Equilibrium, Entropy, Development, and Autopoiesis: Towards a Disequilibrium Economics

KENNETH E. BOULDING

The concept of equilibrium has played a central, but highly ambiguous role in the development of economic thought. Anticipations of the equilibrium concept can undoubtedly be found before Adam Smith, but it is with *The Wealth of Nations* that the concept of an equilibrium of the whole relative price-wage structure suddenly flowers in astonishing detail and accuracy. Economics became a discipline with Adam Smith. I have argued indeed that it is the third oldest of the sciences, after astronomy and physics, in terms of continuous development. Adam Smith was not only the Copernicus and the Newton of economics but, in terms of the theoretical frameworks, I would argue that he went beyond Newton. Though his theory was expressed verbally rather than mathematically, it is essentially a sophisticated theory of ecological equilibrium and evolution in the ecosystem of commodities.

The theory is familiar to all economists. It has two parts, the first being the theory of market price equilibrium. In this it is first argued that there is a relative structure or set of actual market prices, and that, in modern terminology, there is a set function relating the set of actual market prices to the set of excess demands and excess supplies of the marketers. Excess demands are represented by would-be buyers who cannot find sellers to supply them at the existing price set, excess supplies by would-be sellers who cannot find buyers for what they wish to sell at the existing price set. It is then argued that there is some set of market prices at which all excess demands and excess supplies are zero. This is what is meant by "clearing the market." It is argued, furthermore, that if the set of market prices diverges from the equilibrium set, prices that are "too high" create excess supplies and will fall, as sellers with excess supplies are motivated to reduce the prices at which they are offering to sell. Similarly, prices that are "too low" create excess demands and will rise. If, then, the actual set of prices diverges from the equilibrium set, there is a strong tendency to move towards the equilibrium set. The equilibrium set itself, of course, is a function of the parameters of the system, including the distribution of stocks of all exchangeables among the marketers and the preferences of the marketers for all these various exchangeables. As these parameters change, so does the equilibrium position.

Adam Smith, of course, went much further and postulated an equilibrium of what he called "natural" price. This is the same as what Marshall called "normal" price, which is the set of market prices persisting over a sufficient period such that there will be no change in the parameters which determine the market price equilibrium. The argument here is that corresponding to every set of market prices there is a set of the distribution

*Distingushed Professor of Economics Emeritus,
Institute of Behavioral Science, University of Colorado.*

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of perceived economic welfare by occupations, an occupation being a group of people whose decisions are relevant to the production of a particular commodity. In a society of private property these consist of the persons who own the factors of production that are inputs into production. The concepts can perfectly well be expanded to any form of organization, including centrally-planned economies, though here the decision makers include bureaucratic planners who enjoy much slower feedback from the consequences of their decisions.

Then it is further argued that there is some set of continuing market prices (and wages) at which the distribution of economic welfare among occupations is such that there is no overall tendency to shift from one occupation to another or to expand or contract the production of any commodity. If the continuing set of market prices is not equal to the natural or normal price set, some prices, again, will be "too high," meaning that those in the occupation producing this commodity will be unusually well rewarded. Others will be "too low," meaning that those in the occupation producing them will be unusually ill rewarded. If then factors are mobile between occupations, people will move out of the ill-rewarded occupations, thus lowering the output of the commodity and increasing its price in the market, and will move into the well-rewarded occupations, thereby increasing the output and lowering its price. All this assumes, of course, that economic welfare is a function of the terms of trade of the occupation and the structure of terms of trade is a function of the set of market prices.

I translated Adam Smith's Book I, Chapter 7 into language which is perhaps more sophisticated than he would have used, but the ideas are still all there. It is a remarkable intellectual achievement. What is even more remarkable is that Adam Smith also saw very clearly that the parameters which determine the set of normal prices also are subject to constant change. His equilibrium concepts are merely a stepping stone to a much larger dynamics, and despite the fact that Adam Smith introduced the equilibrium concept into the formal structure of economic theory in a way that no one had ever done before, he was also very clear that equilibrium itself was constantly changing. I have often used the analogy of the dog chasing a rabbit. The rabbit is the equilibrium position of the dog. But if it is a wise rabbit, by the time the dog gets there, the rabbit is no longer there, so that the dog is constantly chasing a moving equilibrium. All the equilibria of the real world are like this. Complete stationary equilibrium is known in nature. This does not detract from the usefulness of the concept. In nature the dog never catches the rabbit or, if he does, the equilibrium system is destroyed and we start all over again with new parameters.

Adam Smith went beyond normal price equilibrium into a theory of development, which is really a theory about the pattern of changes in the parameters which determine the natural price set. We should also emphasize that, corresponding to each natural price set, there is a natural quantity set, that is, the quantities (stocks) of commodities in existence, and the quantities that are produced and consumed in each period of time. From each quantity set (which includes both the human population, the capital stock, and the production and consumption of all commodities per unit of time) we can derive measures of overall riches or wealth and so derive an index which will at least give us a clue to economic progress, stagnation, or retrogression. Adam Smith, of course, did not formulate statistically the concept of GNP, but this is only one measure of the concept of aggregate production and consumption which Adam Smith takes as his major indicator of riches. This is shown in the very first sentence of The Wealth of Nations: "The annual labour of every nation is a fund which originally supplies it with all the necessaries and conveniences of life which it annually consumes, and which consists always either of the immediate produce of that labour or in what is purchased with that produce from other nations." Adam Smith is also very clear that the most significant measure of economic welfare or riches, that is, of "the wealth of nations," is the per capita income or consumption of economic goods, a view which has persisted to this day. I have questioned this somewhat myself, arguing that for many purposes the overall capital stock, especially including the quality of human capital, is more significant than the additions to this stock (production) or the subtractions from it (consumption). Adam Smith undoubtedly set the tune for a confusion between stocks and flows, which has plagued economics for more than 200 years. But that is another matter that we need not go into now; if the length of "life" of goods is stable the ratio of production or consumption to stock is a constant, so production or consumption is at least a surrogate measure of stock. As we cannot consume, however, what has not been produced, per capita consumption is very closely related to per capita production which, in turn, is related to the productivity of human activity, that is, of labor. It is the increase in this productivity which is the prime constituent of economic development and the growth in economic welfare.

Adam Smith is remarkably sophisticated in regard to the underlying patterns of this growth in productivity. He sees this growth first of all as a result of the division of labor, that is, specialization. He sees also that this increase in productivity mainly because of the increase in the "skill, dexterity, and judgment" which application to a particular task produces. He also sees that beyond this the critical variable is human knowledge, what he calls the "quantity of science." Just why the "quantity of science" also increases or decreases (Wealth of Nations, Modern Library Edition, p. 10), he does not pursue.

He sees, of course, very clearly that the patterns of change in the normal set of prices and quantities of commodities will depend on the relative rates of productivity increase in different occupations and the production of different commodities. Commodities which enjoy a rate of productivity increase above the average will tend to fall in relative price, those with rates of productivity increase below the average will tend to rise in relative price. He is not quite so clear perhaps in regard to the principle that the pattern of shift in the normal quantity set depends on what now we would call the relative income elasticity of demand for various commodities. There are some commodities in which both the price elasticity and the income elasticity of demand is low, of which the basic necessities of life are perhaps the best example, though sometimes hard to identify. An increase in productivity in these cases will operate mainly to shift resources out of the occupation that produces them and will expand other occupations and their products. Thus, the main result of an increase in agricultural productivity is a decline in the proportion of labor force and other resources devoted to agriculture and an expansion of the labor force devoted to the production of manufactures and of services, coupled with a decline in the relative price of agricultural commodities and an increase in the relative prices of other things.

A very critical question which Adam Smith raised, and which was developed more explicitly by Malthus, is whether the patterns of development or increasing productivity which are due to the increase in skill and knowledge do not themselves lead towards some kind of equilibrium, that is, a stationary state. This concept became of great importance in the economics of the first half of the nineteenth...
century, from Malthus through Ricardo and to John Stuart Mill, although the roots of it are all in Adam Smith’s Wealth of Nations. A critical question is what, if anything, brings the rise in productivity to an end? Implicit in Adam Smith’s view of development is that productivity is the result of two processes—

one, the growth of human skill and knowledge and the accumulation of those capital goods which embody this skill and knowledge and assist it. The other is the underlying scarcity of resources, especially, of course, of land. In classical economics land is generally seen as the ultimate unupgradable resource. Land may temporarily be expanded by new discoveries and migration or, in effect, by improvement in yields, but there are limits to this also, and as human population continues to grow on limited land area, the density of population per square mile or unit of land increases, until finally the rise in knowledge and skill is overcome by the sheer scarcities of the natural resource, and per capita real income must decline to the point where population no longer grows.

The basic assumption here, of course, is that the rate of growth of population is a function of real income and ultimately a declining one. The famous “subsistence level” is that level of per capita real income at which population no longer grows, either because the food supply is inadequate to sustain a sufficient number of infants—"It is not uncommon, I have been frequently told, in the Highlands of Scotland for a mother who has borne twenty children not to have two alive" (Wealth of Nations, Modern Library Edition, p. 79)—or because of deliberate restriction of births for economic or moral reasons. From this follows what I have called the “dismal theorem” in economics—that if only misery can stop the growth of population, the population will grow until it is miserable and starves. Again, however, equilibrium positions depend on the parameters of the system and, as Ricardo saw very clearly, the subsistence level is culturally, not physically, determined. If the working class especially developed extravagant habits and a strong sense of the cost of having children, the subsistence level could well be at a very comfortable level of income.

These principles are illustrated in a very familiar diagram, Figure 1, in which we plot population horizontally and per capita real income or riches vertically. At a given level of knowledge, skill, capital, and technology, we postulate a curve relating population to per capita riches, \( mW, T_0 \). At low populations we suppose that increase in population increases riches (from \( O W \) to \( T_1 W_1 \)) because of diminution of transportation costs and greater opportunity for division of labor, and so on. Beyond a maximum at \( W_0 \), however, increase in population diminishes per capita riches continuously because of the growing scarcity of natural resource factors. If now there is a constant subsistence level of \( S_0 \), this being defined as the level of riches at which the population will just reproduce itself and population increase will be zero, above which population will increase and below which it will decline, then we have an equilibrium at \( T \). At populations below \( ST \), riches will be greater than subsistence and will increase, whereas if greater than \( ST \), riches will be less than subsistence and will decline, so that \( T \) is a stable equilibrium.

If now there is a technological improvement without any change in the subsistence level to a dotted curve \( mW_1, T_1 \), population will increase to \( ST_1 \), but riches will not change. This is what I have called the “utterly dismal theorem,” that if the only thing that can check population is starvation and misery, then any technological improvement enables a larger population to be miserable and starved. If, however, the subsistence level rises, let us say from \( S_0 \) to \( S_0' \), reverting to the original income-population curve, the position of equilibrium will be at \( T_0 \), with population \( S, T_0 \), at a much higher level of riches, \( O S_0' \). The highest level of riches with given knowledge, technology, and so on will be, of course, at the point \( W_0 \). And if this is the subsistence level, \( S_0' \), the population will be as rich as it possibly can be, though in a rather precarious equilibrium. If the subsistence level is higher than this, the population will decline continually and become extinct.

If now the subsistence level itself is a function of knowledge, skill, and per capita riches, we get the famous “race between population and capital” of the classical economists, capital being interpreted to include human capital and human knowledge and skill, so that we may get successively rising population-riches curves, intersecting successively rising subsistence levels at, say, \( T; T_1; T_2 \); and so on. In many countries this has been very characteristic of the last 200 years.

The ultimate question then is whether the rise in knowledge, skill, capital, and so on itself runs into limits at, say, \( T_0 \). Theoretically we must almost suppose that it does, simply because of the fact that the potential of the human mind for knowledge is not infinite, even though we seem to be a very long way from those limits at the moment. The situation is complicated, of course, by the fact that movements towards these equilibria
are often quite slow and that the rate of movement towards equilibrium may itself be part of the change of its parameters. But we can leave these complications for the mathematicians.

Already the spectre of entropy has risen above the horizon. The term "entropy" was invented in 1865 by Clausius, so Adam Smith can hardly be blamed for not being really consciously aware of it. I have argued that the concept of entropy was a little unfortunate, in that it is essentially a concept of negative potential and that potential is a much more attractive and illuminating concept with much broader applications. I have restated what I describe as the "generalized second law," of which the second law of thermodynamics is an example and a special case, that if anything happens it is because there is a potential for its happening, and that after it has happened, that potential has been used up. 

A law of the using up of potential is much more intuitively obvious than a law of increasing entropy.

The entropy concept had very little impact on economics until Nicholas Georgescu-Roegen's remarkable book _The Entropy Law and the Economic Process._ The stationary state concept of the classical economists, even up to John Stuart Mill, assumed in effect that the ultimate resource base of the economy is inexhaustible and that a stationary state can be maintained indefinitely. What was not perhaps realized is that all the possible examples of an indefinitely sustainable resource base involve the utilization of the earth's thoroughput of solar energy and a continuous recycling of materials. A primitive economy based only on agriculture and complete recycling of materials taken out of the soil might conform to this pattern. But such economies have actually been very rare. The modern economy is so clearly based on exhaustible resources in the shape of fossil fuels and concentrated ores that it is not surprising that there has been increasing interest in the implications of the entropy concept for economics.

The problem, however, is very far from simple. What we detect in the history of the human race is the constant interplay of two processes interacting in opposite directions, of which one sometimes dominates and sometimes the other. One process is the entropy principle interpreted as the principle of the exhaustion of a given potential. We see this in the aging and ultimate death of an organism as it exhausts the biological potential contained in its fertilized egg. We see it especially in the exhaustion of mines, oil wells, and deposits of fossil fuels and ores. These processes, however, have been constantly offset by the process of the recreation of potential. Even in terms of thermodynamics, thermodynamic potential is constantly re-created in open systems like the earth, which receive a thoroughput of energy, as the earth does from the sun. This is, of course, at the cost of the realistic exhaustion of the energy stock of the sun and, for the solar system as a whole, entropy is undoubtedly increasing and its potential is being used up. As the earth's processes, for instance in the atmosphere and the oceans, realize and so exhaust potential, and so increase entropy, for instance through rain falling and streams flowing to the oceans, this potential is constantly recycled by the energy from the sun producing new rainfall. Similarly, the entropy processes involved in the using up of the potential of a fertilized egg are continually offset by fertilization of new eggs. The total population of an organism is exempt from these processes of increasing genetic entropy, though it is liable to processes of perhaps of the using up of evolutionary potential which are something larger.

Whether entropy is particularly significant for economic processes depends on the size of potentials relative to the rate of using them up and the probability of potentials being renewed. We certainly do not have to worry about the increasing entropy of the sun. It will assuredly outlast us and any economic system we can envisage. A large number of human economics, however, have been entropic in the sense that they have depended on exhaustible resources, the stocks of which were small enough so that their exhaustion and failure to recreate potential had a noticeable effect on the economy. We see this even in hunting and gathering societies, which have by no means infrequently been overhunted and overhauled to the point where their resource base has been seriously depleted and the societies have either disintegrated or been forced to migrate or adapt. There is a good deal of evidence, for instance, that when the ancestors of the present American Indians invaded North America over the Bering land bridge about 11,000 years ago, they found a continent extraordinarily full of large edible animals which they proceeded to exterminate over a period perhaps of 2,000 years. It is hard to believe that this was not followed by a real catastrophe and the readjustment of the population to a much smaller level.

Deforestation has been an "entropic" aspect of human society for many millennia and, although it is theoretically possible to have an indefinitely sustainable forest, the temptation to overcut and to take more out of a forest than its annual growth seems to have been almost irresistible in a large number of cases, and this is going on in a great many places in the world today. The exhaustion of mines is a phenomenon that goes back to relatively soon after the beginnings of metalurgy. The exhaustion of soils has been by no means uncommon. The idea that primitive societies are somehow more sustainable and less likely to exhaust their potential or developed societies could well be a romantic illusion. The persistence of primitive societies may be more the result of their reaching the Malthusian limits at a level of population so low that it does not make much of a dent on the exhaustible resource base. Concern about entropic processes in today's world may well be a result of the fact that the rise in the human niche, which has resulted from the increase in human knowledge, and especially the applications of science to technology, has created a human population so many orders of magnitude larger than anything experienced in the first 50,000 years of the human race when the human race was so no longer a small population relative to its total environment.

What might be called the "doomsday" literature of the last 10 years or so, beginning with the famous Club of Rome report, of which the latest version is the United States government report on the year 2000, is a reflection of increasing concern about the entropic aspects of economic and social life. This is indeed a very legitimate concern, especially in light of the fact that the expansion of the human population is almost certain to continue at a substantial rate, at least for the next few decades unless some catastrophe intervenes. Furthermore, the strong push for economic development, which is still of great importance to the poorest three-quarters of the human race, suggests that the average pressure on the environment per individual human being will increase, and that the rate of depletion of exhaustible resources will likewise increase.

The critical question for the future is whether the "offsetting process," that is, the recreation of potential, is going to be sufficient to offset the entropic processes of...
exhaustion of current potential. This is something certainly that no one can predict, if only because of the fundamental principle that the recreation of potential depends to a very large extent on the increase in human knowledge and we cannot predict what we are going to know in the future or we would know it now. We must therefore live with irreducible uncertainty. Nevertheless, it is useful to speculate about the potentials for increasing potential. The doomsayers tend to underesti- mate these, or even neglect them altogether, as the original Club of Rome report did. It is curious that there is no general theory in the scientific community of the recreation of potential as there is a theory of its exhaustion, unless we put the general theory of evolution in this category.

The evolutionary process certainly seems to have a "time's arrow," which is at least in a local sense anti-entropic. There is no single indicator for the "rate of evolution." There is nothing like the GNP in the biosphere; still, we can trace three or four processes in which an "anti-entropic" time's arrow seems to show up. There is, for instance, an increase in complexity from the first viruses, whatever the earliest forms of life were, to the human race over 2 or 3 billion years. There is an increase in control and the development of homeostatic or cybernetic mechanisms within organisms, such as perception, input from the senses, temperature regulation, and so on. Then there is an increase in something that might perhaps be called intelligence or cleverness or consciousness (if we want to stick to the letter "C") from the dim perceptions of the amoeba and the plant to the extraordinary map of the universe within the human being. This has presumably happened because the evolutionary process has a certain "prejudice" towards the increase of these potentials, perhaps because, as I have suggested, there is more likely to be an empty niche "at the top" of any ecosystems for organisms that are more complex, more controlled, more conscious, than those at the bottom end of the scale, where any empty niches are more easily filled and are likely to have been filled long ago.

We see exactly the same phenomenon in societal evolution, where again we see a process towards increasing complexity, from the first hunting-gathering bands to the national states and corporations of today. We see also an increase in control, in the development of "social cybernetics," the slow growth of areas of reasonably stable peace, the development of nondoning political cultures and, even in our own century, the improvement of the cybernetics of the economic system, especially in regard to business cycles and unemployment, and perhaps in the next generation, in regard to inflation. There is also growth in consciousness in social systems and in the real time of prevailing images of the social world. We see this, for instance, in the progress of geography, from primitive images of early days to the beautiful and accurate globes and maps of today, even now of the other planets. We see it again in the rise of a much more self-conscious image of the economy and even of the dynamics of the international system and the political culture. Again, the "room at the top" principle applies and this directionality is the result of the existence of empty niches in social systems for the more complex, the more controlled, and the more conscious.

The growth of human knowledge is itself an evolutionary process. The human mind has an enormous capacity for mutation, for fantasy, for the creation of new images of the world. But there is also an important selective factor. Those of our images which are "true," in the sense that they are accurate maps of the world outside, are apt to be more stable than images that are untrue, which are apt to be destroyed in the testing process. Not only the quantity and the complexity of the cognitive content of human minds has steadily increased over the millennia, but the accuracy of this image has also increased. There has been a corresponding increase in human power—the alchemists could never have produced plastics, nor, one should add, the nuclear weapon. All the gurus in the world never got anybody on the moon, and we know now that Purgatory, at least, is not at the South Pole, as Dante presumably thought.

A fairly recent development which crosses a number of different fields of science, and which may throw some important light on the problem of the recreation of potential, is the theory of autopoiesis.

The theoretical foundation of autopoiesis is the principle that in a stochastic system an event of given probability will eventually happen if we wait long enough, no matter how improbable the event. When an event happens, this changes the probability of events, at least in the immediate neighborhood, simply because the structure of the system is changed by the event actually taking place. In thermodynamics this is reflected in the work of Prigogine, in what he calls "dissipative systems," largely in the field of chemistry, where structures may be formed far from equilibrium which, once formed, acquire a certain stability of their own. This idea has been expanded by Zezteny and others, for instance, in biology to problems of cell formation and epigeneis, that is, an enormously mysterious process by which an egg becomes a chicken, and also in social systems in the formation of social structures and organizations.

The application of this idea to economics opens an intriguing and as yet very little explored field of inquiry. The dynamics of Adam Smith's "invisible hand" is remarkably like an example of autopoiesis, for it is a process by which order is built out of independent decisions of varying probability. Equil-librium price theory here perhaps plays the kind of role that homeostatic does in biology, in that it abstracts from the developmental process in its initial stages. But it is very clear that in the developmental process one mutation leads to another. One can think of this in ecological terms, that the filling of one empty niche opens up a large number of others, and so constantly changes the probabilities of the formation of different kinds of structures—commodities, industries, and so forth. The key processes here are the exhaustion of potential creates new niches in the systems, which are then filled, the filling of which creates still more niches, and so on, the system constantly being transformed. A possible example of this would be the exhaustion of whale oil in the mid-nineteenth century, which created an empty niche for kerowine, which created an empty niche for the oil industry, which created gasoline as a byprod-uct, which created an empty niche for the internal combustion engine, which then created empty niches for roads, concrete, supermarkets, shopping centers, house trailers, campgrounds, and the whole burgeoning social ecosystem of modern society. Again, we see complexity, control, and consciousness emerging out of chaos by processes which have much in common with autopoiesis.

Just because there is an empty niche, however, is no guarantee that it will be filled. The limiting factor here is the limits on mutations or, in some cases, migration. There may very well have been an empty niche in the

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Are Women Economists at a Disadvantage in Publishing Journal Articles?

MARIANNE A. FERBER and MICHELLE TEEMAN

Many researchers have found that highly educated women are rewarded less than men with comparable characteristics and achievements. Most of these, as well as some other studies, have also found that women do not have the same characteristics and achievements. They obtain their terminal degrees somewhat later, they are less likely to obtain the highest degree available in a field, they tend to have accumulated less experience per unit of time since their terminal degree, they are less likely to have published less, etc.

*The authors are Professor of Economics, University of Illinois at Urbana-Champaign.


Much attention has been focused on the fact that women are disadvantaged in acquiring credentials, or in the current jargon, accumulating human capital, because of their traditional role as wife and mother. While some consideration has been given to the question whether discrimination also plays a part in this respect, a good deal more needs to be done. This note attempts to make a small contribution to our knowledge of this subject by focussing on one subgroup, namely economists, and one type of credentials, namely publications in scholarly journals.

There are two crucial steps in becoming a successful author that we shall examine. The first step, which is not indispensable, but is becoming increasingly common, is to find a collaborator. Even though men constitute a large majority of all economists, women will not be at a disadvantage in finding a collaborator if an individual woman is as likely to be
