UNCERTAINTY, EVOLUTION, AND ECONOMIC THEORY

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A MODIFICATION of economic analysis to incorporate incomplete information and uncertain foresight as axioms is suggested here. This approach dispenses with "profit maximization"; and it does not rely on the predictable, individual behavior that is usually assumed, as a first approximation, in standard textbook treatments. Despite these changes, the analytical concepts usually associated with such behavior are retained because they are not dependent upon such motivation or foresight. The suggested approach embodies the principles of biological evolution and natural selection by interpreting the economic system as an adoptive mechanism which chooses among exploratory actions generated by the adaptive pursuit of "success" or "profits." The resulting analysis is applicable to actions usually regarded as aberrations from standard economic behavior as well as to behavior covered by the customary analysis. This wider applicability and the removal of the unrealistic postulates of accurate anticipations and fixed states of knowledge have provided motivation for the study.

The exposition is ordered as follows: First, to clear the ground, a brief statement is given of a generally ignored aspect of "profit maximization," that is, where foresight is uncertain, "profit maximization" is *meaningless* as a guide to specifiable action. The constructive development then begins with an introduction of the element of environmental adoption by the economic system of a posteriori most appropriate action according to the criterion of "realized positive profits." This is illustrated in an extreme, random-behavior model without any individual rationality, foresight, or motivation whatsoever. Even in this extreme type of model, it is shown that the economist can predict and explain events with a modified use of his conventional analytical tools.

This phenomenon—environmental adoption—is then fused with a type of individual motivated behavior based on the pervasiveness of uncertainty and incomplete information. Adaptive, imitative, and trial-and-error behavior in the pursuit of "positive profits" is utilized rather than its sharp contrast, the pursuit of "maximized profits." A final section discusses some implications and conjectures.

I. "PROFIT MAXIMIZATION" NOT A GUIDE TO ACTION

Current economic analysis of economic behavior relies heavily on decisions made by rational units customarily assumed to be seeking perfectly optimal situations.[2] Two criteria are well known—profit maximization and utility maximiza-

[1] I am indebted to Dr. Stephen Enke for criticism and stimulation leading to improvements in both content and exposition.

[2] See, e.g., J. Robinson, *Economics of Imperfect Competition* (London: Macmillan), p. 6, for a strong statement of the necessity of such optimal behavior. Standard textbooks expound essentially the same idea. See also P. Samuelson, *Foundations of Economic Analysis* (Cambridge: Harvard University Press, 1946).

tion.[3] According to these criteria, appropriate types of action are indicated by marginal or neighborhood inequalities which, if satisfied, yield an optimum. But the standard qualification usually added is that nobody is able really to optimize his situation according to these diagrams and concepts because of uncertainty about the position and, sometimes, even the slopes of the demand and supply functions. Nevertheless, the economist interprets and predicts the decisions of individuals in terms of these diagrams, since it is alleged that individuals use these concepts implicitly, if not explicitly.

Attacks on this methodology are widespread, but only one attack has been really damaging, that of G. Tintner.[4] He denies that profit maximization even makes any sense where there is uncertainty. Uncertainty arises from at least two sources: imperfect foresight and human inability to solve complex problems containing a host of variables even when an optimum is definable. Tintner's proof is simple. Under uncertainty, by definition, each action that may be chosen is identified with a *distribution* of potential outcomes, not with a unique outcome. Implicit in uncertainty is the consequence that these distributions of potential outcomes are overlapping.[5] It is worth emphasis that each possible action has a *distribution* of potential outcomes, only one of which will materialize if the action is taken, and that one outcome cannot be foreseen. Essentially, the task is converted into making a decision (selecting an action) whose potential outcome *distribution* is preferable, that is, choosing the action with the *optimum distribution*, since there is no such thing as a *maximizing* distribution.

For example, let each of two possible choices be characterized by its subjective distribution of potential outcomes. Suppose one has the higher "mean" but a larger spread, so that it might result in larger profits or losses, and the other has a smaller "mean" and a smaller spread. Which one is the maximum? This is a nonsensical question; but to ask for the optimum distribution is not nonsense. In the presence of uncertainty—a necessary condition for the existence of profits—there is no meaningful criterion for selecting the decision that will "maximize profits." The maximum-profit criterion is not meaningful as a basis *for selecting* the action which will, in fact, result in an outcome with higher profits than any other action would have, unless one assumes nonoverlapping potential outcome distributions. It must be noticed that the meaningfulness of "maximum profits—a realized outcome which is the largest that could have been realized from the available actions"—is perfectly consistent with the meaninglessness of "profit maximization"—a criterion for selecting among alternative lines of action, the potential outcomes of which are describable only as distributions and not as unique amounts.

This crucial difficulty would be avoided by using a preference function as a criterion for selecting most preferred distributions of potential outcomes, but the search for a criterion of rationality and choice in terms of pref-

[3] In the following we shall discuss only profit maximization, although everything said is applicable equally to utility maximization by consumers.

[4] "The Theory of Choice under Subjective Risk and Uncertainty," *Econometrica*, IX (1941), 298–304; "The Pure Theory of Production under Technological Risk and Uncertainty," *ibid.*, pp. 305–11; and "A Contribution to the Nonstatic Theory of Production," *Studies in Mathematical Economics and Econometrics* (Chicago: University of Chicago Press, 1942), pp. 92–109.

[5] Thus uncertainty is defined here to be the phenomenon that produces overlapping distributions of potential outcomes.

erence functions still continues. For example, the use of the mean, or expectation, completely begs the question of uncertainty by disregarding the variance of the distribution, while a "certainty equivalent" assumes the answer. The only way to make "profit maximization" a specifically meaningful action is to postulate a model containing certainty. Then the question of the predictive and explanatory reliability of the model must be faced.[6]

II. SUCCESS IS BASED ON RESULTS, NOT MOTIVATION

There is an alternative method which treats the decisions and criteria dictated by the economic *system* as more important than those made by the individuals in it. By backing away from the trees—the optimization calculus by individual units—we can better discern the forest of impersonal market forces.[7] This approach directs attention to the interrelationships of the environment and the prevailing types of economic behavior which appear through a process of economic natural selection. Yet it does not imply that individual foresight and action do not affect the nature of the existing state of affairs.

In an economic system the realization of profits is the criterion according to which successful and surviving firms are selected. This decision criterion is applied primarily by an impersonal market system in the United States and may be completely independent of the decision processes of individual units, of the variety of inconsistent motives and abilities, and even of the individual's awareness of the criterion. The reason is simple. Realized positive profits, not *maximum* profits, are the mark of success and viability. It does not matter through what process of reasoning or motivation such success was achieved. The fact of its accomplishment is sufficient. This is the criterion by which the economic system selects survivors: those who realize *positive profits* are the survivors; those who suffer losses disappear.

The pertinent requirement—positive profits through relative efficiency—is weaker than "maximized profits," with which, unfortunately, it has been confused. Positive profits accrue to those who are better than their actual competitors, even if the participants are ignorant, intelligent, skilful, etc. The crucial element is one's aggregate position relative to actual competitors, not some hypothetically perfect competitors. As in a race, the award goes to the relatively fastest, even if all the competitors loaf. Even in a world of stupid men there would still be profits. Also, the greater the uncertainties of the world, the greater is the possibility that profits would go to venturesome and lucky rather than to logical, careful, fact-gathering individuals.

The preceding interpretation suggests two ideas. First, success (survival) accompanies relative superiority; and, second, it does not require proper motivation but may rather be the result of fortuitous circumstances. Among all competitors, those whose particular conditions happen to be the most appropriate of those offered to the economic system for testing and adoption will be "se-

[6] Analytical models in all sciences postulate models abstracting from some realities in the belief that derived predictions will still be relevant. Simplifications are necessary, but continued attempts should be made to introduce more realistic assumptions into a workable model with an increase in generality and detail (see M. Friedman and L. Savage, "The Utility Analysis of Choices Involving Risks," *Journal of Political Economy*, LVI, No. 4 [1948], 279).

[7] In effect, we shall be reverting to a Marshallian type of analysis combined with the essentials of Darwinian evolutionary natural selection.

lected" as survivors. Just how such an approach can be used and how individuals happen to offer these appropriate forms for testing are problems to which we now turn.[8]

III. CHANCE OR LUCK IS ONE METHOD OF ACHIEVING SUCCESS

Sheer chance is a substantial element in determining the situation selected and also in determining its appropriateness or viability. A second element is the ability to adapt one's self by various methods to an appropriate situation. In order to indicate clearly the respective roles of luck and conscious adapting, the adaptive calculus will, for the moment, be completely removed. All individual rationality, motivation, and foresight will be temporarily abandoned in order to concentrate upon the ability of the environment to *adopt* "appropriate" survivors even in the absence of any adaptive behavior. This is an apparently unrealistic, but nevertheless very useful, expository approach in establishing the attenuation between the ex post survival criterion and the role of the individual's adaptive decision criterion. It also aids in assessing the role of luck and chance in the operation of our economic system.

Consider, first, the simplest type of biological evolution. Plants "grow" to the sunny side of buildings not because they "want to" in awareness of the fact that optimum or better conditions prevail there but rather because the leaves that happen to have more sunlight grow faster and their feeding systems become stronger. Similarly, animals with configurations and habits more appropriate for survival under prevailing conditions have an enhanced viability and will with higher probability be typical survivors. Less appropriately acting organisms of the same general class having lower probabilities of survival will find survival difficult. More common types, the survivors, may appear to be those having *adapted* themselves to the environment, whereas the truth may well be that the environment has *adopted* them. There may have been no motivated individual adapting but, instead, only environmental adopting.

A useful, but unreal, example in which individuals act without any foresight indicates the type of analysis available to the economist and also the ability of the system to "direct" resources despite individual ignorance. Assume that thousands of travelers set out from Chicago, selecting their roads completely at random and without foresight. Only our "economist" knows that on but one road are there any gasoline stations. He can state categorically that travelers will *continue* to travel only on that road; those on other roads will soon run out of gas. Even though each one selected his route at random, we might have called those travelers who were so fortunate as to have picked the right road wise, efficient, foresighted, etc. Of course, we would consider them the lucky ones. If gasoline supplies were now moved to a new road, some formerly luckless travelers again would be able to move; and a new pattern of travel would be observed, although none of the travelers had changed his particular path. The really possible paths have changed with the changing environment. All that is needed is a set of varied, risk-taking

[8] Also suggested is another way to divide the general problem discussed here. The process and rationale by which a unit chooses its actions so as to optimize its situation is one part of the problem. The other is the relationship between changes in the environment and the consequent observable results, i.e., the decision process of the economic *society*. The classification used in the text is closely related to this but differs in emphasizing the degree of knowledge and foresight.

(adoptable) travelers. The correct direction of travel will be established. As circumstances (economic environment) change, the analyst (economist) can select the types of participants (firms) that will now become successful; he may also be able to diagnose the conditions most conducive to a greater probability of survival.[9]

IV. CHANCE DOES NOT IMPLY NONDIRECTED, RANDOM ALLOCATION OF RESOURCES

These two examples do not constitute an attempt to base all analysis on adoptive models dominated by chance. But they do indicate that collective and individual random behavior does not per se imply a nihilistic theory incapable of yielding reliable predictions and explanations; nor does it imply a world lacking in order and apparent direction. It might, however, be argued that the facts of life deny even a substantial role to the element of chance and the associated adoption principle in the economic system. For example, the long lives and disparate sizes of business firms and hereditary fortunes may seem to be reliable evidence of consistent foresighted motivation and nonrandom behavior. In order to demonstrate that consistent success cannot be treated as prima facie evidence against pure luck, the following chance model of Borél, the famous French mathematician, is presented.

Suppose two million Parisians were paired off and set to tossing coins in a game of matching. Each pair plays until the winner on the first toss is again brought to equality with the other player. Assuming one toss per second for each eight-hour day, at the end of ten years there would still be, on the average, about a hundred-odd pairs; and if the players assign the game to their heirs, a dozen or so will still be playing at the end of a thousand years! The implications are obvious. Suppose that some business had been operating for one hundred years. Should one rule out luck and chance as the essence of the factors producing the long-term survival of the enterprise? No inference whatever can be drawn until the number of original participants is known; and even then one must know the size, risk, and frequency of each commitment. One can see from the Borél illustration the danger in concluding that there are too many firms with long lives in the real world to admit an important role to chance. On the contrary, one might insist that there are actually too few!

The chance postulate was directed to two problems. On the one hand, there is the actual way in which a substantial fraction of economic behavior and activity is effected. On the other, there is the method of analysis which economists may use in their predictions and diagnoses. Before modifying the extreme chance model by adding adaptive behavior, some connotations and implications of the incorporation of chance elements will be elaborated in order to reveal the richness which is really inherent in chance. First, even if each and every individual acted in a haphazard and nonmotivated manner, it is possible that the variety of actions would be so great that the resulting collective set would contain actions that are best, in the sense of perfect foresight. For example, at a horse race with enough bettors wagering strictly at random, someone will win

[9] The undiscerning person who sees survivors corresponding to changes in environment claims to have evidence for the "Lysenko" doctrine. In truth, all he may have is evidence for the doctrine that the environment, by competitive conditions, selects the most viable of the various phenotypic characteristics for perpetuation. Economists should beware of economic "Lysenkois m."

on all eight races. Thus individual random behavior does not eliminate the likelihood of observing "appropriate" decisions.[10]

Second, and conversely, individual behavior according to some foresight and motivation does not necessarily imply a collective pattern of behavior that is different from the collective variety of actions associated with a random selection of actions. Where there is uncertainty, people's judgments and opinions, even when based on the best available evidence, will differ; no one of them may be making his choice by tossing coins; yet the aggregate *set* of actions of the entire group of participants may be indistinguishable from a set of individual actions, each selected at random.[11]

Third, and fortunately, a chance-dominated model does not mean that an economist cannot predict or explain or diagnose. With a knowledge of the economy's realized requisites for survival and by a comparison of alternative conditions, he can state what types of firms or behavior relative to other possible types will be more viable, even though the firms themselves may not know the conditions or even try to achieve them by readjusting to the changed situation if they do know the conditions. It is sufficient if all firms are slightly different so that in the new environmental situation those who have their fixed internal conditions closer to the new, but unknown, optimum position now have a greater probability of survival and growth. They will grow relative to other firms and become the prevailing type, since survival conditions may push the observed characteristics of the set of survivors toward the unknowable optimum by either (1) repeated trials or (2) survival of more of those who happened to be near the optimum—determined ex post. If these new conditions last "very long," the dominant firms will be different ones from those which prevailed or would have prevailed under other conditions. Even if environmental conditions cannot be forecast, the economist can compare for given alternative potential situations the types of behavior that would have higher probability of viability or adoption. If explanation of past results rather than prediction is the task, the economist can diagnose the particular attributes which were critical in facilitating survival, even though individual participants were not aware of them.[12]

Fourth, the bases of prediction have been indicated in the preceding paragraph, but its character should be made explicit. The prediction will not assert that every—or, indeed, any—firm necessarily changes its characteristics. It asserts, instead, that the characteristics of the new *set* of firms, or possibly a set of new firms, will change. This may be

[10] The Borél gamblers analogue is pertinent to a host of everyday situations.

[11] Of course, the economic units may be going through a period of soul-searching, management training, and research activity. We cannot yet identify mental and physical activity with a process that results in sufficient information and foresight to yield uniquely determinate choices. To do so would be to beg the whole question.

[12] It is not even necessary to suppose that each firm acts as if it possessed the conventional diagrams and knew the analytical principles employed by economists in deriving optimum and equilibrium conditions. The atoms and electrons do not know the laws of nature; the physicist does not impart to each atom a wilful scheme of action based on laws of conservation of energy, etc. The fact that an economist deals with human beings who have sense and ambitions does not *automatically* warrant imparting to these humans the great degree of foresight and motivations which the economist may require for his customary analysis as an outside observer or "oracle." The similarity between this argument and Gibbsian statistical mechanics, as well as biological evolution, is *not* mere coincidence.

characterized by the "representative firm," a purely statistical concept—a vector of "averages," one dimension for each of the several qualities of the population of firms. A "representative firm" is not typical of any one producer but, instead, is a set of statistics summarizing the various "modal" characteristics of the population. Surely, this was an intended use of Marshall's "representative firm."

Fifth, a final implication drawn from consideration of this extreme approach is that empirical investigations via questionnaire methods, so far used, are incapable of evaluating the validity of marginal productivity analysis. This is true because productivity and demand analyses are essential in evaluating relative viability, even though uncertainty eliminates "profit maximization" and even if price and technological changes were to have no consciously redirecting effect on the firms. To illustrate, suppose that, in attempting to predict the effects of higher real wage rates, it is discovered that every businessman says he does not adjust his labor force. Nevertheless, firms with a lower labor-capital ratio will have relatively lower cost positions and, to that extent, a higher probability of survival. The force of competitive survival, by eliminating higher-cost firms, reveals a population of remaining firms with a new average labor-capital ratio. The essential point is that individual motivation and foresight, while sufficient, are not necessary. Of course, it is not argued here that therefore it is absent. All that is needed by economists is their own awareness of the survival conditions and criteria of the economic system and a group of participants who submit various combinations and organizations for the system's selection and adoption. Both these conditions are satisfied.[13]

As a consequence, only the method of use, rather than the usefulness, of economic tools and concepts is affected by the approach suggested here; in fact, they are made more powerful if they are not pretentiously assumed to be necessarily associated with, and dependent upon, individual foresight and adjustment. They are tools for, at least, the diagnosis of the operation of an economic system, even if not also for the internal business behavior of each firm.

V. INDIVIDUAL ADAPTING VIA IMITATION AND TRIAL AND ERROR

Let it again be noted that the preceding extreme model was designed to present in purest form only one element of the suggested approach. It is not argued that there is no purposive, foresighted behavior present in reality. In adding this realistic element—adaptation by individuals with some foresight and purposive motivation—we are expanding the preceding extreme model. We are not abandoning any part of it or futilely trying to merge it with the opposite extreme of perfect foresight and "profit maximization."

Varying and conflicting objectives motivate economic activity, yet we shall here direct attention to only one particular objective—the sufficient condition of realized positive profits. There are no implications of "profit maximization," and this difference is important. Although the latter is a far more extreme objective when definable, only the former is the sine qua non of survival and success. To argue that, with perfect competition, the two would come to the same thing is to conceal an important difference by means of a very implausible as-

[13] This approach reveals how the "facts" of Lester's dispute with Machlup can be handled with standard economic tools.

sumption. The pursuit of profits, and not some hypothetical undefinable perfect situation, is the relevant objective whose *fulfilment* is rewarded with survival. Unfortunately, even this proximate objective is too high. Neither perfect knowledge of the past nor complete awareness of the current state of the arts gives sufficient foresight to indicate profitable action. Even for this more restricted objective, the pervasive effects of uncertainty prevent the ascertainment of actions which are supposed to be optimal in achieving profits. Now the consequence of this is that modes of behavior replace optimum equilibrium conditions as guiding rules of action. Therefore, in the following sections two forms of conscious adaptive behavior are emphasized.

First, wherever successful enterprises are observed, the elements common to these observable successes will be associated with success and copied by others in their pursuit of profits or success. "Nothing succeeds like success." Thus the urge for "rough-and-ready" imitative rules of behavior is accounted for. What would otherwise appear to be merely customary "orthodox," nonrational rules of behavior turns out to be codified imitations of observed success, e.g., "conventional" markup, price "followship," "orthodox" accounting and operating ratios, "proper" advertising policy, etc. A conventionally employed type of behavior pattern is consistent with the postulates of the analysis employed, even though the reasons and justifications for the particular conventions are not.[14]

Many factors cause this motive to imitate patterns of action observable in past successes. Among these are: (1) the absence of an identifiable criterion for decision-making, (2) the variability of the environment, (3) the multiplicity of factors that call for attention and choice, (4) the uncertainty attaching to all these factors and outcomes, (5) the awareness that superiority relative to one's competitors is crucial, and (6) the nonavailability of a trial-and-error process converging to an optimum position.

In addition, imitation affords relief from the necessity of really making decisions and conscious innovations, which, if wrong, become "inexcusable." Unfortunately, failure or success often reflects the willingness to depart from rules when conditions have changed; what counts, then, is not only imitative behavior but the willingness to abandon it at the "right" time and circumstances. Those who are different and successful "become" innovators, while those who fail "become" reckless violators of tried-and-true rules. Although one may deny the absolute appropriateness of such rules, one cannot doubt the existence of a strong urge to create conventions and rules (based on observed success) and a willingness to use them for action as well as for rationalizations of inaction. If another untried host of actions might have been even more successful, so much the worse for the participants who failed, and even for those who missed "perfect success."

Even innovation is accounted for by imitation. While there certainly are those who consciously innovate, there are those who, in their imperfect attempts

[14] These constructed rules of behavior should be distinguished from "rules" which, in effect, do no more than define the objective being sought. Confusion between objectives which motivate one and rules of behavior are commonplace. For example, "full-cost pricing" is a "rule" that one cannot really follow. He can try to, but whether he succeeds or fails in his objective of survival is not controllable by following the "rule of full-cost pricing." If he fails in his objective, he must, of necessity, fail to have followed the "rule." The situation is parallel to trying to control the speed of a car by simply setting by hand the indicator on the speedometer.

to imitate others, unconsciously innovate by unwittingly acquiring some unexpected or unsought unique attributes which under the prevailing circumstances prove partly responsible for the success. Others, in turn, will attempt to copy the uniqueness, and the imitation-innovation process continues. Innovation is assured, and the notable aspects of it here are the possibility of unconscious pioneering and leadership.

The second type of conscious adaptive behavior, in addition to imitation, is "trial and error." This has been used with "profit maximization," wherein, by trial and ensuing success or failure, more appropriate actions are selected in a process presumed to converge to a limit of "profit maximization" equilibrium. Unfortunately, at least two conditions are necessary for convergence via a trial-and-error process, even if one admits an equilibrium situation as an admissible limit. First, a trial must be classifiable as a success or failure. The position achieved must be comparable with results of other potential actions. In a static environment, if one improves his position relative to his former position, then the action taken is better than the former one, and presumably one could continue by small increments to advance to a local optimum. An analogy is pertinent. A nearsighted grasshopper on a mound of rocks can crawl to the top of a particular rock. But there is no assurance that he can also get to the top of the mound, for he might have to descend for a while or hop to new rocks. The second condition, then, for the convergence via trial and error is the continual rising toward some *optimum optimorum* without intervening descents. Whether decisions and actions in economic life satisfy these two conditions cannot be proved or disproved here, but the available evidence seems overwhelmingly unfavorable.

The above convergence conditions do not apply to a changing environment, for there can be no observable comparison of the result of an action with any other. Comparability of resulting situations is destroyed by the changing environment. As a consequence, the measure of goodness of actions in anything except a tolerable-intolerable sense is lost, and the possibility of an individual's converging to the optimum activity via a trial-and-error process disappears. Trial and error becomes survival or death. It cannot serve as a basis of the *individual's* method of convergence to a "maximum" or optimum position. Success is discovered by the economic system through a blanketing shotgun process, not by the individual through a converging search.

In general, uncertainty provides an excellent reason for imitation of observed success. Likewise, it accounts for observed uniformity among the survivors, derived from an evolutionary, adopting, competitive system employing a criterion of survival, which can operate independently of individual motivations. Adapting behavior via imitation and venturesome innovation enlarges the model. Imperfect imitators provide opportunity for innovation, and the survival criterion of the economy determines the successful, possibly because imperfect, imitators. Innovation is provided also by conscious wilful action, whatever the ultimate motivation may be, since drastic action is motivated by the hope of great success as well as by the desire to avoid impending failure.

All the preceding arguments leave the individual economic participant with imitative, venturesome, innovative, trial-and-error adaptive behavior. Most conventional economic tools and concepts

are still useful, although in a vastly different analytical framework—one which is closely akin to the theory of biological evolution. The economic counterparts of genetic heredity, mutations, and natural selection are imitation, innovation, and positive profits.

VI. CONCLUSIONS AND SUMMARY

I shall conclude with a brief reference to some implications and conjectures.

Observable patterns of behavior and organization are predictable in terms of their relative probabilities of success or viability *if* they are tried. The observed prevalence of a type of behavior depends upon both this probability of viability and the probability of the different types being submitted to the economic system for testing and selecting. One is the probability of appearance of a certain type of organization (mutation), and the other is the probability of its survival or viability, once it appears (natural selection). There is much evidence for believing that these two probabilities are interrelated. But is there reason to suppose that a high probability of viability implies a high probability of an action's being taken, as would be implied in a system of analysis involving some "inner directed urge toward perfection"? If these two probabilities are not highly correlated, what predictions of types of action can the economist make? An answer has been suggested in this paper.

While it is true that the economist can define a profit maximization behavior by assuming *specific* cost and revenue conditions, is there any assurance that the conditions and conclusions so derivable are not too perfect and absolute? If profit maximization (certainty) is not ascertainable, the confidence about the predicted effects of changes, e.g., higher taxes or minimum wages, will be dependent upon how close the formerly existing arrangement was to the formerly "optimal" (certainty) situation. What really counts is the various actions actually tried, for it is from these that "success" is selected, not from some set of perfect actions. The economist may be pushing his luck too far in arguing that actions in response to changes in environment and changes in satisfaction with the existing state of affairs will converge as a result of adaptation or adoption toward the optimum action that should have been selected, if foresight had been perfect.[15]

In summary, I have asserted that the economist, using the present analytical tools developed in the analysis of the firm under certainty, can predict the more adoptable or viable types of economic interrelationships that will be induced by environmental change even if individuals themselves are unable to ascertain them. That is, although individual participants may not know their cost and revenue situations, the economist can predict the consequences of higher wage rates, taxes, government policy, etc. Like the biologist, the economist predicts the effects of

[15] An anomalous aspect of the assumption of perfect foresight is that it nearly results in tautological and empty statements. One cannot know everything, and this is recognized by the addendum that one acts within a "given state and distribution of the arts." But this is perilously close, if not equivalent, to saying either that action is taken only where the outcome is accurately foreseen or that information is always limited. The qualification is inserted because one might contend that it is the "*constancy* of the state and distribution of arts" that is necessary as a *ceteris paribus*. But even the latter is no solution. A large fraction of behavior in a world of incomplete information and uncertainty is necessarily directed at increasing the state of arts and venturing into an unknown sphere. While it is probably permissible to start with a prescribed "distribution of the knowledge of the arts," holding it constant is too restrictive, since a large class of important and frequent actions necessarily involves changes in the state and distribution of knowledge. The modification suggested here incorporates this search for more knowledge as an essential foundation.

environmental changes on the surviving class of living organisms; the economist need not assume that each participant is aware of, or acts according to, his cost and demand situation. These are concepts for the economist's use and not necessarily for the individual participant's, who may have other analytic or customary devices which, while of interest to the economist, serve as data and not as analytic methods.

An alternative to the rationale of individual profit maximization has been presented without exorcising uncertainty. Lest isolated arguments be misinterpreted, let it be clearly stated that this paper does not argue that purposive objective-seeking behavior is absent from reality, nor, on the other hand, does it indorse the familiar thesis that action of economic units cannot be expressed within the marginal analysis. Rather, the contention is that the precise role and nature of purposive behavior in the presence of uncertainty and incomplete information have not been clearly understood or analyzed.

It is straightforward, if not heuristic, to start with complete uncertainty and nonmotivation and then to add elements of foresight and motivation in the process of building an analytical model. The opposite approach, which starts with certainty and unique motivation, must abandon its basic principles as soon as uncertainty and mixed motivations are recognized.[16] The approach suggested here is intellectually more modest and realistic, without sacrificing generality. It does not regard uncertainty as an aberrational exogenous disturbance, as does the usual approach from the opposite extreme of accurate foresight. The existence of uncertainty and incomplete information is the foundation of the suggested type of analysis; the importance of the concept of a class of "chance" decisions rests upon it; it permits of various conflicting objectives; it motivates and rationalizes a type of adaptive imitative behavior; yet it does not destroy the basis of prediction, explanation, or diagnosis. It does not base its aggregate description on individual optimal action; yet it is capable of incorporating such activity where justified. The formalization of this approach awaits the marriage of the theory of stochastic processes and economics—two fields of thought admirably suited for union. It is conjectured that the suggested modification is applicable to a wide class of events and is worth attempts at empirical verification.[17]

[16] If one prefers, he may believe that the suggestions here contain reasons why the model based on certainty may predict outcomes, although individuals really cannot try to maximize profits. But the dangers of this have been indicated.

[17] Preliminary study in this direction has been very convincing, and, in addition, the suggested approach appears to contain important implications relative to general economic policy; but discussions of these are reserved for a later date.