EVOLUTIONARY CONCEPTS IN ECONOMICS

Ulrich Witt
Institute for Study of Economic Evolution
University of Freiburg, Germany

INTRODUCTION

Decade after decade, production, markets, and institutions in the economy are shaken up by incessant innovativeness and restructuring. Economic doctrine, by contrast, is oriented towards market equilibrium and optimally adjusted agents. Doubts as to whether such an orientation can do justice to the historical record seem to motivate the recent growing interest in evolutionary concepts in economics. The evolutionary approach—focusing on becoming rather than being in the economy—does indeed try to offer an alternative, and the number of relevant contributions is rapidly growing. There is the Schumpeterian tradition [Schumpeter, 1934; Winter, 1971; Nelson and Winter, 1982; Day, 1984; Dii, Freeman, Nelson, Silverberg, and Sutro, eds., 1985] which focuses predominantly on technical progress, innovation, industrial development, and market structure, business cycles, and growth in long waves. There are contributions from the Austrian and subjectivist camp [Hayek, 1978; Leachmann, 1986; Losby, 1991] which emphasize the role of subjective knowledge, ignorance, and the market process as guided by discovery activities and contributions by Institutionalsists [Dierolf, 1986; Gordon and Adams, 1989; Hodgson, 1992]. Furthermore, there is work which relies on analogies with the neo-Darwinian theory of evolution in biology [Haldane, 1981; Hirschleifer, 1982; Faber and Foersters, 1990; Metcalfe and Sorgiota, 1991]. Most recently, formal notions derived from the theory of non-linear dynamics, synergy, and the concept of self-organization have inspired a new class of works [Blatten, Casti, and Johansson, eds., 1987; Arthur, 1988; Weidlich and Braun, 1992].

The variance of scope, method, and background in these contributions is obvious. Nonetheless, all of them share a common interest in, and a particular interpretation of, historical economic change. Change, to a large extent, is considered as an endogenously generated phenomenon, i.e., something coming from within the economy. The present paper sets out to develop the underlying concepts in a more systematic fashion and aims at showing that a coherent research program is gaining shape in evolutionary economics. To start with, focus is put on novelty which here is given a key role in understanding evolution. Some epistemological problems are outlined and the question of how to explain what motivates the creation of novelty is briefly addressed. When it comes to the translation of novelty into innovative activities, population thinking, a significant attitude of the evolutionary approach, becomes relevant and is discussed. Change in population features is explained on the basis of two important concepts in evolutionary theorizing, frequency-dependency and selection effects. As is demonstrated, these two effects are examples of a very general phenomenon called replicator dynamics. Focus then shifts to some reinterpretations which an evolutionary perspective might suggest with respect to classical notions of competition and progress. The last section offers some tentative conclusions.
ENGLISH ECONOMIC CHANGE AND THE ROLE OF NOVELTY

For the present purpose, evolution can be defined as the self-transformation of an observed system over time. According to the theory of natural selection, evolution is a process of adaptation to the environment, and the outcome of this process is a system that is better suited to the environment than the original system. Evolution is thus a process of change, and the study of evolution is the study of change.

The concept of novelty is central to the study of evolution. Novelty refers to the introduction of new ideas, practices, or technologies that are different from those that were previously used. The introduction of novelty can be thought of as a process of innovation, and it is the process by which new ideas, practices, or technologies are introduced into a system.

The study of novelty is important because it allows us to understand how systems change over time. The study of novelty also allows us to understand how systems are able to adapt to changing environments. The introduction of novelty is a process that is central to the study of evolution, and it is a process that is important for understanding how systems change over time.

The study of novelty is also important for understanding how systems are able to adapt to changing environments. The introduction of novelty is a process that is central to the study of evolution, and it is a process that is important for understanding how systems are able to adapt to changing environments. The introduction of novelty is a process that is central to the study of evolution, and it is a process that is important for understanding how systems are able to adapt to changing environments.
However, this argument does not seem to get to the core of the problem as it might be taken account for, in a more sophisticated optimization model, by adding further constraints.

What actually impedes standard rational choice analysis in investigating how novelty changes the economy — but not only in this domain — is an old, but never satisfactorily settled, question: the subjectivism problem. The subjective nature of individual preferences is a generally accepted tenet in economics. Yet, the problem of how subjective imaginations determine the individual's assessment of feasible action, and what imaginations these are, has been overcome by the fiction of perfect information, i.e., the assertion that everybody, including the scientific observer, has the same knowledge. This fiction, at least in the domain of emerging novelty, is untenable. As the subjectivist school (Shackle, 1973; Lashley, 1976) has always claimed, imagination and action knowledge are highly subjective. New notions emerge within, and are assessed against, the individual's specific experience and interpretation, and these vary greatly between people. Indeed, the endemic generation of new ideas even tends to increase the variety of perceptions. Thus, where regularities in the translation of novelty into innovative activities are being searched for, individualistic rational choice analysis encounters only a large number of subjective idiosyncrasies which are difficult, if not impossible, to objectify.

This insight may justify some of the reservations in evolutionary economics with respect to rational choice models, and it motivates the shift to 'population thinking' (Sobel, 1984, Ch. 5.3; Hirschleifer, 1962; Metcalfe, 1989) which characterizes the alternative route an evolutionary approach offers. Population thinking puts individual choices in perspective with the variety of behavior chosen in an appropriately defined group or population. As viewed from the level of the population, the decision making of all individuals, whether innovative, imitative, or conservative, affects the relative frequencies of behavior present in the population. Whatever the idiosyncratic differences in subjective preferences, perceptions, and interpretations, there may be some generic features which cause systematic changes of the frequency distribution of behavior.

One example that can be mentioned here is the influence of generic elements in individuals' decision making as culturally informed interpretation patterns (Schlicht, 1990), prevailing world views and paradigms — in short, all those objects diffusion and social learning (imitation) research deals with empirically (Witt, 1985a). Still more evidently, a systematic effect arises whenever the decisions made by diverse individuals depend on what the others do. This interdependency creates a kind of correlated individual adjustment or conformity which is labeled, in what follows, the frequency-dependency effect. Another systematic influence is exerted by the selection effect. Selection pressure that limits the influence of idiosyncratic factors may come from outside the population or, as an unintended outcome of intra-group interactions, may be established through mutually imposed constraints.

Selection arguments have a tradition in evolutionary economics where, by analogy to the theory of natural selection, the firms' competencies in a competitive market or industry have been related to differential growth and/or survival (Aleshin, 1950; Winter, 1964; Matthews, 1984). Firms which behave relatively poorly internally and are in the market place are supposed to be driven out of the market by those firms in the population whose behavior allows them to prosper and grow, provided competition — or selection pressure — is fierce enough. The analogy with biology, despite its being only a rough one, allows some contingencies implied by the selection effect argument to be grasped immediately. These contingencies, in particular, are: advantages/disadvantages on which selection pressure operates are relative to the current composition of the population; the adaptive optima which can be reached by the entire population in the selection process are only local; and there is a possibility of coexistence of mutually dependent variants in selection equilibrium — so called polymorphisms (Haillagan and Jøsling, 1983, with economic examples).

**RepliCator Dynamics**

The frequency-dependency effect mentioned in the previous section expresses the fact that an individual makes her decision in a way that in some respect depends on how many other members of the population already have made a particular choice. For expository convenience assume the simplest, bivariate case: choices between alternative a and alternative b (where the latter amounts to not choosing a). Furthermore, let the individuals in the population make their decisions one after another. This is typically the case in the dissemination of novelty where the alternatives are adopting an innovation or not adopting it. The decision of one individual in a series then can be expressed as the marginal change in the relative frequency of a-choices in the population. Given frequency-dependency, this marginal change in the relative frequencies of behavior itself depends on the frequencies already achieved. The phenomenon is well-known in biology, but also has gained increasing attention in various fields of economics. Its various appearances all follow the same patterns of what has been called "repliCator dynamics" (Schuster and Sigmund, 1983).

Assume, for an individual in the population making a choice at time t, that the perceived advantage of choosing a over b depends on F(t), the relative frequency with which a already has been chosen in the population up to time t, and on the influence of the diverse idiosyncratic subjective factors. To simplify the exposition, let the influence of the subjective factors be represented by random variation with expectation zero. Assume further that the dependency with respect to F is the same for all individuals in the population. Focusing on the deterministic part (i.e., omitting the random influence), the advantage is a function of F(t) alone. It seems reasonable, now, to assume that an individual is more likely to decide for a, the greater is the perceived advantage of doing so. Therefore, the probability f(t) that a rather than b is chosen at time t can be supposed to vary monotonously with the advantage (subject to the constraint 0 ≤ f(t) ≤ 1) and f(t) = 0 for a negative advantage. This leads to the function

\[ f(t) = \phi(F(t)) \]

an evident expression of the frequency-dependency effect.

Consider the graphs of \( \phi \) for two alternative specifications in Figures 1 and 2. In the case of Figure 1, the advantage of choosing a dwindles as the advantage becomes more common. This seems to be a frequent pattern in markets where being among the early innovators is rewarded, for example, because competitive pressure on the supply side increases as \( F \) increases. As viewed from the population level, the particular behavior, or innovations or replicators over time until a relative frequency, indicated by an asterisk, is reached where the likelihood of a being chosen in t equals the relative frequency of a in the population at time t (hence the locus of such points on the 45°-line in Figure 1) so that, in the mean, \( F(t) \) is exactly stabilized.
A different situation emerges if the advantage of choosing $\alpha$ increases in a non-linear fashion as in Figure 2. Such a case may arise, for example, if two competing novelties diffuse simultaneously and positive externalities are present which increase with the number of adopters of either of the alternatives $\alpha$ or $\beta$. In Figure 2 the process is assumed to start with $f(0) = F^* = 0.5$. However, the adoption probability rises above the mean $F^*$ to the right of $F^*$ so that the process is attracted to $F^{**} = 1$ once a tendency in that direction has developed, and vice versa to the left of $F^*$. Hence, $F^*$ is an unstable fixed point. Even though the historical path may initially be equally well attracted to $F^*$ as to $F^{**}$, it is likely to be “locked in” once, due to random fluctuations in the realization of the adoption process, a bias in one or other direction has emerged.

The bifurcation in Figure 2 with two locally stable attractors $F^* = 0$ and $F^{**} = 1$ is the simplest possible example of a feature which is crucial for understanding evolution — the fact that there are multiple equilibria to which the historical process can be attracted alternatively. This idea clearly contrasts with most of the theorizing in economics which focuses on unique equilibria (and often imposes strong assumptions in order to assure their existence). Yet, the future of the system only becomes what is essential for evolution — an open or indeterminate development, though not one that is arbitrary or inexplicable, if the trajectory of a system is not uniquely determined as converging to a globally stable equilibrium.

In the form in which the frequency-dependency effect has been expressed in equation (1), time is not made explicit although the effect materializes in a process over time. Focusing on this process, which describes the dissemination (or replication) of alternative $\alpha$ in the population under consideration, $f_\alpha$ can be interpreted as the probability that one more individual in the population chooses $\alpha$ during a marginal increment of time. Accordingly, the difference between $f_\alpha$ and $F_\alpha$ gives the change of the relative frequency at the margin. When taking the limit the frequency-dependency effect thus can be expressed by the differential equation

$$\frac{df_\alpha}{dt} = \phi(f_\alpha - F_\alpha)$$

with $\phi$ a sign-preserving function and $\phi(0) = 0$.

For simplicity, let $\phi$ be a one-to-one mapping and assume $F_\alpha > 0$. Divide both sides of equation (2) by $F_\alpha$ so that the rate of change $\omega_\alpha$ of the relative frequency of alternative in the population results as

$$\omega_\alpha = \frac{df_\alpha}{F_\alpha dt} = \phi(f_\alpha - F_\alpha)$$

Here $\omega_\alpha = f_\alpha / F_\alpha > 0$ is a measure of the advantage of the alternative $\alpha$. Defining the measure for the alternative $\beta$ analogously, the average (weighted) advantage of all alternatives adds to 1. Hence, the rate of change in the relative frequency of one alternative follows from equation (3) as the difference between the individual alternative’s advantage and the average population advantage. This is precisely the concept of “replicator dynamics” which has been shown by Schuster and Sigmund (1983) to be the basic pattern underlying many evolution phenomena.

Indeed, the selection effect mentioned in the previous section is simply another example of replicator dynamics. The various forms of economic behavior which are continually being created through innovative activities clash in the markets, or the political arena, and compete with each other. Because not all of them are able to succeed, the process of competition well can be imagined to work as a selection device which continually works to eliminate variants and, thus, to reduce the variety of economic
behavior in the population. Whether, and to what extent, the elimination of variants is a matter of individual learning and anticipatory adjustment may be left open. What matters is that elimination will be enforced, in one way or other. If a definite selection criterion can be identified, it should be possible, therefore, to explain the changes in the frequency distribution of behavior without recourse to the intangible subjective background of all the activities of the individuals involved.

A simple example, which is due to Metcalfe (1989), may illustrate the basic idea. Suppose there are n firms, indexed i = 1, ..., n, in a homogeneous, competitive market at time t. Accounting for innovativeness here by differences in the firms’ distance from the best practice technology, assume firms have different, but constant, unit costs c. Denote the industry’s average unit cost of production by c(t). Output is chosen such that firm i has a market share s_i(t), Σ s_i(t) = 1, or, to state it differently, the relative frequency of technology i in the industry is s_i. Let the current aggregate market supply be sold under competitive conditions at the demand price p(t) = c(t) determined according to an invariant market demand function with the usual properties. The difference p - c is the profits per unit produced. Because of the different unit costs, all firms active in the market also have different profits. For convenience assume that costs cannot be manipulated by the firms (in the short run). If selection pressure is a significant feature at all, losses cannot be eternal in infinitum.

Under the chosen assumptions, selection pressure therefore can be assumed to translate profit differentials into adjustments of the firms’ output, that is, of s_i. If a firm’s market share contracts (expands) faster, the firm’s absolute loss (profit) at a given aggregate supply at time t is higher. This can be expressed in the form of the differential equation

$$\frac{ds_i}{dt} = s_i(c(t) - c).$$

Now divide both sides of equation (4) by s_i. The rate of change of the market share of firm i, the relative frequency of the respective technology in the industry, then follows as the difference between the individual firm’s cost performance and the industry’s average cost performance — the basic logic of the replicator dynamics. In effect, the assumptions now imply a uniquely determined time path which leads to the conventional perfect competition solution. Because further innovativeness (changes in the firms’ costs) exist, the selection effect drives all firms but the lowest cost producer out of the market.

**ECONOMIC EVOLUTION AND THE MARKETS**

The idea that selection pressure, interpreted in a broader understanding as the general impact of competition, exerts a systematic influence on the economy is certainly not new. However, as a convening theoretical representation of the competitive process in what was designated as a static theory is lacking, the notion seems to have lost out in economic theory against the much better developed concepts of optimization and equilibrium. The attempt directly to model the selection effect and its dynamics on the micro level is therefore one thing; it is another to reassert, within the evolutionary approach, classical notions of competition and the coordinating power of the markets. As a point of departure for such a reappraisal, the effect which innovation exerts on the economy can be chosen in the perspective taken here it creates the variety on which selection pressure operates. In several diffusion models it could be shown that profit differentials, productivity differentials, and growth differentials are generated and sustained on the industry level as well as on the aggregate level as long as innovations are continually infused [Tera, 1984; Silverberg, 1987; Euphmann, 1992]. Empirical evidence seems to confirm the existence of such differentials [Mueller, 1990].

The observation supports the view that variety increases, ceteris paribus, with the innovation rate and decreases with selection pressure, where variety is measured by the mentioned differentials. This implies that profit differentials, or the variance of the profit distribution in an economy, should be positively correlated with the intensity of innovative activities. Put differently, a tendency for profit differentials to diminish in an economy should indicate waning innovativeness [Holmstädter, 1996]. Since innovations can be considered the major sources of productivity increases, such a tendency would have detrimental effects on future aggregate growth and employment. Causes of waning innovativeness can be several. They can be interpreted as discretionary, historical events conditioned by political or economic circumstances. This would give economic policy room for taking counter measures.

Alternatively, waning innovativeness may be considered a cyclical phenomenon. This has been claimed in the recently revived debate on long waves (Kontrastifizcylcles) with reference to long-term cycles in the occurrence of basic innovations [Manahal, 1978; Freeman, Clark, and Soete, 1982]. Empirical evidence seems to provide impressive support for the thesis [Kleinmich, 1987]. An attempt to explain the long-term cycles in basic innovations can be made on the basis of the search motivation hypothesis discussed above. There, a relationship has been established between the current state of the aspiration level and the inclination to search for novelty. In this light, waning innovativeness can be a consequence of variety created by earlier basic innovations. Since those innovations allow good profits to be made over extended periods by many firms, aspiration levels are satisfied. Search and experimentation slacken. However, as the inflow of basic innovations is reduced, the selection effect gradually gains in importance. The erosion of variety and thus profits increasingly threatens the aspiration levels of growing numbers of agents. Search for, and experimenting with, basic innovations is triggered increasingly often so that the rate of basic innovations eventually rises again enabling another cycle to start.

In the perspective of evolutionary economics, the coordinating power of a system of markets has to be seen against the background of the interplay of innovativeness and selection pressure. Compared to the general equilibrium approach with its strong assumptions about the information available to the agents, an evolutionary interpretation has to start from entirely different premises. In an economic environment where variety increasing and eroding activities continuously transform what is observable in the markets, agents cannot be perfectly informed about all conditions relevant to their decision making. What they do know is that an ultimate budget constraint exists and is the cause of all opportunity costs. Furthermore, the agents are likely to know that there is a limit to manipulating their budget constraints through exchange over time: all prices have an upper bound, where demand is zero, and a lower bound, where the own costs of making an offer can no longer be covered. A living has to be made from exchanges at prices between the upper and the lower bound. Hence, economic viability bounds exist for all agents. Agents who do not manage to keep within these bounds over time do not survive economically. Losses and overdrawing of budgets alert the agents of the need to adjust their expenses and their price and supply behavior appropriately.
Since all the constraints are imposed mutually, the threat of being driven out of the market thus may induce mutual coordination efforts. Only in the hypothetical case where no innovative activities occur, does selection pressure have the time to erode variety so that the upper and lower price bound eventually would collapse into unique, zero-profit, competitive prices in all markets. Then, and only then, the state of perfect coordination, on which general equilibrium theory focusses so exclusively, would be reached. However, there are systematic incentives to search for novelty and try out innovations. As just argued, dwindling profits are likely to trigger search for novelty and innovative activities with a de-coordinating effect. Innovations tend to expand the innovators' viability bounds while contracting those of the innovators' competitors. Variety eroding and generating activities thus resurface here as coordinating and de-coordinating tendencies in the markets, and the dynamic balance between them produces a "viable coordination" (Witt, 1983). This means that agents by and large manage to keep within the viability bounds.

For the understanding of the coordination function of the markets, it is not necessary, and, in fact, not possible to know or reconstruct all the individual dispositions and subjective views. This may be left safely to "competition as a discovery procedure" (Hayek, 1975). Production, trading, division of labor do take place, but the individual plans and imaginings are not perfectly compatible with one another. There are surprises, miscalculations, backlashes, and losses that hurt but do not necessarily destroy the agents' economic existence. Indeed, overall efficiency losses are constrained because of the sanction of bankruptcy. Compared to the fictitious state of perfect coordination in general equilibrium theory, the allocation resulting from viable coordination is only vaguely theoretically determined. Nevertheless, because of the existence of mutually imposed constraints on individual behavior, viable coordination implies a considerable degree of order. Its vague allocative implications not withstanding, this interpretation reproduces the classes' view of the markets as a self-regulating system. There is a notable parallel even in the 'vagueness' with respect to the allocative implications [cf. Adam Smith, 1979, Book I, Ch.7]. General equilibrium theory has increased precision substantially but, as it appears, only by moving from fact to fiction.

LONG-RUN PERSPECTIVES

The question of where the incessant interplay of innovativeness and selection pressure leads in the long run has found little attention in economics although it seems comparable, in its weightiness and depth, to the core problems of classical moral and social philosophy. Indeed, probably the most daring attempt to address the question, the theory of societal evolution developed by Hayek (1986), draws on classical thinking and tries to blend it with ideas that come close to a form of Social Darwinism. In a nutshell, Hayek argues that societal evolution is the outcome of an unplanned, cultural process of collective transmission and replication of "learned rules of conduct" in society. Those groups which succeed in developing and passing on rules better suited to governing their social interactions are supposed to grow and feed a larger number of people. Their relative superiority may enable such groups to conquer and/or absorb less well-equipped competing groups and thus extinguish their rules. A growing population requires specialization and division of labor which, in turn, presuppose that the spontaneous order that governs impersonal interactions is increasingly extended. The rules become ever more differentiated, abstract, and difficult to under-
EASTERN ECONOMIC JOURNAL

and economic growth in terms of two crucially interacting factors: knowledge and energy [Boulding, 1961, Ch. 1; Weissmahr, 1992]. However, the work on conceptualizing these categories in an evolutionary theory of production, growth, and environment is only just beginning.

CONCLUSIONS

An attempt has been made here to outline some basic concepts of an evolutionary approach to economics. This approach focuses on economic and social change, on the emergence of novel ways of running the economy, on becoming rather than being. Particular emphasis is put on those changes which originate from the various activities of the agents whose behavior economic theory is concerned with—hence the notion of endogenous change. It has been shown how hypotheses on the respective, innovative, activities which account for the epistemological problems implied by novelty can be developed. Considerations relating to these problems suggest, it has been argued, that attention be paid to population thinking, a typical attitude of theories dealing with evolution. Two generic features resulting from such a perspective, frequency-dependency and selection effect, have been explored together with their common ground in the notion of regulatory dynamics. Finally, the relevance of these ideas for reappraising, within an evolutionary approach, the classical notions of competition, the coordinating power of markets, and the long-run tendencies in the economy have been discussed.

NOTES

The author is grateful to John Livingstone, Glen Metcalfe, Joseph A. Weissmahr for helpful discussions.

1. A striking example is the recent literature on industrial "innovation" (Baumol, 1986). Search for novelty is interpreted here as a problem of optimal investment in productive R&D activities: All competitors are assumed to search for the same "innovation" which they must be closely interchangeable in their meaning and implications. From the profits that will accrue from it are assumed to be appreciable.

2. The assumption of the distinction between "innovative" and "innovation" crucial, assuming that, due to the scarcity of entrepreneurial skills, innovations are much more than inventions.

3. As rightly pointed out by Lachmann [1986], if the task is to explore a specific historical individual's choice observed at a certain time, the subjunctive problem allows hardly more than inference as interpreted as in Mises's methodology of services. An excellent criticism of a naive rational-choice foundation of economics can be found in Mises [1966].

4. Among them are the theory of consumer behavior (Stone, 1965), with E. A. Leamer's discussion of the "prisoner's dilemma" (1976). The theory of innovation (Klamer, 1986), product life-cycle models (Mason and Wind, 1976), and technology diffusion models (Metcalfe, 1986). Likewise, the effect is at the core of the recent work on market-organization, learning-by-using, technological "lock in" (Arthur, 1980; Kline, 1988). David, 1985, see below. An apparent pattern, but derived within the framework of evolutionary game theory, in work focusing on the emergence of institutions (Schelling, 1982; Alchian, 1980; Wind, 1986). For further examples see Schelling [1978]. Veljan [1986] had already taken note of the effect and made a major argument of it without, of course, labeling it that way.

5. Note that in the iterative case $F_1 = F_2 = 0$ and $F_3 = F_4 = 1$.

REFERENCES


