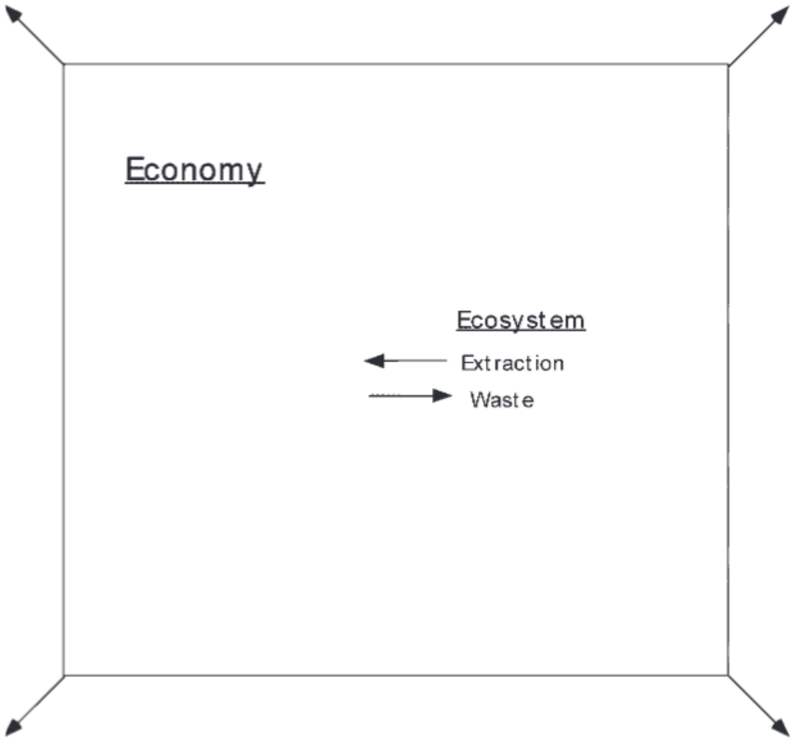

Figure 2.3 • The ecosystem as a subsystem of the economy.

conceptual worlds, and no empirical measurements will resolve the difference.

In the vision of Figure 2.3, the ecosystem is merely the extractive and waste disposal sector of the economy. Even if these services become scarce, growth can still continue forever because technology allows us to "grow around" the natural sector by the substitution of manmade for natural capital, following the dictates of market prices. Nature is, in this view, nothing but a supplier of various indestructible building blocks, which are substitutable and superabundant. The only limit to growth, in this view, is technology, and since we can always develop new technologies, there is no limit to economic growth. The very notion of "uneconomic growth" makes no sense in that paradigm. Since the economy is the whole, the growth of the economy is not at the expense of anything else; there is no opportunity cost to growth. On the contrary, growth enlarges the total to be shared by the different sectors.[5] Growth does not increase

[5]A note of caution: the dark gray stuff in Figure 2.1 is in physical dimensions. The dark gray stuff in Figure 2.3 is probably thought of by neoclassical economists as GNP; it is in units of value and therefore not strictly physical. But value is price times quantity, and the latter has an irreducible physical component. Indeed it is mainly changes in that physical component that economists seek to measure in calculating *real* GNP—i.e., changes in GNP not due to changes in prices.

the scarcity of anything; rather, it diminishes the scarcity of everything. How can one possibly oppose growth?

A Paradigm Shift

Where conventional economics espouses growth forever, ecological economics envisions a steady-state economy at optimal scale. Each is logical within its own preanalytic vision, and each is absurd from the viewpoint of the other. The difference could not be more basic, more elementary, or more irreconcilable.

In other words, ecological economics calls for a "paradigm shift" in the sense of philosopher Thomas Kuhn,[6] or what we have been calling, following economist Joseph Schumpeter,[7] a change in preanalytic vision. We need to pause to consider more precisely just what these concepts mean. Schumpeter observes that "analytic effort is of necessity preceded by a preanalytic cognitive act that supplies the raw material for the analytic effort" (p. 41). Schumpeter calls this preanalytic cognitive act "Vision." One might say that vision is the pattern or shape of the reality in question that the right hemisphere of the brain abstracts from experience, and then sends to the left hemisphere for analysis. Whatever is omitted from the preanalytic vision cannot be recaptured by subsequent analysis. Correcting the vision requires a new preanalytic cognitive act, not further analysis of the old vision. Schumpeter notes that changes in vision "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 preexisting state of the science." (p. 41). It is this last point that is most emphasized by Kuhn (who was apparently unaware of Schumpeter's discussion).

Kuhn distinguished between "normal science," the day-to-day solving of puzzles within the established rules of the existing preanalytic vision, or "paradigm" as he called it, and "revolutionary science," the overthrow of the old paradigm by a new one. It is the common acceptance by scientists of the reigning paradigm that makes their work cumulative, and that separates the community of serious scientists from quacks and charlatans. Scientists are right to resist scientific revolutions. Most puzzles or anomalies, after all, do eventually get solved, one way or another, within the existing paradigm. And it is unfortunate when people who are too lazy to master the existing scientific paradigm seek a shortcut to fame by summarily declaring a "paradigm shift" of which they are the leader. Nevertheless, as Kuhn demonstrates, paradigm shifts, both large and small, are

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[6]T. Kuhn, *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press, 1962.

[7]J. Schumpeter, *History of Economic Analysis*, New York: Oxford University Press, 1954.

undeniable episodes in the history of science—the shift from the Ptolemaic (Earth-centered) to the Copernican (sun-centered) view in astronomy, and Newton's notions of absolute space and time versus Einstein's relativity of space and time—are only the most famous. As Kuhn demonstrates, there does come a time when sensible loyalty to the existing paradigm becomes stubborn adherence to intellectual vested interests.

Paradigm shifts are obscured by textbooks whose pedagogical organization is, for good reason, logical rather than historical.[8] Physics students would certainly be unhappy if, after learning in the first three chapters all about the ether and its finely grained particles, they were suddenly told in Chapter 4 to forget all that stuff about the ether because we just had a Newtonian paradigm shift and now accept action at a distance unmediated by fine particles (gravity)!

Thirty years ago, a course in the history of economic thought was required in all graduate economics curricula. Today such a course is usually not even available as an elective. This is perhaps a measure of the (over)confidence economists have in the existing paradigm. Why study the errors of the past when we now know the truth? Consequently, the several changes in preanalytic vision in the history of economic thought are unknown to students and to many of their professors.

A change in vision from seeing the economy as the whole to seeing it as a part of the relevant Whole—the ecosystem—constitutes a major paradigm shift in economics. In subsequent chapters, we will consider more specific consequences of this shift.

The Circular Flow and the Linear Throughput

Differing preanalytic visions lead to a few basic analytical differences as well, although many tools of analysis remain the same between standard and ecological economics, as we'll discuss later.

Given that standard economics has a preanalytic vision of the economy as the whole, what is its first analytic step in studying this whole? It is depicted in Figure 2.4, the familiar circular flow diagram with which all basic economics texts begin. In this view, the economy has two parts: the production unit (firms) and the consuming unit (households). Firms produce and supply goods and services to households; households demand goods and services from firms. Firm supply and household demand meet in the goods market (lower loop), and prices are determined there by the interaction of supply and demand.

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[8]Textbooks are designed to initiate the student into the reigning paradigm as efficiently as possible. Chapter 2 builds on Chapter 1, Chapter 3 builds on Chapters 1 and 2, etc. Efficient pedagogy is logical and cumulative. But the history of science is not so tidy. In history there are times when we have to throw out earlier chapters and start over. This textbook is not immune to this danger, although we have tried to be sensitive to it.

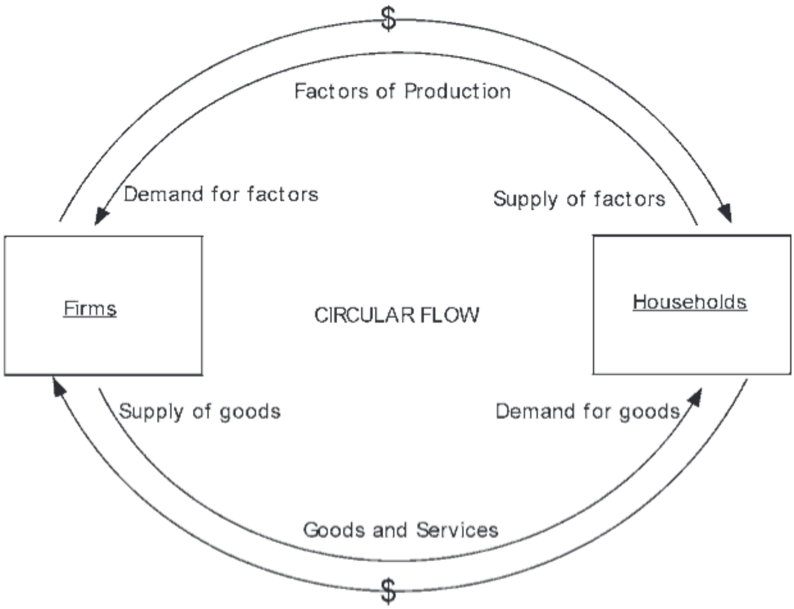

Figure 2.4 • The circular flow of the economy.

At the same time, firms demand factors of production from the households, and households supply factors to the firms (upper loop). Prices of factors (land, labor, capital) are determined by supply and demand in the factors market. These factor prices, multiplied by the amount of each factor owned by a household, determine the income of the household. The sum of all these factor incomes of all the households is National Income. Likewise, the sum of all goods and services produced by firms for households, multiplied by the price at which each is sold in the goods market, is equal to National Product. By accounting convention, National Product must equal National Income. This is so because profit, the value of total production minus the value of total factor costs, is counted as part of National Income.

THINK ABOUT IT!
Would the equality still hold if profits were negative? Explain.

The upper and lower loops are thus equal, and in combination they form the circular flow of exchange value. This is a very important vision. It unifies most of economics. It shows the fundamental relationship between production and consumption. It is the basis of microeconomics, which studies how the supply-and-demand plans of firms and households emerge from their goals of maximizing profits (firms) and maximizing utility (households). It shows how supply and demand interact under different market structures to determine prices, and how price changes lead to changes in the allocation of factors to produce a different mix of goods and services. In addition, the circular flow diagram also provides the basis for macroeconomics—it shows how the aggregate behavior of firms and households determines both National Income and National Product.

Say's Law: Supply Creates Its Own Demand

The equality of National Income and National Product, as mentioned, guarantees that there is always enough purchasing power in the hands of households in the aggregate to purchase the aggregate production of firms. Of course, if some firms produce things households do not want, the prices of those things will fall, and if they fall below what it cost to produce them, those firms will make losses and go out of business. The circular flow does not guarantee that all firms will sell whatever they produce at a profit. But it does guarantee that such a result is not impossible because of an overall glut of production in excess of overall income. This comforting feature of the economy is known as **Say's Law**—supply creates its own demand. For a long time, economists believed Say's Law ruled out any possibility of long-term and substantial unemployment, such as occurred during the Great Depression. However, the experience of the Depression led John Maynard Keynes to reconsider Say's Law and the comforting conclusion of the circular flow vision.

There may indeed always be enough income generated by production to purchase what is produced. But there is no guarantee that all the income will be spent, or spent in the current time period, or spent on goods and services, or spent in the national market. In other words, there are leakages out of the circular flow. There are also corresponding injections into the circular flow. But there is no guarantee that the leakages and injections will balance each other.

Leakages and Injections

What are these leakages and injections? One leakage from the expenditure stream is savings. People refrain from spending now in order to be able to spend later. The corresponding injection is investment. Investment results in expenditure now, but increased production only in the future. Thus, the circular flow can be restored if Saving equals Investment. This recycling of savings into investment is accomplished through financial markets and interest rates. In Figure 2.5, the shaded rectangles represent the financial institutions that collect savings and lend to investors.

A second leakage from the circular flow is payment of taxes. The corresponding injection is government expenditure. The rectangle represents the institutions of public finance. Public finance policies can balance the taxes and government spending, or intentionally unbalance them to compensate for imbalances in Savings and Investment. For example, if saving exceeds investment, the government might avoid a recession by allowing government expenditures to exceed taxes by the same amount.

The third leakage from the national circular flow is expenditure on imports. The corresponding injection is expenditure by foreigners for our exports. International finance and foreign exchange rates are mechanisms for balancing exports and imports. Again the corresponding institutions are represented by the rectangle. The circular flow is restored if the sum of leakages equals the sum of injections, that is, if savings plus taxes plus imports equals investment plus government spending plus exports. If the sum of leakages is greater than the sum of injections, unemployment or deflation tends to result. If the sum of injections is greater than the sum of leakages, we tend to have either expansion or inflation.

Leakages and injections are shown in Figure 2.5, an expanded circular

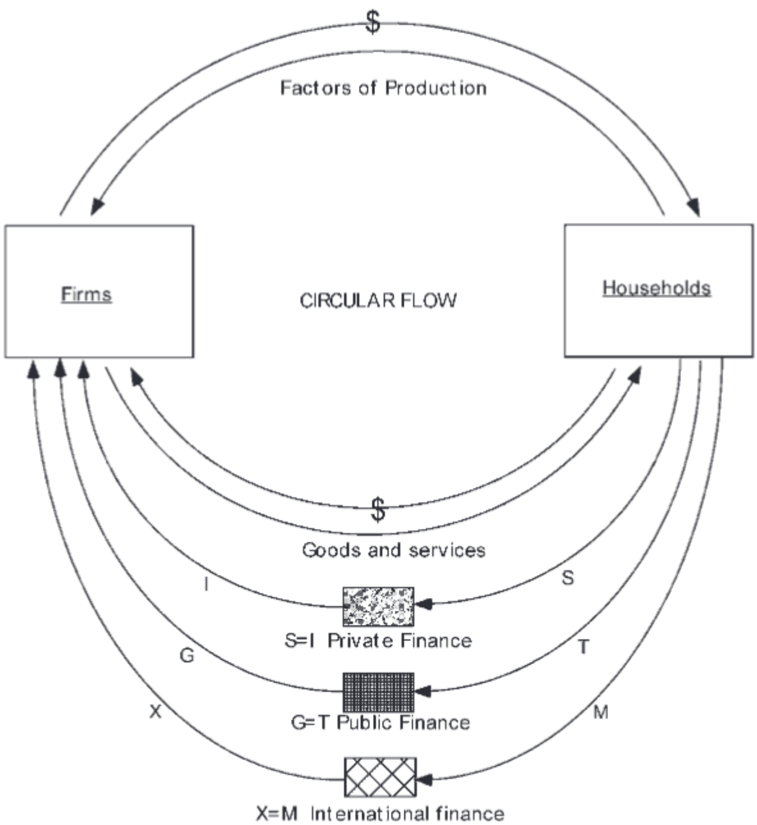

Figure 2.5 • The circular flow with leakages and injections. S = savings, I = investment, G = government expenditure, T = taxes, X = exports, M = imports.

flow diagram. For simplicity we have assumed that households are net savers, net taxpayers, and net importers, while firms are net investors, net recipients of government expenditure, and net exporters.

The circular flow diagram unites not only micro- and macroeconomics, but also shows the basis for monetary, fiscal, and exchange rate policy in the service of maintaining the circular flow so as to avoid unemployment and inflation. With so much to its credit, how could one possibly find fault with the circular flow vision?

There is no denying the usefulness of the circular flow model for analyzing the flow of exchange value. However, it has glaring difficulty as a description of a real economy. Notice that the economy is viewed as an isolated system. Nothing enters from outside the system; nothing exits the system to the outside. But what about all the leakages and injections just discussed? They are just expansions of the isolated system that admittedly make the concept more useful, but they do not change the fact that nothing enters from outside and nothing exits to the outside. The whole idea of analyzing leakages and injections is to be able to reconnect them and close the system again. Why is the isolated system a problem? Because an isolated system has no outside, no environment. This is certainly consistent with the view that the economy is the whole. But a consequence is that there is no place from which anything can come, or to which it might go. If our preanalytic vision is that the economy is the whole, then we cannot possibly analyze any relation of the economy to its environment. The whole has no environment.

What is it that is really flowing around and around in a circle in the circular flow vision? Is it really physical goods and services, and physical laborers and land and resources? No. It is only abstract exchange value, the purchasing power represented by these physical things.[9] The "soul" embodied in goods by the firms is abstract exchange value. When goods arrive to the households, the "soul" of exchange value jumps out of its embodiment in goods and takes on the body of factors for its return trip to the firms, whereupon it jumps out of the body of factors and reincorporates itself once again into goods, and so on. But what happens to all the discarded bodies of goods and factors as the soul of exchange value transmigrates from firms to households and back *ad infinitum*? Does the

[9]We are careful to say "abstract exchange value" rather than "money" because not even money in the sense of currency can circulate as an isolated system. Money wears out and has to be replaced by new money. The physical wear and tear of hand-to-hand circulation means that even money has to have a throughput to maintain its circulation. Because fractional money circulates more rapidly than notes of higher denomination, we usually adopt metal coins rather than paper to withstand the higher velocity of circulation of small denominations. For this reason, as inflation has eroded its value, the U.S. Treasury has periodically attempted to issue the dollar in coin form, though without much success.

system generate wastes? Does the system require *new* inputs of matter and energy? If not, then the system is a perpetual motion machine, a contradiction to the Second Law of Thermodynamics (about which more later). If it is not to be a perpetual motion machine (a perfect recycler of matter and energy), then wastes must go somewhere and new resources must come from somewhere outside the system. Since there is no such thing as perpetual motion, the economic system cannot be the whole. It must be a subsystem of a larger system, the Earth-ecosystem.

The circular flow model is in many ways enlightening, but like all abstractions, it illuminates only what it has abstracted out of reality and leaves in darkness all that has been abstracted from. What has been abstracted from, left behind, in the circular flow model is the linear throughput of matter-energy by which the economy lives off its environment. Linear throughput is the flow of raw materials and energy from the global ecosystem's sources of low entropy (mines, wells, fisheries, croplands), through the economy, and back to the global ecosystem's sinks for high entropy wastes (atmosphere, oceans, dumps). The circular flow vision is analogous to a biologist describing an animal only in terms of its circulatory system, without ever mentioning its digestive tract. Surely the circulatory system is important, but unless the animal also has a digestive tract that connects it to its environment at both ends, it will soon die either of starvation or constipation. Animals live from a metabolic flow—an entropic throughput from and back to their environment. The **law of entropy** states that energy and matter in the universe move inexorably toward a less ordered (less useful) state. An entropic flow is simply a flow in which matter and energy become less useful; for example, an animal eats food and secretes waste, and cannot ingest its own waste products. The same is true for economies. Biologists, in studying the circulatory system, have not forgotten the digestive tract. Economists, in focusing on the circular flow of exchange value, have entirely ignored the metabolic throughput. This is because economists have assumed that the economy is the whole, while biologists have never imagined that an animal was the whole, or was a perpetual motion machine.

Linear Throughput and Thermodynamics

The linear throughput is in physical units and is strictly subject to the laws of conservation of mass and energy, and the law of entropy. The circular flow is in units of abstract exchange value and is not subject to any obvious physical limits. The circular flow can nominally grow forever by virtue of inflation, but we set this case aside to ask if the real economic value in the sense of satisfying wants, of qualitative development, can grow forever.

The Fallacy of Misplaced Concreteness

Obviously, a model that abstracts from the environment and considers the economy in isolation from it cannot shed any light on the relation of the economy to the environment. This kind of mistake was given a name by the philosopher and mathematician Alfred North Whitehead. He called it the **fallacy of misplaced concreteness**. By that he meant the error of mistaking the map for the territory, the error of treating an abstract model, made with the purpose of understanding one aspect of reality, as if it were adequate for understanding everything, or entirely different things, things that had been abstracted from in making the model. Whitehead was no enemy of abstract thought. He emphasized that we cannot think without abstraction. All the more important, therefore, to be aware of the limits of our abstractions. The power of abstract thought comes at a cost. The fallacy of misplaced concreteness is to forget that cost.

Let's take a closer look at what standard economists have abstracted from in the circular flow model—namely, the throughput, the metabolic flow from raw material inputs to waste outputs. The throughput is in physical units. Consequently, the laws of physics apply strictly to it.

The *First Law of Thermodynamics* states that neither matter nor energy can be either created or destroyed.

By the **First Law of Thermodynamics**, the conservation of matter and energy, we know that throughput is subject to a balance equation: Input

Box 2-2 The Laws of Thermodynamics

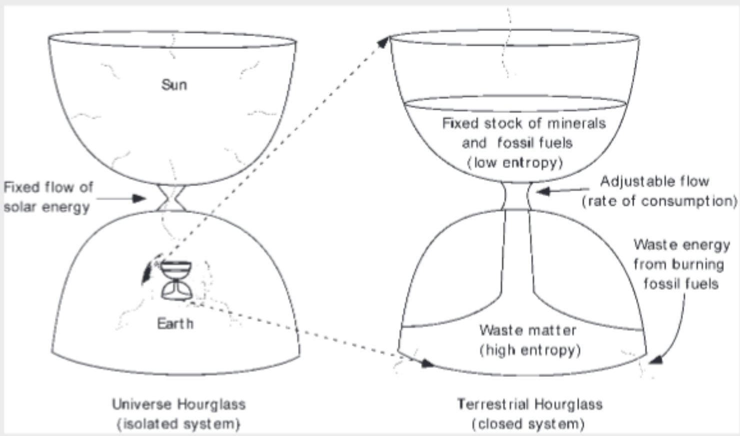

Figure 2.6 • The entropy hourglass (based on Georgescu-Roegen).

The hourglass on the left is an isolated system; no sand enters, no sand exits. Also, within the hourglass there is neither creation nor destruction of sand; the amount of sand in the hourglass is constant. This, of course, is the analog of the First Law of Thermodynamics, the conservation of matter and energy. Finally, there is a continual running down of sand in the top chamber and an accumulation of sand in the bottom chamber. Sand in the bottom chamber has used up its potential to fall and thereby do work. It is high-entropy or unavailable matter-energy. Sand in the top chamber still has potential to fall; it is low-entropy or available matter-energy (still useful). This is the analogy of the Second Law of Thermodynamics: Entropy, or "used-up-ness," increases in an isolated system. The hourglass analogy is particularly apt because entropy is "time's arrow" in the physical world—that is, we can tell earlier from later by whether or not entropy has increased. However, unlike a real hourglass, the entropy hourglass cannot be turned upside down!

With a bit of license, we can extend the basic analogy by considering the sand in the upper chamber to be the stock of low-entropy fossil fuel on Earth, depicted in the right-hand figure. Fossil energy is used at a rate determined by the constricted middle of the hourglass, but unlike a normal hourglass, humans alter the width (i.e., they change the rate of consumption of fossil fuels). Once consumed, the sand falls to the bottom of the chamber, where it accumulates as waste and interferes with terrestrial life processes.

To represent solar energy, the top of the hourglass on the left would be vast (from the human perspective) as would the bottom; solar energy, too, ends as waste heat, but it is not confined to the Earth. It does not disappear, but it radiates into outer space, and unlike waste matter does not accumulate on Earth. The constricted middle, however, would be quite small, and humans would be unable to adjust it. The solar source of low entropy is stock-abundant but flow-limited. In other words, there is a lot of it, but we get only a little at a time. The terrestrial source is stock-limited but flow-abundant, until the stock runs out. The asymmetry is important. With industrialization we have come to depend more and more on the least abundant source of low entropy. However convenient in the short run, this will be uneconomic in the long run.

equals output plus accumulation. If there is accumulation, the economic subsystem is growing. In steady-state equilibrium, growth and accumulation would be zero, and input flow would equal output flow. In other words, all raw material inputs eventually become waste outputs.The throughput has two ends: depletion of environmental sources, and pollution of environmental sinks. Ignoring throughput is the same as ignoring depletion and pollution. Unlike exchange value, the flow of throughput is not circular; it is a one-way flow from low-entropy sources to high-entropy sinks. This is a consequence of the **Second Law of Thermodynamics**, the entropy law. We can recycle materials, but never 100%; recycling is a circular eddy in the overall one-way flow of the river. Energy, by the entropy law, is not recyclable at all. More precisely, it is recyclable, but

The *Second Law of Thermodynamics* states that entropy never decreases in an isolated system. Although matter and energy are constant in quantity (First Law), they change in quality. The measure of quality is entropy, and basically it is a physical measure of the degree of "used-up-ness" or randomization of the structure or capacity of matter or energy to be useful to us. Entropy increases in an isolated system. We assume the universe is an isolated system, so the Second Law says that the natural, default tendency of the universe is "shuffling" rather than "sorting." In everyday terms, left to themselves, things tend to get mixed up and scattered. Sorting does not occur by itself.

it always takes more energy to do the recycling than the amount that can be recycled. Thus, recycling energy is not physically impossible but always economically a loser—regardless of the price of energy. No animal can directly recycle its own waste products as its own food. If it could, it would be a perpetual motion machine. In strict analogy, no economy can function by directly reusing only its own waste products as raw materials.

The circular flow diagram gives the false impression that the economy is capable of direct reuse. Some very good textbook writers have explicitly affirmed this false impression. For example, Heilbroner and Thurow,[10] in a standard economics text, tell us that "the flow of output is circular, self-renewing, self-feeding." In other words the economy is a perpetual motion machine. To drive the point home, the first study question at the end of the chapter is, "Explain how the circularity of the economic process means that the outputs of the system are returned as fresh inputs." It would have been reasonable to ask how dollars spent reappear as dollars earned in the circular flow of exchange value, and how purchasing power is regenerated in the act of production. But explaining how outputs are returned as inputs, indeed *fresh* inputs, requires the student to discover the secret of perpetual motion! Of course, the authors do not really believe in perpetual motion; they were trying to get across to the student the importance of replenishment—how the economic process reproduces itself and keeps going for another round. Certainly this is an important idea to stress, but the key to understanding it is precisely that replenishment must come from *outside* the economic system. This is a point conventional economists tend to neglect, and it leads to the mistaking of the part for the whole. If the economy is the whole, it has no outside; it is an isolated system.

The error in the text cited is fundamental, but not unique. It is representative of most standard texts. Heilbroner and Thurow have the virtue of clear expression—a virtue that makes it easier to spot errors. Other texts leave the student with the same erroneous impression, but without forthrightly stating the implication in words that cause us to think again. Nor is the error confined to standard economists. Karl Marx's models of simple and expanded reproduction are also isolated circular flow models. Marx, with his theory that labor was the source of all value, was even more eager than standard economists to deny any important role to nature in the functioning of the economy and creation of value. For Marx, the idea that nature embodied scarcity was an abomination. All poverty was the result of unjust social relations, or class exploitation, not the "niggardliness of nature." Thomas Malthus had argued that overpopulation relative to

[10]R. Heilbroner and L. Thurow, *The Economic Problem*, New York: Prentice-Hall, 1981, pp. 127, 135.

natural capacities was also an independent cause of poverty, and that social revolution could not eliminate poverty. Marx felt that Malthus' ideas were a threat to his, and treated him with contempt and vituperation. Political debates between neo-Marxists and neo-Malthusians continue to this day.[11]

The Importance of Throughput

Let's turn from the theoretical reasons for the importance of throughput to an empirical look at its size and composition in modern economies. The following paragraph is from a book about the dependence of the economy on the environment:

> *Researchers have calculated that industry moves, mines, extracts, shovels, burns, wastes, pumps, and disposes of 4 million pounds of material in order to provide one average middle-class American family's needs for a year. In 1990, the average American's economic and personal activities mobilized a flow of roughly 123 dry-weight pounds of material per day—equivalent to a quarter of a billion semitrailer loads per year. This amounts to 47 pounds of fuel, 46 of construction materials, 15 of farmland, 6 of forest products, 6 of industrial minerals, and 3 of metals of which 90% is iron and steel. Net of 6 pounds of recycled materials, that Average American's daily activities emitted 130 pounds of gaseous material into the air, created 45 pounds of material artifacts, generated 13 pounds of concentrated wastes, and dissipated 3.5 pounds of nongaseous wastes into the environment in such scattered forms as pesticides, fertilizers, and crumbs of material rubbed off tires. In addition, the person's daily activities required the consumption of about 2,000 pounds of water that after use is sufficiently contaminated that it cannot be reintroduced into marine or riparian systems, and produced 370 pounds of rock, tailings, overburden, and toxic water as a result of extracting oil, gas, coal, and minerals. . . . In sum, Americans waste or cause to be wasted nearly 1 million pounds of materials per person per year.*[12]

That's a lot of throughput to abstract from—to leave out of our model! It all ends up as waste, but necessary waste to support our population at our standard of consumption, with our present technology. Better technologies, as well as a better ordering of our priorities, can reduce the throughput without lowering the quality of life. However, by how much, and by what policies, are big issues in ecological economics.

In 1997, a coalition including the World Resources Institute (WRI, U.S.), the Wuppertal Institute (Germany), the Netherlands Ministry for

[11]See H. Daly, A Marxian-Malthusian View of Poverty and Exploitation, *Population Studies*, May 1971.

[12]P. Hawken, A. Lovins, and H. Lovins, *Natural Capitalism*, Boston: Little, Brown, 1999, pp. 51–52.

Housing Spatial Planning and Environment, and the National Institute for Environmental Studies (Japan) attempted to measure throughput in each of their industrial countries for the period 1975–1993.[13] Their basic finding was that total material requirements (per-capita annual flows) for each of the four countries did not change much between 1975 and 1993. The range was 45–85 metric tons of natural resources per person per year, with the U.S. at the high end, Japan at the low end, and Germany and the Netherlands in between. Over the period, the U.S. flows declined slightly and those of the other countries rose slightly. Most of the decline in U.S. requirements was accounted for by better soil erosion control, not better industrial efficiency. The roughly constant total resource requirements over time are the product of a declining resource requirement per dollar of gross domestic product (GDP) with a growing number of dollars of GDP, in all four countries. We have become more *efficient* but not more *frugal*. It is as if we developed cars that got twice as many miles per gallon and then drove twice as many miles, thereby burning the same number of gallons.

THINK ABOUT IT!
Which goal do you think should come first, efficiency or frugality? We will come back to this, but maybe you can answer it already.

While it is important to have empirical information on the physical size, composition, and change over time in the throughput, we also must have some basis for judging the environmental costs of these flows. How large are they relative to the capacity of the ecosystem to absorb and regenerate them? Exactly what opportunity costs do these flows inflict on us? On other species? Partial answers are given by the World Wildlife Fund (WWF):[14]

> *While the state of the Earth's natural ecosystems has declined by about 33 per cent over the last 30 years ("Living Planet Index"), the ecological pressure of humanity on the Earth has increased by about 50 per cent over the same period ("World Ecological Footprint"), and exceeds the biosphere's regeneration rate.*

In terms of our "economy as subsystem" diagram (Figure 2.1), this means that the capacity of natural capital (light gray stuff) to supply life-support services has declined by about 33%, and that the demand generated by manmade capital (dark gray stuff) for life-support services, provided by the light gray stuff, has increased by about 50%—and this has occurred over the past 30 years. There are two blades to this scissors:

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[13] *Resource Flows: The Material Basis of Industrial Economies*, Washington, DC: WRI, 1997.

[14] World Wildlife Fund, UNEP, *Living Planet Report 2000*, Gland, Switzerland: WWF International, 2000, p. 1.

increasing demand for carrying capacity (ecological footprint), and decreasing supply of carrying capacity (living planet index). Both blades of the scissors are being squeezed by the same hand—namely, growth. The "ecological footprint" is the number of hectares of productive land or sea required to support one average person at the world average consumption level. The study estimates that as of 1997 the ecological footprint of the Earth's total population was at least 30% higher than the Earth's biological reproductive capacity. This deficit is made up by consuming or drawing down natural capital, thus "borrowing from" or perhaps "robbing" the future. Scholars may have statistical arguments over the best measures of carrying capacity demanded and supplied, but the basic qualitative conclusion of unsustainable trends is hard to deny.

BIG IDEAS to remember

- Whole and part
- Open, closed, and isolated systems
- Optimal scale
- Full world versus empty world
- Diminishing marginal utility
- Increasing marginal costs
- Paradigm and preanalytic vision
- Circular flow
- Linear throughput
- Say's Law
- Leakages and injections
- Laws of thermodynamics
- Fallacy of misplaced concreteness
- Entropy hourglass
- Measures of throughput volume