# EVOLUTIONARY CONCEPTS IN ECONOMICS

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## 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 — focussing 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; Dosi, Freeman, Nelson, Silverberg, and Soete, eds., 1988] which focusses 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; Lachmann, 1986; Loasby, 1991] which emphasize the role of subjective knowledge, ignorance, and the market process as guided by discovery activities and contributions by Institutionalists [Dopfer, 1986; Gordon and Adams, 1989; Hodgson, 1992]. Furthermore, there is work which relies on analogies with the neo-Darwinian theory of evolution in biology [Boulding, 1981; Hirshleifer, 1982; Faber and Proops, 1990; Metcalfe and Saviotti, 1991]. Most recently, formal notions derived from the theory of non-linear dynamics, synergetics, and the concept of self-organization have inspired a new class of works [Batten, 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.

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## ENDOGENOUS 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. Accordingly, economic evolution must be related to the capacity of an economy, or some part of it, to generate change from within. Mere adaptation to exogenously changed data (as change is usually interpreted in economic theory) is not everything. How is endogenous change produced? A sufficient condition — and, it is submitted here, a generic feature of evolution — is the creation of novelty within the system under concern which, after emerging, may disseminate [Witt, 1993]. In the domain of economics, and in accordance with its action orientation, novelty is the outcome of human creativity and of the discovery of new possibilities for action. If the newly discovered possibility of acting is taken up, this action is called an innovation.

Unfortunately, novelty is an amorphous concept. By its very nature nobody can positively anticipate its meaning and implications. Their revelation must be awaited. Evolutionary theory is therefore seriously constrained in its ability to make predictions. It only seems possible to exclude certain outcomes from occurring whatever kind of novelty may emerge [Hayek, 1964]. But, since the number of still possible outcomes is unbounded, substantive predictions as to what future novelty will reveal thus cannot be derived. This trivial, but epistemologically momentous "bound of unknowledge" [Shackle, 1983], which constrains what may be called pre-revelation analysis, is violated often so that paradoxical results follow.[1] Once novelty is there, and assuming that its meaning and implications of novelty have been revealed fully at least to the scientific observer,[2] the dissemination of novelty may be investigated without further methodological hurdles. This is the domain of post-revelation analysis where the meaning and implications are "new" in a subjective sense only to the individual adopter who, in the process of dissemination, is confronted with them for the first time. On the basis of the assumed full knowledge, the scientific observer is able to develop and test hypotheses about the individual adopters' reactions to those properties.

The distinction between pre-revelation and post-revelation analysis points to inherent limitations in the formulation of transition laws in economics (as in the human sciences in general). To the extent to which the future course of events is contingent on the specific meaning of novelty to be revealed in the future, the assumption of a dynamic system with a known, uniquely determined solution would clearly be a misconception. Strictly speaking, the validity of such dynamic systems (difference and differential equations) is confined to post-revelation analysis, for example, to modelling diffusion, and is contingent on the assumption that no further novelty will intervene. Special instances are (1) the trivial case where a dynamic system whose unknown analytical solution is itself the transition law and where numerical iterations thus are the very revelation procedure as, for example, in tracing the time series of a chaotic motion; (2) the case where the transition law is left unspecified except that certain qualitative properties are submitted to hold as, for example, stability or bifurcation properties.

In spite of epistemological intricacies, several problems seem open to investigation in pre-revelation analysis. Given that human creativity is the source of novelty in the domain of economics, an important question is why, and under what conditions, people come up with novelty. Two factors seem to play a role here. First, there is considerable empirical evidence that humans feel pleasure or thrill from experiencing novelty. The strength of the feeling varies with the degree of relative deprivation of the feeling: the more boring a life becomes, the more novel cognitive stimuli are appreciated (Scitovsky



[1976] builds a whole book around this hypothesis.) The motivation to create novelty may thus be explained by a preference for novelty as such, i.e., precisely for experiencing the revelation of the yet unknown. To what extent newly envisioned possibilities of action are indeed pursued is a different question. Lack of skill or motivation may prevent it.[3] Moreover, historically, different societies have responded differently to innovative activities. Conservative societies tend to particularly disapprove of innovative activities in the economic sphere while tolerating or even approving them in other domains, for instance in the arts or in warfare. As a consequence, the newly discovered possibilities of acting may be pursued highly selectively.

A second factor that motivates the search for, and creation of, novelty is frustration with the *status quo* [Hagen, 1970, with historical examples]. This motivation cannot be explained in terms of the standard choice model as this has no room for such an emotion. A suitable interpretation is provided, however, by the theory of adaptive aspiration levels and the satisficing model [March and Simon, 1958, 47-52] which is well known in economics. Suppose, for instance, the set of choices feasible for an individual is significantly deteriorating. This means that the best presently feasible action is inferior to the best one in the past. According to the optimization model, the individual adjusts to the new, but inferior, optimum (which in extreme cases may even be known to be lethal). According to the satisficing hypothesis, by contrast, such a situation violates the current aspiration level. The divergence generates motivation to search for new, not yet known, choices even though — and for the epistemological reasons this is crucial — it is not known whether the search will be successful.

The motivation to search declines the longer the search is continued without a success appearing, because the aspiration level is adjusted according to the past record of successes and failures. With continued failures, the aspiration level eventually converges to the presently feasible best option and the motivation to search thus fades away. If, on the other hand, search turns out to be successful, in the sense that a better than the presently feasible best option is discovered, then the aspiration level increases to this new level. While the satisficing model thus suggests that search for novelty is typically triggered in situations of crises (which may be anticipated crises) the preference-for-experiencing-novelty hypothesis predicts a basic rate of innovativeness which, in the long run, may vary with the cultural or social acceptance of innovations.

## POPULATION THINKING, FREQUENCY-DEPENDENCY, AND SELECTION EFFECT

The process of mental creation of novelty tends to generate more ideas about new possibilities of actions than the individual actually can translate into innovative activities. Some choice therefore must take place, and in this choice two more alternatives are usually available: keeping to the best behavior presently practiced or, if available, imitating innovative behavior created by other agents. Assuming the conditions of post-revelation analysis are satisfied, the situation seems to suggest standard rational choice analysis, i.e., the theory of optimizing behavior, as appropriate modelling tools for post-revelation analysis. Several contributions to evolutionary economics do indeed use these tools. On the other hand, several strands of evolutionary economics reject the optimization approach on the basis of a bounded rationality argument. Decision problems of this sort are considered too complex so that the agents are bound to decide on the basis of rules-of-thumb and routines [Nelson and Winter, 1982], or "haberation" [Day, 1987].

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, 1972; Loasby, 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 endogenous 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' [Sober, 1984, Ch. 5.3; Hirshleifer, 1982; 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.[4] 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 such as culturally learned interpretation patterns [Schlicht, 1990], prevailing world views and paradigms — in short, all those objects diffusion and social learning (imitation) research deals with empirically [Witt, 1989a]. 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' comparative performance in a competitive market or industry have been related to differential growth and/or survival [Alchian, 1950; Winter, 1964; Matthews, 1984]. Firms which behave relatively poorly internally and/or 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 [Hallagan and Joerding, 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 $\alpha$ and alternative $\beta$ (where the latter amounts to not choosing $\alpha$). 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 $\alpha$-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.[5] Its various appearances all follow the same patterns of what has been called "replicator dynamics" [Schuster and Sigmund, 1983].

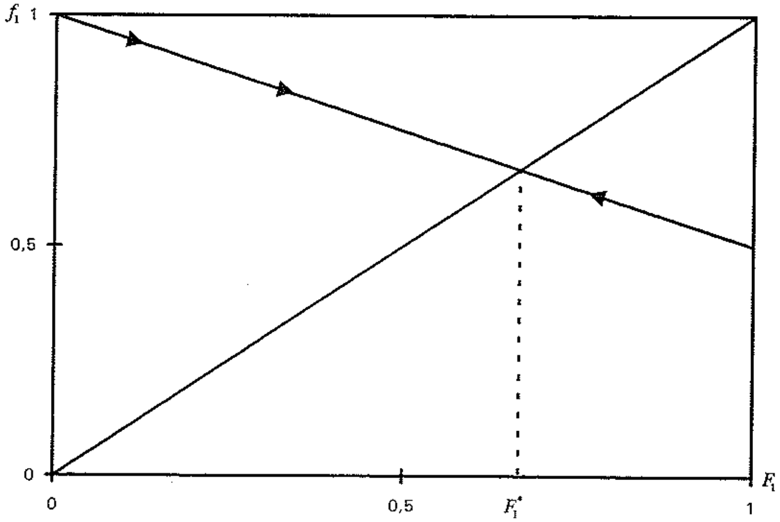
Assume, for an individual in the population making a choice at time $t$, that the perceived advantage of choosing $\alpha$ over $\beta$ depends on $F_\alpha(t)$, the relative frequency with which $\alpha$ already has been chosen in the population up to time $t$, and on the influence of the diverse idiosyncratic 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 $F_\alpha$ is the same for all individuals in the population. Focussing on the deterministic part (i.e., omitting the random influence), the advantage is a function of $F_\alpha(t)$ alone. It seems reasonable, now, to assume that an individual is more likely to decide for $\alpha$, the greater is the perceived advantage of doing so. Therefore, the probability $f_\alpha(t)$ that $\alpha$ rather than $\beta$ is chosen at time $t$ can be supposed to vary monotonously with the advantage (subject to the constraint $0 \leq f_\alpha \leq 1$ and $f_\alpha = 0$ for a negative advantage). This leads to the function

$$f_\alpha(t) = \psi(F(t)), \tag{1}$$

an evident expression of the frequency-dependency effect.[6]

Consider the graphs of $\psi$ for two alternative specifications in Figures 1 and 2. In the case of Figure 1, the advantage of choosing $\alpha$ dwindles as the alternative 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 $F_\alpha$ increases. As viewed from the population level, the particular behavior, $\alpha$, disseminates or replicates over time until a relative frequency, indicated by an asterisk, is reached where the likelihood of $\alpha$ being chosen in $t$ equals the relative frequency of $\alpha$ 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.

**FIGURE 1**



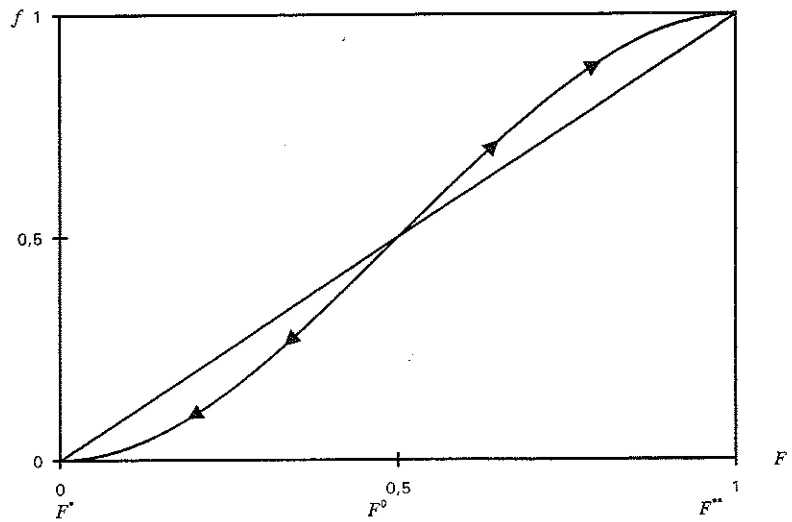

A different situation emerges if the advantage of choosing α increases in a non-linear fashion as in Figure 2. Such a case may arise, for example, if two competing novelties diffuse simultaneously and positive externalities are present which increase with the number of adopters of either of the alternatives α or β.[7] In Figure 2 the process is assumed to start with $f(0) = F_\alpha^\circ = 0.5$. However, the adoption probability rises above the mean $F(t)$ to the right of $F_\alpha^\circ$ so that the process is attracted to $F_\alpha^{**} = 1$ once a tendency in that direction has developed, and *vice versa* to the left of $F_\alpha^\circ$. Hence, $F_\alpha^\circ$ is an unstable fixed point. Even though the historical path may initially be equally well attracted to $F_\alpha^*$ as to $F_\alpha^{**}$, 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 $F_\alpha^* = 0$ and $F_\alpha^{**} = 1$ 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 focusses 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. Focussing on this process, which describes the dissemination (or replication) of alternative α in the population under consideration, $f_\alpha$ can be interpreted as the probability that one more individual in the population chooses α during a marginal increment of time. Accordingly, the difference between $f_\alpha$ and $F_\alpha$ gives the change of the relative frequency



**FIGURE 2**




at the margin. When taking the limit the frequency-dependency effect thus can be expressed by the differential equation

$$\text{(2)} \qquad dF_\alpha/dt = \phi(f_\alpha(t) - F_\alpha(t))$$

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

For simplicity, let φ 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 $w_\alpha$ of the relative frequency of alternative in the population results as

$$\text{(3)} \qquad w_\alpha = a_\alpha - 1.$$

Here $a_\alpha = f_\alpha(t)/F_\alpha(t) \geq 0$ is a measure of the advantage of the alternative α. Defining the measure for the alternative β 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 technologic, assume firms have different, but constant, unit costs $c_i$. Denote the industry's average unit cost of production by $c(t)$. Output is chosen such that firm $i$ has a market share $s_i(t)$, $\Sigma_i s_i(t) = 1$, 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 $\pi_i = c(t) - c_i$ is the profit/loss 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 born *ad 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

$$ds_i/dt = s_i\,(c(t) - c_i).^8 \tag{4}$$

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) are absent, 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 convincing theoretical representation of the competitive process in what was designed 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 reassess, 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 innovativeness 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 [Iwai, 1984; Silverberg, 1987; Englmann, 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 [Helmstädter, 1990]. Since innovations can be considered the major source 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 (Kontratieff cycles) with reference to long-term cycles in the occurrence of basic innovations [Mensch, 1979; Freeman, Clark, and Soete, 1982]. Empirical evidence seems to provide impressive support for the thesis [Kleinknecht, 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 continually 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 reappear here as coordinating and de-coordinating tendencies in the markets, and the dynamic balance between them produces a "viable coordination" [Witt, 1985]. 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, 1978]. Production, trading, division of labor do take place, but the individual plans and imaginations are not perfectly compatible with one another. There are surprises, misallocations, 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.[9] Its vague allocative implications not withstanding, this interpretation reproduces the classics' 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 1, 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 [1988], 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 selective 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, unintentionally, propagate the superior sets of 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 understand. Over thousands of years during which human civilization grew, an "extended order" — a paraphrase for the system of markets — thus has evolved spontaneously.



Hayek's grand view leaves several details open so that it is not entirely clear how the cultural transmission of, and selection among, rules of conduct operates [Vanberg, 1986]. Since it is linked to differential growth of the groups, his argument implies as long-run predictions an increasing complexity of economic interactions and absolutely increasing consumption funds available for feeding a growing human population. Though certainly not contradicting the historical record in general, the logical foundation of the prediction is challenged by the fact that the fastest population growth apparently occurs today in societies with the least efficient rules of conduct. Moreover, if all one can say about the long-run direction of societal evolution is that the human population is likely to grow and consumption to increase (not necessarily per capita) then this may appear to be a disappointingly meager result. Does the evolutionary approach have more to offer? Looking on innovativeness and selection pressure as the driving forces, the criteria are, in the last resort, the producers' decisions on which new option to pursue and the consumers' choices. A straight forward conjecture, therefore, is that a bias in selecting a particular kind of novelty from the incessant inflow of new ideas, and a persistently high valuation of it, would accumulate in the long run so that a directed path in economic evolution results. Is there anything beyond idiosyncratic subjective preferences, perceptions, plans that can be expected to induce a systematic bias? An answer to the affirmative seems possible, but its implications may still appear somewhat meager.

It can be speculated that subjective preferences are less autonomous than usually implicitly assumed. Economists have been reluctant to inquire more deeply into the question of what it is that people have preferences for, arguing that it should be left to neighboring disciplines. Yet insights in the neighboring disciplines do point to commonalities in preferences and in how preferences develop [Witt, 1991]. Although individuals certainly vary significantly in this respect, humans do have a basic, genetically determined bias in their preferences which, as an outcome of man's phylogeny, is directed to the physical needs for survival and preservation of the species. Economic evolution seems to have been influenced for a very long time by these preferences in a very elementary way: the poorer the economy, the more desperately people have striven to satisfy their caloric needs. A severe restriction in the production of food is the energy and, to a lesser degree, the materials [Georgescu-Roegen, 1971]. It therefore may be conjectured that much of the economic evolution in the long run has shown a clear tendency: all novelty related to technological or institutional devices which allow the energy at man's disposal to increase have been eagerly translated into respective innovations [Hesse, 1992a; 1992b].

It is only a relatively recent phenomenon of the industrialized countries that, at the mass level, man has been able to increase the volume of production significantly beyond what is necessary for immediate physical survival. As holds generally in evolution, affluence creates conditions that allow a species to deviate from genetic necessity without facing a break down. An affluence phenomenon commonly observed in nature is a significant decline in physical effort. Saving human physical effort means utilizing non-human energy resources. The more this is possible, the more human leisure can be enjoyed. It seems plausible, therefore, that the direction of future economic evolution will follow a path of technological and institutional changes which will continue to increase energy utilization. If this conjecture is correct, it may be worthwhile for evolutionary economics to consider reformulating the basics of the theory of production and economic growth in terms of two crucially interacting factors: knowledge and energy [Boulding, 1981, 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 focusses 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 causes of change which originate from the very 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 replicator 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

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1. A striking example is the recent literature on industrial "innovation" races [Reinganum, 1989]. Search for novelty is interpreted here as a problem of optimal investment in competitive R&D activities. All competitors are assumed to search for the same "innovation" which thus must be clearly anticipatable in its meaning and implications. Even the profits that will accrue from it are assumed to be anticipatable.
2. The assumption abstracts from the observation [Georghiou, Metcalfe, Evans, Ray, and Gibbons, 1986] that novelty is in many cases translated into innovative activities in a trial-and-error process in which further novelty may turn up.
3. If so, no innovation results. As is well-known, Schumpeter [1934] found the distinction between novelty ("invention") and innovation crucial, assuming that, due to the scarcity of entrepreneurial skills, innovations are much rarer than inventions.
4. As rightly pointed out by Lachmann [1986], if the task is to explicate a specific historical individual's choice observed at a certain time, the subjectivism problem allows hardly more than inference by introspection as suggested in Max Weber's methodology of *verstehen*. An excellent criticism of a naïve rational choice foundation of economics can be found in Mueller [1993].
5. Among them are the theory of consumer behavior [Granovetter and Soong, 1986; Weise, 1992], social learning hypotheses as a solution to prisoners' dilemmas [Witt, 1986], the theory of revolution [Kuran, 1989], product life-cycle models [Mahajan and Wind, 1986], and technology diffusion models [Metcalfe, 1988]. Likewise, the effect is at the core of the recent work on network-externalities, learning-by-using, technological "lock in" [Arthur, Ermoliev, and Kaniovsky, 1987; David, 1987; see below]. It appears similarly, but derived within the framework of evolutionary game theory, in work focussing on the emergence of institutions [Hirshleifer, 1982; Sudgen, 1989; Witt, 1989b]. For further examples see Schelling [1978]. Veblen [1899] had already taken note of the effect and made a major argument of it without, of course, labeling it that way.
6. Note that in the bivariate case $f_\beta = 1 - f_\alpha$ and $F_\beta = 1 - F_\alpha$.



7. Examples can be found in the case of new technical standards in the generalized Polya-urn model by Arthur [1989] or in the case of different quality standards in the production of consumer durables in the synergetic model by Weidlich and Braun [1992].
8. Obviously $ds_i/dt = 0$ if either $c(t) - c_i = 0$, which is the case only for the firm whose unit costs are exactly those of the average practice in the industry, or $s_i = 0$, that is, if the firm is no longer active in the market. As long as the best practice is not the average practice in the industry there is at least one firm with growing and at least one firm with shrinking $s_i$. By the same token, $c(t)$ is decreasing until $s_i = 0$ for all $i$ except the best practice firm.
9. As recognized by Schumpeter [1942, Ch.8], the incentives to search for innovative improvements, in fact, may generate growth and material welfare in the longer run which would outweigh all fictitious efficiency losses.

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