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Evolutionary Economics

by

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Evolutionary Economics*

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ABSTRACT

This article reviews the way of thinking about economic problems and the research agenda associated with the evolutionary approach to economics. This approach generally focuses on the processes that transform the economy from within and on their consequences for firms and industries, production, trade, employment and growth. The article highlights the major contributions to evolutionary economics and explains its key concepts together with some of their implications.

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Introduction

Evolutionary economics focuses on the processes that transform the economy from within and investigates their implications for firms and industries, production, trade, employment and growth.

These processes emerge from the activities of agents with bounded rationality who learn from their own experience and that of others and who are capable of innovating. The diversity of individual capabilities, learning efforts, and innovative activities results in growing, distributed knowledge in the economy that supports the variety of coexisting technologies, institutions, and commercial enterprises. The variety drives competition and facilitates the discovery of better ways of doing things. The question in evolutionary economics is therefore not how, under varying conditions, economic resources are optimally allocated in equilibrium given the state of individual preferences, technology and institutional conditions. The questions are instead why and how knowledge, preferences, technology, and institutions change in the historical process, and what impact these changes have on the state of the economy at any point in time.

Posing the questions this way has consequences for the way theorizing is done in evolutionary economics. First, preferences, technology and institutions become objects of analysis rather than being treated as exogenously given. Second, following from the very notion that evolution is a process of self-transformation, the causes of economic change are in part considered to be endogenous, and not exclusively exogenous shocks. More specifically, these causes are identified with the motivation and capacity of economic agents to learn and to innovate. Third, the evolutionary process in the economy is assumed to follow regular patterns on which explanatory hypotheses can be based, rather than forming an erratic sequence of singular historical events.

These three meta-premises are widely shared in evolutionary economics. However, the details of the argument, methods, and even the specification of the attribute ‘evolutionary’ vary, corresponding to the different theoretical traditions in which evolutionary economics is rooted. The concept of evolution has a long history

in economics and social philosophy. This antedates – and, to a certain extent, has influenced – Darwin’s theory of the origin of species by means of natural selection. Where the concept of evolution originally stood for a process of betterment (of human society), the Darwinian revolution in the sciences purged these progressive, teleological connotations. Today, evolutionary thought usually defines itself in relation to the Darwinian theory of evolution, the contributions to evolutionary economics not excepted. Some authors consider Darwinian theory to be the master theory. Others borrow from it at a heuristic level for their analogy-driven theorizing in economics. Yet others explicitly dissociate themselves from Darwinian thought.

Schumpeter and the neo-Schumpeterian synthesis

Schumpeter avoided the term ‘evolution’. He considered it a Darwinian concept and denied such concepts any economic relevance. However, in his theory of capitalist development Schumpeter (1934) clearly subscribes to the three meta-premises above. The restructuring of the economy is explained as emerging endogenously from ever new waves of major innovations implemented by pioneering entrepreneurs with unique capabilities and motivation. Technology and the institutions of capitalism are endogenized. The transformation process of the economy is assumed to be governed by regular patterns, that is, cycles of investment and growth – booms and depressions – triggered by the innovations that occur ‘in waves’ and diffuse throughout the economy in competitive imitation processes.

In Schumpeter (1942, 83) innovations that ‘incessantly revolutionize the economic structure from within’ remain central, but the innovating agents change. Previously viewed as achievements of unique promoter-entrepreneurs, innovations now appear as the routine output of trained specialists in large corporations. Correspondingly, the driving force of capitalist development is identified in the risky R&D investments of the large trusts – undertaken only if they expect proper returns to be earned. To protect these returns from being competed away immediately, the large, innovative corporations tend to engage in monopolistic practices. Such practices are incompatible with the ideal of perfect competition, but without them there would be significantly fewer R&D investments and innovations. Moreover, Schumpeter (1942,

ch. 8) claims that monopolistic practices work for only a limited time before innovations are eventually imitated or invalidated by rival innovations. Despite temporary monopolistic practices, competition by innovation thus boosts economic growth and raises prosperity more than fiercer price competition could ever do. This notion of ‘Schumpeterian competition’ induced a long debate about the relationships between firm size, market structure, and innovativeness in which, however, the broader concept of endogenous economic change was lost from sight.

Endogenous change returns to centre stage in Nelson and Winter’s (1982) neo-Schumpeterian restatement of evolutionary economics that blends Schumpeter’s ideas with Darwinian concepts on the one hand and elements of the behavioural theory of the firm on the other. Schumpeter (1942) had not been specific about the innovative operations of the large corporations. To fill the gap, Nelson and Winter assume that, because of bounded rationality, firms operate on the basis of organizational routines. Different firms develop different routines for producing, investing, price setting, using profits, searching for innovations, and so forth, resulting in a diversity of competitive behaviours in the industry. By analogy with the principle of natural selection, Nelson and Winter argue that this diversity tends to be eroded whenever competing routines lead to differences in the firms’ market performance and profitability. The better the firms perform, the more likely they are to grow, and the less reason they have to change their routines. The opposite holds for poorly performing firms. Much as differential reproductive success raises the share of better adapted genes in the gene pool of a population, differential firm growth thus raises the relative frequency of the better adapted routines in the ‘routine pool’ of the entire industry.

Instead of being a matter of optimal, deliberate substitution between given alternatives, in this view, the firms’ competitive adaptations to changing market conditions are forced on them by selection processes operating on their routines. However, in a Schumpeterian spirit, Nelson and Winter also account for innovative moves – a breaking away from old routines – in an industry’s response to changing market conditions. New ways of doing things, for example in responding to rising input prices, are established by search processes which are themselves guided by higher-level routines. Modelled as random draws from a distribution of productivity increments, innovations raise the average performance of the industry and regenerate

the diversity of firm behaviours for selection to operate on. Some of the firms are driven out of the market, while the surviving ones tend to grow. Under innovation competition, technology and industry structure thus co-evolve and feed a non-equilibrating economic growth process. Regarding the debate on Schumpeterian competition, Nelson and Winter's analysis suggests a reversal of cause and effect: a high degree of concentration within an industry (an indicator of monopolistic power) may evolve as a consequence of, rather than being a prerequisite for, a high rate of innovativeness in the industry.

Selection principles and processes

Analogies between natural selection and market competition are not new. Better-adapted variants of firm behaviour have often been argued to prevail in an industry just as better-adapted variants tend to prevail under natural selection pressure in the population of a species (an argument that has sometimes been misunderstood as vindicating profit-maximizing behaviour). The logic of the argument can be rendered more precise (Metcalf, 1994). Consider an industry with firms $i = 1, \dots, n$ producing a homogeneous output with unit cost $c_i = \text{const}$. Assume that the firms use different organizational routines which result in a non-degenerate unit cost distribution. Let $s_i(t)$ denote the market share of firm i at time t measured by output. In a competitive market in which trade takes place at a uniform price $p(t)$,

$$p(t) = c(t) = \sum_i s_i(t) \cdot c_i, \quad (1)$$

with $c(t)$ as the average level of unit cost in the industry. By eq. (1), the average profit in the industry is zero. For at least one firm i , however, individual profit $\pi_i = p(t) - c_i > 0$ unless the entire market is served by the firm with the lowest level of unit cost.

Let the firm's growth be expressed in terms of the rate of change of its market share $(ds_i(t)/dt)/s_i(t)$ that is assumed to be a monotonic function ϕ of the firm's profit. With (1) inserted into the individual profit equation, the rate of change of the firm's market share can therefore be written as

$$\frac{ds_i(t)dt}{s_i(t)} = \varphi(c(t) - c_i) = \varphi(\pi_i(t) - \pi(t)). \quad (2)$$

Hence, performance differences across firms and their routines translate into corresponding differential growth rates of the firms.

The ‘replicator’ eq. (2) corresponds to what is called ‘Fisher’s principle’ in population genetics (Hofbauer and Sigmund, 1988, ch. 3). Let the fitness of an organism carrying a certain genetic trait be a constant. If it exceeds the average fitness in a population, the relative share of that trait in the population increases and vice versa. Consequently, natural selection raises average fitness over time to the level of the highest individual fitness. The change of the mean population fitness is proportional to the variance of the individual fitness. Analogously, with $c(t)$ as the measure for ‘population fitness’ in eq. (2), $dc(t)/dt = f(\text{Var}(c_i)) \geq 0$.

If individual fitness is not constant, Fisher’s principle no longer applies. Suppose individual unit costs decrease with the firms’ output, for example because of scale economies. The replicator equation can then have several fixed points representing multiple selection equilibria associated with a different average cost level (Metcalfe, 1994). Which of the multiple equilibria the process converges to – and, consequently, whether the ex ante most profitable cost practice is eventually selected – depends on the initial conditions. Selection does not necessarily drive fitness or, for that matter, profits to the largest maximum. (Replicator equations with multiple equilibria can also result if the individual fitness terms depend on the population shares of their carriers. Such a frequency dependency is characteristic of models in evolutionary game theory; see Hofbauer and Sigmund, 1988, ch. 16).

To influence the underlying distribution of traits or behaviours, selection requires sufficiently inert conditions. In economic transformation processes this condition is often systematically violated. For example, firms facing a declining market share and/or profitability have strong incentives to modify their operations, that is, to replace inferior routines and/or to search for innovations. In general, with innovations playing a central role – as in Schumpeterian capitalist development – the

volatility of the firms' environment increases and makes inertia rather unlikely. Industry dynamics are then more likely to be shaped by the generation and diffusion of innovations following their own time patterns rather than by selection processes. While in the case of selection processes theorizing focuses at the population level ('population thinking'), the explanation of the generation and diffusion of innovations can benefit from reconstructing motives and capabilities at the individual level.

Emergence and diffusion of innovations

Important as innovations are for economic transformation processes, the possibilities for analysing how they emerge are limited because the underlying cognitive processes are basically unknown. What can nonetheless be analysed is why and when agents are motivated to search for innovations, provided their motivation is not made contingent on the – as yet unknown – outcome of the search (as in models of optimal choices between known alternatives that are therefore not applicable here). Often search motivation is triggered by a state of dissatisfaction or deprivation that the agents want to overcome by actions still to be found. Among the causes may be unsatisfied curiosity, a motivation to achieve something (Schumpeter, 1934), or an agent's aspiration level that is temporarily not satisfied (Nelson and Winter, 1982, ch. 9). Where individual motivations like these occur in an uncorrelated way, they induce a base rate of innovative activity in the economy. If, in contrast, search motivation arises in a correlated way, for example in an economic crisis or when an industry is exposed to major innovations, the rate of innovative activities can rise far above the base rate. This is the case, for example, when firms need to innovate or be fast imitators with sufficient absorptive capacity in order to survive and therefore routinely engage in R&D.

Once an innovation is created or discovered by an agent, its implications can be grasped. Suppose, after assessing its benefits and costs, an agent implements an innovation. The implementation can usually be observed by competitors and/or other potential users. Since, in the absence of independent, own experience, people often draw conclusions from observing what others do, some observers may thus infer that the innovation is profitable and may start imitating it. Other observers may draw this

conclusion only after a number of competitors and/or potential users have also signalled that they expect to benefit from adopting the innovation. Observational learning of this kind implies a dependency of the individual imitation or adoption behaviour – and, hence, the diffusion of the innovation – on the relative frequency of adopters.

The logic of this dependency can be captured by a function $q(t) = g(F(t))$, depicting the probability $q(t)$ that an agent who decides in t will adopt the innovation against the relative frequency of adopters $F(t)$ at time t . For $q(t) > F(t)$ the expected relative share of adopters grows with each additional decision and vice versa for $q(t) < F(t)$. The diffusion dynamics

$$\frac{dF(t)}{dt} = q(t) - F(t) \quad (3)$$

therefore hinge on the shape of the function g . For the quadratic function $q(t) = aF(t) - aF(t)^2$, $a > 1$, for instance, $F(t)$ converges to a fixed point F^a , $0 < F^a \leq 1$, that depends on the size of a . (By integration of eq. (3) the diffusion path can in this case be shown to follow the well-known S-shaped logistic trend.)

For the cubic function $q(t) = 3F(t)^2 - 2F(t)^3$, to take that example, the condition $q(t) = F(t)$ is satisfied if F equals 0, $\frac{1}{2}$, or 1. Inserting the cubic function into eq. (3), $F=0$ and $F=1$ can be shown to represent stable fixed points of eq. (3) while $F^* = \frac{1}{2}$ represents an unstable fixed point. This implies that for $F(t) < F^*$ the probability of adopting the innovation is too small to induce a spontaneous diffusion process. If $F(t)$ were for some reason to exceed F^* – representing a ‘critical mass’ of adopters – the innovation would however spread. The reason could be fluctuations of $F(t)$ that randomly cumulate, but are not represented in this simple deterministic model. (This explanation also plays a role in evolutionary game theory where the question is, for example, whether a new convention can emerge in a coordination game; see Young, 1993). Another reason could be that somebody organizes a collective action by which the critical mass of agents is made to believe that more than the share F^* of agents will adopt the innovation.

With major technological innovations, competing variants or designs that serve the same user needs are often spawned simultaneously. The diffusion processes of the competing variants are interdependent if, for each of the variants, the users' utility varies with the number of adopters. Such 'economies to adoption' of alternative variants have been diagnosed, for example, for electric current transmission, video recorder systems, or the layout of typewriter keyboards. The underlying pattern is again a frequency-dependency effect that can be analysed as before, if only two rival variants are assumed and the decision of agents who adopt neither of these is neglected.

Let $q(t)$ denote the probability of adopting the first variant and $F(t)$ its share of adopters at time t . Suppose both variants become available simultaneously and offer the same inherent benefits. For the first variant the development is captured by the cubic function above, interpreted as the mean process of a stochastic adoption process. With an identical number of initial adopters, $F(0) = F^* = 1/2$ and $q(t) = 1/2$. Once $F(t) \neq 1/2$ for $t > 0$, economies to adoption raise the individual adoption probability of one of the variants over that of the other. As a consequence, the realization of the stochastic diffusion process initially fluctuates around F^* . Over time, however, small historical events and cumulative random fluctuations drive the process in the direction of either $F = 0$ (first variant disappearing) or $F = 1$ (second variant disappearing). In competitive diffusion processes of this kind, the prevailing state of the technology is thus 'path-dependent', and the process can be 'locked in' to the one variant if it is assumed, in addition, that over time the number of adopters grows beyond all bounds (Arthur, 1994, ch. 3). This means that, for $t \rightarrow \infty$, the likelihood of passing F_c by cumulative random fluctuations goes to zero.

The evolution of industries and the institutions backing innovativeness

The substitution processes that the diffusion of new products and techniques induces shake up the established production structures. Factor owners and producers are forced to make adjustments – often painful ones that depreciate earlier investments and acquired competencies. While such 'pecuniary externalities' are inevitable concomitants of innovations, the longer-run consequence of innovativeness is – as

Schumpeter (1942) had postulated – a rising standard of living of the masses. As a result of innovativeness, labour productivity and per capita income increase. New products and services absorb the growing consumption expenditures where established markets tend to be satiated. New employment opportunities emerge in new industries. To understand the working of the innovative transformation process and its policy implications, it is often useful to reconstruct the historical record of the evolution of entire industries (Malerba et al. 1999). Many of them, like the auto industry or the computer industry, grow out of a few major innovations for which new markets can be established or existing ones can substantially be expanded. Industries continue to grow over time under the pressure of imitative competition, often following a path of technical improvements that evolves within a ‘technological paradigm’ (cf. Dosi, 1988).

Such regular patterns of change at the industry level can for many, though not all, industries be characterized in a stylized way by a life-cycle metaphor (Klepper, 1997). Soon after their markets have been established by early innovators, the industries experience heavy entry and exit activities by competitors who partly imitate and partly add new varieties. While the market is expanding, a drastic shake-out in the number of firms occurs so that eventually a few large firms dominate the industry, and diversity in products and processes is reduced. In the beginning, product innovations are a main source of competitive advantages. Over time, however, the importance of process innovations increases. They raise productivity, drive down unit costs, and tend to intensify price competition. One cause of these patterns of industry evolution seems to be increasing returns to process innovations. These favour first movers that have been able to attain a sufficient size to spread development costs over larger output bases. With fiercer price competition, the firms with higher unit costs tend to be driven out of the industry, as in the selection model discussed above. Market concentration rises. With fewer innovations at that stage in the industry, its growth slows down, if the industry is not stagnating or declining.

Industry evolution is often connected with spatial effects. Innovative production techniques and new products often grow out of initiatives, competencies, endowments, and institutional settings in particular locations (Antonelli, 2001). If such complementary and interdependent local innovative activities gain momentum

and trigger a self-augmenting process of firm growth and firm founding activities in close spatial proximity, an ‘industrial cluster’ can emerge. During early phases of the industry life cycle, a substantial share of the corresponding national or international industrial innovative activity may even be concentrated in such locations, Silicon Valley being the paradigmatic case. In such regions, income and employment are boosted. For policymaking the question therefore arises under what conditions innovative industrial clusters emerge and how and when their emergence can be fostered (Brenner, 2004).

The early growth of innovative industries creates new employment opportunities. At later stages of the industry life cycle, when price competition and substitution pressure from innovative industries force the industry to raise labour productivity to reduce costs, employment is usually gradually lost. (For this reason, an industrial cluster that dominates a region can, in later stages of the industry life cycle, become a drag on local employment and prosperity.) At the macroeconomic level, the stages reached in the life cycles of the industries interact in a complex way with productivity and income growth rates, and with the overall changes in employment (Metcalfe, Foster and Ramlogan, 2006). Although these interactions have not yet been fully explored, it seems clear that at least two conditions must be met to maintain a high level of aggregate employment. First, innovative industries with new employment opportunities must emerge at the right times to compensate for the labour-saving technical progress. Second, the workforce must be able to adjust to the qualification requirements of the innovative industries and technologies. Since there is no self-regulating mechanism fulfilling the first condition, and because of delays and frictions in satisfying the second condition, the evolution of the industries is not necessarily a smooth transformation process. Aggregate employment and domestic income can vary substantially with the pace at which innovative industries emerge and expand.

However, high levels of education and training are likely to raise innovativeness and the qualifications of the workforce. Ensuring this with an adequate institutional infrastructure – a productive national system of innovations – is an important policy option in supporting and smoothing the transformation process. This is even more true from a global perspective. A country’s growth potential and its

competitive advantage in trade hinge on when the country gains access to newly emerging technological opportunities and where in the innovative industries' life cycle it enters the market. History shows that differences between countries in this respect correspond to differences in their national innovation systems (Fagerberg, 2002).

Darwinian perspectives on economic evolution

The neo-Schumpeterian approach considers the concept of selection as constitutive for evolutionary economics. Economic selection processes, operating on the diversity of individual behaviours, force adaptations on populations of agents who are prevented by their bounded rationality from deliberately adapting optimally. The import of the selection concept is not meant to extend Darwinism to the economic domain. Such an extension was, however, advocated by Veblen (1898) under the influence of the Darwinian revolution of his time. He coined the term 'evolutionary' economics for such an approach (Hodgson, 2004). A Darwinian perspective on the economic domain can indeed help to clarify how evolutionary economics fits with the Darwinian world view now prevailing in the sciences and in this way offer new insights (Witt, 2003).

In the economic domain, the bulk of change to be explained occurs within single generations. In contrast, the Darwinian theory of natural selection focuses on inter-generational change and is therefore relevant only for explaining the basis on which economic evolution rests. These are, first, the long-term constraints man-made economic evolution is subjected to and, second, the innate dispositions and adaptation mechanisms in humans (shaped earlier in human history by natural selection) that define the basic behavioural repertoire. Veblen (1898) focused on habits, including habits of thought, which he assumed to emerge from hereditary traits and past experiences, given the traditions, conventions and material circumstances of the time. (Habits play the crucial role in Veblen's explanation of the 'cumulative causation' of institutions which, in turn, he regarded as the key to understanding the different forms of economic life and their genesis.)

In a similar vein one may focus on human preferences that emerge from the interplay of inherited dispositions and innate conditioning learning mechanisms – both of these shared by all humans with the usual genetic variance. A prominent example of innate dispositions is the altruistic attitudes that play a prominent role in evolutionary game theory (Hofbauer and Sigmund, 1988, ch. 14). Other examples of innate dispositions can be found in certain forms of consumption. The genetically fixed learning mechanism accumulates the influence of a lifelong history of reinforcement and conditioning. It is responsible for the emerging variety of individual preferences and keeps them changing over time.

Following Hayek (1988, ch. 1), innate behaviour can be conjectured to play a key role in the evolution of human institutions. They emerge, he argues, through social learning of ‘rules of conduct’ that starts from primitive, genetically fixed, forms of social behaviour and add on new elements by trial and error. Over their history, different groups or whole societies thus build up a diversity of rules that regulate their interactions. The group members’ innovativeness is channelled into economic activities provided institutional regulations do not discourage this or fail to protect the capital accumulation that is necessary to realize innovations. Those groups that succeed in developing and passing on rules able to better meet these conditions can therefore be expected to grow and prosper in terms of population size and per capita income. Their differential success may enable such groups to conquer and/or absorb less well-equipped, competing groups and thus propagate better adapted institutions.

Economic evolution is, of course, also shaped in an essential way by human intelligence. By cognitive learning, problem solving and inventiveness, knowledge about institutions, opportunities and technologies is created (Mokyr, 2002). In the longer run, the enabling effects of cumulative knowledge generation emerging over time matter more than the effects of economizing on scarce resources at each point in time. From a Darwinian perspective the most significant tendency in the use of cumulative knowledge is the manipulation of natural constraints to better accord them with human preferences. This has enlarged the niche for the human species and has improved living conditions for an ever-increasing number of its members. At the same time, however, knowledge accumulation has contributed to dramatically increasing the human share in the use of natural resources. According to Georgescu-Roegen’s

(1971) evolutionary approach to production theory, this way of solving problems implies a risky long-term impact on nature, the ultimate basis of the human economy. To account for these risks further innovative efforts that transform the economy from within seem indispensable.

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