Agriculture - Economic aspects

AGRICULTURAL ECONOMICS IN AN EVOLUTIONARY PERSPECTIVE

Kenneth E. Boulding
Distinguished Professor of Economics Emeritus
Institute of Behavioral Science
University of Colorado
Boulder, Colorado 80309

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The search for an evolutionary perspective in economics goes back a long way. I have argued, indeed, that Adam Smith was the first evolutionary economist, that Malthus was the second, and that it was no accident that Darwin got his idea of natural selection when he was reading Malthus one evening "for amusement" (page 120). The search for an evolutionary perspective is a search for a model which will enable us to perceive structure and pattern in the great ongoing flux of the universe through space and time.

The evolutionary "vision," which is perhaps a better word for it than "model," is a way of looking at an enormously complex universe, rather than an explicit model of a simpler reality. It sees the evolution of the universe as a process of constant ecological interaction under continually changing parameters. At any one moment the universe is a set with a large number of populations of different species. A population is a set of elements which are alike enough to be interesting, though they may not be identical in form and structure. A species is anything which has a population. It may include subatomic particles, photons and electrons, chemical atoms, molecules, DNA and genetic structures, cells, organisms, human beings, ideas, words, commodities, securities, money, and so on. The population of any species grows by additions and declines by subtractions. Additions may come from the formation of elements, from chemical reaction, as when hydrogen combines with oxygen to produce H_2O; from replications as with DNA; from births in the case of organisms; from the growth of seeds and plants; from the learning of know-how or know-what; from the production of human artifacts and goods; and so on. Subtractions come from such things as atomic fission, which destroys elements; the disassociation of chemical compounds; the disintegration or mutation of DNA; the death of organisms; the forgetting of learned structures; the consumption of commodities; and so on.

A population grows if additions exceed subtractions, and declines if subtractions exceed additions. If it declines far enough, it becomes extinct and is reduced to zero. In any one population the additions and subtractions will be functions of all other populations of species around it that constitute its environment. Some of these will have favorable effects and make the population grow; others will have unfavorable effects and make it decline. For any population in a given environment we can postulate that it will have an equilibrium level at which additions equal subtractions and the population neither grows nor declines. If this equilibrium is to be stable, then at a population lower than the equilibrium level, it must increase; above the equilibrium level, it must diminish.

In a given habitat we can postulate an ecological equilibrium in which all interacting populations are in equilibrium. Each population is at a level at which, on the whole, it is neither rising nor falling.

An equilibrium population may be called a "niche" in such a system. This is a term used rather loosely by ecologists, but the above definition seems to be most meaningful.

The ecological interaction which creates niches is "selection." It is a very complex process. Darwin's "struggle for existence" is a most unfortunate metaphor. Actually ecological interaction involves very little struggle. Most of it is completely unconscious. There are three major types of such interaction: First, cooperative or symbiotic interaction in which an increase in population A produces an increase in the equilibrium value of population B, and vice versa. Then there is mutually competitive interaction in which an increase in population A produces a diminution in the equilibrium value of population B, and vice versa. Then there is a mixed relationship characterized, for instance, by predation or parasitism, in which an increase in A, a predator, diminishes the equilibrium population of B, but an increase in the population of B increases the population of A. There are limiting cases here of indifference. Thus, an increase in A might increase or decrease B, but an increase in B may not affect A at all. This happens sometimes when A is a dominant species.

Ecological equilibrium is, of course, a mental construct. It is probably never found in nature, although it is a useful concept because it does interpret the dynamics of ecosystems as they may be approaching an equilibrium. The equilibrium position, however, is a function of the parameters of the system and these parameters are constantly changing. This is mutation. The change may be in physical parameters such as temperature, as when the earth warms up or cools off in a succession of ice ages. There may be changes in material population such as soils and soil components which erode. There may be atmospheric changes following eruptions or the impact of the asteroid which is supposed to have exterminated the dinosaurs. Then there are genetic changes which create new biological species. A change in a single parameter of an ecological system may change the niches of all populations in it. This is the great ecological principle that everything depends on everything else.

In order to complete the model, two further concepts must be developed. The first is that of the "empty niche" -- that is, the population which would have a niche in an ecosystem if it existed. Thus, in the nineteenth century there was clearly an empty niche in Australia both for rabbits and for European-type humans. Once they were introduced, they expanded rapidly into the niche. The filling of an empty niche, however, changes all the existing niches in the system and indeed, the system of empty niches itself. The introduction of rabbits into Australia probably diminished many populations of indigenous species. It also created an empty niche for the organism which produces myxomatosis, a disease of rabbits. When this was introduced, the niche for rabbits shrank. A constant ecological ballet is going on, therefore, all the time, with empty niches being filled, parameters changing, and the niche structure changing. This is evolution. If there is such a thing as a final ecological equilibrium, it is a very long way off and we know nothing about it. The universe is a disequilibrium system and has been from the very beginning.

The second important concept is that of production, which is a special form of addition to populations, which rises to prominence with the development of DNA and of life and the distinction which then develops between the genotype and the phenotype, the egg and the chicken. Production is the process by which a genotype is transformed into a phenotype. It is not of great significance in pre-biological evolution of physical and chemical species. The phenomenon of catalysis, the role of which in physical and chemical evolution is still largely unknown, is in some sense a precursor of genetic structure in the sense that the catalyst has a structure which imposes its own patterns on its physical and chemical environment.

With the development of DNA, however, the distinction between the genotype and the phenotype becomes very important. DNA has two remarkable properties: the first is that of self-reproduction (I have sometimes called it "the first three-dimensional xerox machine"); second, its property of "know-how" -- that is, its ability or organize the production of a phenotype. We see this in a primitive form in asexual reproduction as each half of a divided cell is able to grow into a complete cell because each half contains the essential genetic information which organizes its growth. We see it spectacularly in sexual reproduction, where a fertilized egg has the capacity of growing into a member of the phenotype species which produced it and hence creates an addition to the species population.

Production, then, is the process by which the genotype becomes the phenotype. It starts off with the genetic factor, which is the "know-how." In order for this know-how to be realized, however, there has to be a sufficient amount of the "limiting factors," which can be classified roughly as energy, materials, space, and time. A fertilized egg must be able to capture energy for at least three purposes: to transport and transform selected materials into the growing organism, to sustain the temperatures at which these transformations can take place, and to convey information which selects the materials. The right materials must also be available. There must be space in which these processes can be carried out. And there must be time for them to be carried out. For all the limiting factors there is some minimum below which the potential for growth of the fertilized egg into a phenotype cannot be realized. If there is not enough energy of the appropriate kinds, if there is a deficiency even in a single material which is necessary, if there is not enough space, if there is not enough time, the growing phenotype will die before it matures and the fertilized egg will not contribute to the perpetuation of the species.

These concepts apply with suitable modifications to the evolution of social systems, just as they do to biological systems. With the biological development of the human race, an extraordinarily new evolutionary factor was introduced because of the remarkable capacity of this organism for developing both "know-what" and "know-how." No previous organism had anything remotely like the capacity of the human race for developing cognitive and valuational structures within its nervous systems. Humans can form images in their minds which correspond in considerable degree, not only with the whole human environment, but also which have the capacity of visualizing changes in this environment and carrying out these images of change in the production of human artifacts. Human artifacts comprise material artifacts, from flint knives to space shuttles; organizational artifacts, from the hunting band to NASA; and personal artifacts -- that is, human beings with learned structures within them derived from other human beings.

With the development of the human race, evolution on our planet becomes increasingly what I have called "noogenetic." Even in pre-human evolution, a distinction between the purely biogenetic -- that is, DNA and all that -- and the noogenetic -- that is, learned structures transmitted from one generation to the next by a learning process -- has increasing significance. With the advent of the human race, however, noogenetic evolution becomes of overwhelming importance. In human beings the biogenetic evolution seems virtually to have ceased, at least in the last 50,000 years, and the biological gene pool of the human race has changed very little. In terms of human artifacts -- material, organizational, and personal -- however, the impact has been enormous. No part of the world ecosystem has been unaffected by it -- cities, highways, agriculture, airplanes, chemicals -- by this time hundreds of thousands of species of human artifacts have transformed the whole ecosystem of the earth, in what by biological standards is a fantastically short space of time. Many biological species have become extinct or are on the way to extinction; others may be on the way to creation, with the potentiality now for human beings intervening in the biogenetic structure.

Human artifacts are as much a part of the ecological system of the earth as are biological artifacts. They consist of populations of species interacting both with other human artifacts and with biological species. Even paleolithic humans created large-scale biological extinctions. With the development of agriculture and the neolithic, considerable changes in the recombinations and selection process of biological species (crops, livestock) took place. With the discovery of the use of fire, the input of organized energy into the system was increased enormously, with the subsequent development of cooking, pottery, metals, and a great variety of new artifacts. The rise of science in the last 500 years has created a positive explosion of new artifacts -- chemicals, radioactive elements, machines, airplanes, computers, and so on.

The pattern of mutation (filling empty niches) applies just as much to human artifacts as to biological organisms. The niches for human artifacts are created to a very large extent by human demands and valuations. Whether these niches are filled depends on the changes in the noogenetic structure -- that is, in the know-what and the know-how of the human race.

The production of human artifacts differs from that of biological organisms only in the complexity of the genetic structures. Biological evolution never got much beyond two sexes . The evolution of human artifacts is essentially "multi-parental." It involves the bringing together of know-how from a great many different sources. Human artifacts differ from biological organisms also in that their genetic structure is not contained in the artifacts themselves, but in other artifacts. The know-how that enables animals to reproduce is contained in the animals themselves. The know-how that permits the production of automobiles is not contained in the automobile, but in human beings and in plans, blueprints, libraries, and all the various prosthetic devices of human knowledge.

Nevertheless, the principle that production consists of the process by which the genotype becomes the phenotype is just as applicable to human artifacts as to biological organisms. Although production originates in the genetic factor of know-how, it requires limiting factors of energy, materials, space and time. If these limiting factors are not available in sufficient quantities, the potential for know-how will not be realized. An increase in know-how, however, can often push back the limits of the limiting factors, and indeed has done so constantly, both in biological evolution and in societal evolution. Prior genetic mutation through history permitted the biosphere to utilize forms of energy and materials which previously it could not utilize. In societal evolution, likewise, the growth of human knowledge and know-how has permitted a continual expansion of the niche of the human race and of its artifacts, by developing new forms of energy use, new materials, space-economizing and time-economizing techniques, and so on.

What does all this mean for economics, and especially for agricultural economics? Economics, I have sometimes argued, is the third oldest of the sciences, after physics and astronomy. Its theoretical structure crystalized in Adam Smith; it has not basically changed much since. Adam Smith had a clear concept of the system of commodities as an equilibrium system of quantities and prices, the equilibrium price system being that at which each commodity existed in an equilibrium population in which production and consumption were equal. Malthus applied this idea with particular cogency to what today we would call the concept of the "human niche." Both Adam Smith and Malthus were interested in development--that is, changes in the parameters of the system which increased its variety and complexity. It arose fundamentally, as Adam Smith saw, from the "quantity of science"--that is, human knowledge and know-how. In some sense, therefore, Adam Smith was the first in the scientific community to transcend a Newtonian equilibrium and to see the social system at least as an ongoing evolutionary process. He did not apply this to biological systems, for in his time, for instance in his contemporary Linnaeus, biology was only in the stage of achieving taxonomy, and did not develop any serious theoretical structures.

Unfortunately, Adam Smith in the first three chapters of The Wealth of Nations never developed his extraordinary insights regarding the impact of the division of labor on human learning and the essential role of human learning in production. We may perhaps blame the historical accident of structure of British agriculture in the eighteenth century, with its rather clear categories of landlords renting land to entrepreneurial capital-owning farmers employing landless capitalist laborers for creating the taxonomy of factors of production as land, labor, and capital. In terms of the price system, this taxonomy has much value. Rent, profit, and wages do emerge as categories of some homogeneity and great interest from the point of view of distributional theory.

Who originally used the term "factors of production" and identified these as land, labor, and capital, I must confess I have not investigated. The concept, however, was formalized by Ricardo and became part of mainline economics under Mill. Marshall was never able to escape from this, although he tried to add a fourth factor, "organization," which he never quite identified as "know-how." Marshall was very clearly uneasy about the Newtonian quality of equilibrium economics and felt that economics should use biological rather than mechanical models. He was never able to achieve this transition. Walras, unfortunately, by formalizing mathematically the mechanical aspects of general equilibrium, pushed economics into a still more Newtonian model. Keynes, again, never escaped from the equilibrium trap, and the supposedly developmental economics of Harrod and Domar can only be described as a disaster. It is totally incapable of illuminating the enormous complexity of developmental processes and leads to a neglect of the major element in them, which is the learning process.

The greatest disaster of all, of course, was Marx, whose labor theory of production must be blamed mainly on Ricardo, although Adam Smith is not blameless. It has been a major disaster for the human race and has created an evolutionary dead end in the communist societies, which bodes ill for the future. Marx, however, learning from Ricardo, at least saw the existing stock of human artifacts as the end product of innumerable acts of human labor, stretching back presumably to Adam and Eve. This was at least a primitive evolutionary perspective, seeing the present as a result of the history of the past. But as both Ricardo and Marx predated Darwin, and even Darwin knew very little about genetics, ecology, or morphogenesis, they can hardly be blamed for being primitive.

Both Ricardo and Marx missed the crucial point which Adam Smith had begun to see, that it is human knowledge and know-how which is the real genetic factor, not "labor," which from the point of view of production is a hopelessly heterogeneous aggregate. I have argued indeed that land, labor, and capital, from the point of view of the theory of production, are medieval aggregates with all the scientific validity of earth, air, fire, and water, and that they represent a totally inadequate taxonomy of the production process and of the evolutionary process. Once we look at production from the point of view of one genetic factor, know-how, and a set of limiting factors which may limit its operation, the whole process looks very different.

Another disaster was the development of what I have sometimes called the "cookbook theory" of production, in which Wicksteed, Walras, John Bates Clark, and so on, removed even the vestiges of Adam Smith's essentially evolutionary thought from economics. Here production has no history whatever. It consists of mixing land, labor, and capital in a cooking pot and out come potatoes or automobiles. The whole concept of a production function involving heterogeneous aggregates of land, labor, and capital is pure economic alchemy and has been a total blind alley. The more sophisticated the theory of production got from Cobb-Douglas to constant elasticity of substitution production functions, the more useless it became, simply because it started off with a false taxonomy. No matter how elegant alchemy becomes, it will never produce synthetic plastics!

A further result of the cookbook theory of production was an almost total neglect of the problem of exhaustible resources. The ingredients were somehow always assumed to be in the kitchen--a kitchen, indeed, full of inexhaustible widow's cruses of land, labor, and capital, all willing to be poured into the cooking pot. It almost took the OPEC crisis of 1973 to awaken us to the fact that our boasted riches and productivity depended in no small measure on the exhaustion of exhaustible resources, not only in energy but also in materials.

The implications of the evolutionary perspective for agricultural economics could well be profound. In the first place, agriculture is the one sector of economic life which is inescapably close to the biological processes and in which, therefore, the relations between biological and societal evolution are of particular importance. Agriculture indeed consists of the application of human knowledge and know-how to changing the parameters of ecosystems in particular habitats in order to create a new quasi-equilibrium set of largely biological populations which is higher on the scale of human values. In other words, the business of agriculture is to transform an ecosystem so that it produces wheat instead of brambles, fat cattle instead of starving deer, sheep and pigs instead of buffalo and coyotes, thereby increasing the niche of the human race. This process involves a combination of noogenetic intervention, working through biogenetic processes. Up to now the impact of the noogenetic process has mainly been on selection, creating ecosystems with low populations of things low on the scale of human values, like food. To agriculture, of course, we should also add silviculture and the transformation of forest ecosystems and aquaculture, by which human know-how transforms the ecosystems of ponds, lakes, and rivers.

The parametric change which is introduced into these ecosystems by human intervention is complex and often produces unexpected results. Plowing rearranges the materials in the soil to make it more favorable to the growth of desired plants, but also may lead to soil erosion. Artificial fertilizers have pushed back some of the limiting factors of the materials affecting plant growth, but may also pollute streams and rivers. New seeds, hybridization, increase yields per acre by pushing back the space limitation, but through monoculture may increase the dangers of ecological disaster through exposure to new pests and diseases. An important aspect of humanly created ecosystems that is often neglected is their vulnerability to uncontrolled parametric change. The Irish potato famine of the 1840's was a classic example of an agricultural improvement which led to human catastrophe through vulnerability. One worries a bit about what might happen in the United States if we had a combination of a corn blight, a wheat rust, and a soy beetle all in the same year!

It is clear that agriculture must be regarded as part of the general evolutionary process of the planet, which has profoundly changed its aspect and its ecosystems, mainly through selection, in response to human valuations. We may indeed be on the edge of even more dramatic changes as a result of our potentiality for intervening in genetic as well as selective processes, through recombinant DNA, and eventually, who knows, through chemical reconstructions of DNA. As a result, we may speed up biological evolution to an unprecedented rate. It is a very important question as to whether this may not make the whole system of the earth more vulnerable than it has been in the past. One of the remarkable phenomena in the evolution of this planet has been the capacity of the process to survive, and indeed even in some sense benefit from, catastrophe. If the record of the rocks is to be trusted--which it is not very much--the evolutionary process has been punctuated by catastrophes which separate one geologic age from the next. These catastrophes seem to have led to very widespread extinction of the species of the previous age, which apparently opened up new niches, almost always for more advanced species, at least by human standards. Exactly why this should be so is by no means clear.

The evolutionary perspective in economics does not give us a Newtonian "celestial mechanics" of commodities, and this is because of the nature of the reality itself which it is trying to describe, which is profoundly indeterministic. Evolution takes place by the filling of empty niches. There is no guarantee that empty niches will be filled before they close. This introduces a profound element of indeterminancy into the system, and any attempt to reduce it to a kind of Newtonian mechanics is bound to fail, simply because it is not that kind of reality. This is why, for instance, empirical attempts to explain development in terms of land, labor, and capital production functions have been so unsuccessful. We have always had to fall back on some vague concept of technological change, which is a kind of surrogate for the genetic know-how factor.

Agriculture is peculiarly important in the development of society because of the capacity for improvements in agriculture to create empty niches in many other fields, and even to increase the capacity for filling existing empty niches. A good example would be what I have sometimes called the "turnip theory" of Western European, especially British, expansion in the last 200 or 300 years. The introduction of the turnip into Western European, and especially into British, agriculture in the early part of the eighteenth century, transformed the medieval three-field system into a four-course totation. Turnips and other root crops enabled the previously fallow field to be used. The main reason for having the fallow field in medieval agriculture was to get rid of the weeds. With row crops and horse hoeing husbandry this could be done and still have a crop. Furthermore, clover could be introduced to restore fertility. This substantially increased the overall yield per acre, particularly in livestock feed. This permitted livestock to be kept through the winter instead of having to be slaughtered off at Christmas. This permitted breeding and improvement of livestock. This increased human protein consumption, which led to a diminution in infant mortality that was spectacular, especially in Britain in the mid-eighteenth century. This led to a population explosion which previous improvements in ocean transportation spread around the world to Australasia, North America, and South Africa. This created empty niches for new industrial production and so on to the present day.

An increase in yield per acre in agriculture will increase the size of the human niche, but an increase in yield per worker, because of the relative income inelasticity of the demand for food, diminishes the proportion of the population in agriculture, and expands the niches for nonagricultural goods. The filling of each new empty niche by invention (for instance, in textiles or in machinery) opened up new niches elsewhere, which again had repercussions in agriculture. Thus, the exhaustion of whale oil in the mid-nineteenth century due to the overkilling of whales opened up a niche for kerosene. It is not surprising, therefore, that the oil industry started in 1858. The development of chemistry permitted the transformation of crude oil into kerosene and gasoline, which at first was an unwanted byproduct. This created an empty niche for the internal combustion engine and the automobile, which in turn created empty niches for highways, the cement industry, supermarkets, and shopping centers. This also fed back into agriculture through the tractor and the substitution of fossil fuels and energy for horses, which released further food supply and led to further increases in the output per person, to the point where now in the rich countries something between 4 and 10 percent of the population produces all the food that is consumed, leaving 90 percent for other things. Only 200 years ago, food production took 80 or 90 percent, leaving only 10 or 20 percent for other things.

What then does this evolutionary perspective imply for the future of agricultural economics? If there is indeed an empty niche, as I hope, for a genuinely post-Newtonian evolutionary economics, it seems reasonable to look to agricultural economics, with its rich biological involvement and its long tradition of both empirical and applied research, to pioneer in this development. This may mean the abandonment of some degree of mathematical rigor, which easily turns into _rigor mortis_ when the real world that is being investigated is not itself mathematically rigorous and has large elements in it of randomness and unpredictable parametric change. This is not to defend sloppy thinking, casual empiricism, or merely analogical reasoning. Models, however, must be appropriate to the system that they attempt to describe, and there is a great opportunity here for the development of a mathematics which is appropriate to evolutionary reality. If the theory of fuzzy sets can be expanded into a theory of fuzzy processes we may be much closer to the real world than we are when we try to find stable parameters which do not exist in nature. A symbolic representation of evolutionary reality in a simplified manner is very much needed and should be a real challenge to the mathematicians, for the mathematics which is really appropriate to evolutionary and to social systems does not yet exist. The social sciences in the twentieth century have been captured by essentially seventeenth-century mathematics, with a little dash of nineteenth-century probability and statistics, much of which is quite inappropriate to the type of real world which is being investigated.

Agricultural economics strikes me as being the ideal starting point for empirical investigation into both limiting-factor models and exhaustible-factor models, both aspects of what might be called "genetic production theory." It is obvious in agriculture that human know-how has been the critical factor in agricultural production. This know-how, however, is limited in its realization by the limiting factors of energy, materials, space and time, but is also constantly engaged in pushing back these limits. An important aspect of limiting-factor theory is that it is the <u>most</u> limiting factor which is important. If we are climbing a mountain, even if it is a utility mountain, it is the first fence that we come to that stops us. Other fences might lie beyond this and if we push back the first fence they may become the most important, but at any one time it is the first limiting factor that demands the major part of our attention.

An increase in the know-how or genetic factor, of course, may change all the limiting factors, for they all interact with each other. Hybrid corn, for instance, certainly economized space. It also economized time, being quicker and easier to harvest. It may even have economized energy input, utilizing more solar energy and less muscle or fossil fuel power, but I am not sure of this. It probably did not economize materials, but increased the necessity for artificial fertilizers. What we have here is a complex shift in the fences that crisscross the productivity hill. They are by no means easy to unscramble. Unscrambling these effects would be much more rewarding than trying to develop Cobb-Douglas production functions, or any kind of constant parameter function. Sometimes indeed the most important limiting factor could be an undetected trace element.

Another large field of research which opens up is the study of the impact of relative price structures, particularly of their certainty and uncertainty on agriculture. The relative price structure operates through wages, prices, profits, and rents. Its impact on production is mediated through its impact on the limiting factors. Yet this is something which the cookbook theory of production completely overlooks. Labor is a complex aggregate of know-how, muscular energy released through the burning of food, material structures that determine health and vigor, diet and nutrition. In Adam Smith, and oddly enough even in Jevons, labor was a kind of input-output apparatus to transform food into other things. Feeding agricultural workers produced more food. Feeding industrial workers transformed food into textiles or metals or machines if the laborer was employed in these areas, very much in the way that a cow was an input-output machine for turning grass into milk and meat. This at least was closer to the complexity of the real world than the assumption that labor was an independent measurable factor of production, which when stirred in with capital and land became cheese. The opportunities for empirical research guided by the limiting-factor theory seem to me to be very great.

Finally, agricultural economics is an excellent field for the study of the economy as a subset of the larger evolutionary ecosystem of the world, particularly for what I have been calling "echo effects." If agricultural economics cannot be part of a general ecological science there is not much hope for us. Ecological systems are also "echo systems," in which any act or event echoes and re-echoes all over the system, and the final effect may be extremely different from the initial disturbance. We see this particularly in the problem of distributions of economic welfare, which often end up very far from an initial intended act. Agricultural policy is an extraordinary case in point, where, for instance, price supports that originally were conceived to help the poor in fact have helped the rich farmer and chased the poor farmer out of agriculture, perhaps--or perhaps not--to be better off elsewhere. Such policies have benefited the non-agricultural population much more than the agricultural population, have created all sorts of strange redistributions among the owners of land, like the impact of the tobacco quota, and have ended up with a very different kind of overall ecosystem than their authors imagined. Agriculture is also a good example of a reverberant system, where the echoes do not die away but set the system on a course of irreversible evolutionary change.

It is a fundamental principle of evolutionary theory that our capacity for predicting the future is extremely limited. Celestial mechanics only had the success that it had in predicting eclipses because the evolution of the solar system had virtually ceased. Agricultural economics deals with one of the most significant and rapid evolutionary systems in the world and should, therefore, be very skeptical of prediction of any kind. Nevertheless, it does lead us to the search for empty niches and for the possibilities of filling them, and this may be a much more important guide to policy and to human behavior than mechanical prediction. The guide to societal evolution is search, both historically and in work on the future. Agricultural economics has a peculiar opportunity to study and improve the process of search for empty niches and for new mutations. Newtonian economics may have come to a dead end. But every evolutionary dead end seems to have created a search for an open road, and in this last reflection one can indulge in a good deal of hope and optimism. This is an age of Jeremiahs, quite legitimately, if we are confined to contemplating the future of the world as if it were not an evolutionary system. But the evolutionary model emphasizes the unexpectedness of the future, and in unexpectedness there is always hope.

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