A Layman's Guide to Evolutionary Economics

by Jan Fagerberg[1]

Jan.fagerberg@tik.uio.no

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Abstract

During the last decades we have seen a revival of interest in the works of Joseph Schumpeter and "evolutionary" ideas in economics more generally. This paper presents an overview and interpretation of these developments. Following an introductory discussion of the concepts and ideas (and their origins) the main characteristics of Schumpeter's own contribution are presented. On this basis we make an assessment of the more recent contributions in this area, the (mostly applied) "neo-schumpeterian" literature that attempts to use Schumpeterian concepts to empirically analyse real world phenomena, and the more formal "evolutionary modelling" literature associated with the names of Sidney Winter and Richard Nelson. Finally we raise the question of how much the different contributions considered in the paper actually have in common (is there a common core?), and what the differences and similarities are when compared to other approaches (particularly the so-called "new growth theory").

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Contents

1. Introduction

During the last two decades we have seen a growing interest in "evolutionary" ideas among economists. New professional associations focusing on these ideas have been founded and for more than fifteen years there has been a journal, Journal for Evolutionary Economics, devoted particularly to this topic. It would perhaps be natural to expect that source for these ideas was to be found in another science, namely biology, in which evolutionary ideas have been dominant for more than a century. In fact, there is a long tradition in economics for using biological metaphors, as evidenced by economists as different as Thorstein Veblen, Alfred Marshall and Friedrich Hayek. Marshall, for instance, is famous for his statement that "The Mecca of the economist lies in economic biology rather than economic dynamics" (Marshall 1949, p. xii). The increasing popularity of the term "evolutionary" might be seen as a proof of the continuing influence of evolutionary biology on the social sciences.

However, the precise connection between evolutionary biology and evolutionary economics, obvious as it may seem, is actually a matter of considerable controversy (and has been so for a long time). Joseph Schumpeter, arguably the most prominent evolutionary economist ever,[2] was particularly hostile to any attempt to base

[2] This view is commonly accepted among evolutionary economists with the exception of Hodgson (1993). In his account Schumpeter is lumped together with Marx and the neoclassicals and criticized for underestimating the role of creation of novelty/variety in social evolution. However, while it may be acknowledged that Schumpeter inherited a lot from Marx, and that he was not so

economic analyses on mere analogies with Darwinism (Schumpeter 1934, p. 57). Writing in the beginning of the previous century he was so fed up with contemporary attempts to blend natural and social sciences under the evolutionary banner that he for a while abandoned the term evolution altogether.[3] Nevertheless, later he retreated on this position and acknowledged, "although this term is objectionable on several counts, it comes nearer to expressing our meaning than does any other" (Schumpeter 1939, p. 86). The point was of course that he wished to analyse capitalist development as an evolutionary process based on a perspective that was firmly rooted in economics and the social sciences and not copied more or less uncritically from biology or physics. Many contemporary social scientists would undoubtedly side with him in this endeavour. It has been argued, also, that it was actually the biologists who copied the evolutionary perspective from the social sciences, not the other way around.[4] Leaving this as it may,

anti-neoclassical as people sometimes imply, it is certainly not correct that he overlooked the role of continuing novelty in economic evolution (see sections 2 and 5 in this paper).

[3] "… the evolutionary idea is now discredited in our field (…). To the reproach of unscientific and extra-scientific mysticism that now surrounds the "evolutionary" ideas, is added that of dilettantism. With all the hasty generalisations in which the word "evolution" plays a part, many of us has lost patience" (Schumpeter 1934, p. 58)

[4] This interpretation is based on the following quotation from Darwin "In October 1838, that is, fifteen month after I had begun my systematic enquiry, I happened to read for amusement "Malthus on Population", and being well prepared to appreciate the struggle for existence which everywhere goes on (…), it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. (...) Here, then, I had at last a theory by which to work." Charles Darwin (1887, p. 83), cited after Mailath (1988), p. 1347. Schumpeter, it might be noted, was quite sceptical to the alleged importance of Malthus' work for Darwin's work, although he acknowledged that" quite insignificant events and suggestions may release a

the dominant view among evolutionary economists now seems to be that the differences between biological evolution on the one hand and social and economic evolution on the other are too large to allow for the development of a common evolutionary theory applicable to both (Metcalfe 1998, Nelson and Winter 1982). While, as suggested by Darwin and accepted by most biologists, changes in biology can be adequately described as a slow, stochastic process, the same does not hold for the social sphere. Changes in the social sphere are clearly much faster, more cumulative and of a more "conscious" character than in biology, and this arguably requires a different theoretical framework from the one developed for biological evolution.[5]

There is also the question of precisely what to mean with the term "evolution". Geoff Hodgson, in his book "Economics and Evolution", warns, "Nothing is more guaranteed to generate confusion and stultify intellectual progress than to raise such a muddled term to the centrepiece of economic research, while simultaneously suggesting that a clear and well defined approach to scientific enquiry is implied" (Hodgson, 1993, p. 38). He points out that there are several different uses of the term. In the older, (non-biology) sense, evolution simply means development or (long-run) change.[6] However, with the emergence of evolutionary ideas in biology the concept came to be associated with a process of qualitative change taking place in historical time. The great

given current of thought"(Schumpeter 1954, p. 445-6).

[5] This was pointed out already by Penrose (1952).

[6] The term comes from the Latin "volvare", meaning "roll", see Hodgson 1993, p. 37.

propagator of this more recent use of the term was according to Hodgson not Charles Darwin, who adopted it rather reluctantly at and a late stage, but Herbert Spencer, an influential scientist and philosopher of the Victorian age.[7] It is in this more recent sense the term has come to be used in economics. Hence in this paper we will use the term "economic evolution" to designate a process of qualitative, economic change taking place in historical time.

This perspective on economic evolution leads to several important questions: How does new quality (innovation) emerge? What decides whether and to what extent the new qualities are accepted by the economic environment (selection/diffusion)? What are the consequences for the economic system at large? These are the kind of questions that will be in focus in this paper, which is aimed at presenting a broad, non-technical overview of "evolutionary economics". With this term we shall understand theories, methods, insights and questions that are of relevance for the study of economic evolution as defined above. The potentially relevant literature is of course very large, and there is no way in which we can do justice to all of it. To keep it manageable we shall limit the discussion to analyses of capitalist evolution during the last few centuries. Thus, the thematic focus of our discussion will be close to that of Schumpeter's work on capitalist evolution, with its emphasis on a) innovation as the

[7] For Spencer evolution was characterized by increasing specialisation and complexity, or "a change from a indefinite, incoherent homogeneity, to a definite, coherent heterogeneity through continuous differentations" (Spencer 1892, p. 10, cited after Hodgson 1993, p. 82). He associated evolution in this sense with progress and the emergence of fitter, better adapted forms. In fact, the term "survival of the fittest" was invented by Spencer, not Darwin (ibid, p. 81).

driving force behind economic, social and institutional change, b) the central role played by capitalist firms in this process and c) a historical perspective. Moreover, we shall emphasize that for evolutionary economists, "evolution evolves but accepts no destiny" (Freeman and Louca 2001, p. 4), i.e., capitalist evolution is to be considered as an open-ended process characterized by continuous change.[8] This is essentially what "a historical perspective" means in the present context. This also explains why there is a qualitative difference between the evolutionary approach and approaches that emphasize "equilibrium" (and "convergence" towards it) as theoretical tools. We discuss Schumpeter's contribution in section two of this paper. In section three we present some of the applied work on capitalist evolution that emerged from the 1960s onwards, to a large extent based on Schumpeterian ideas. Section four is devoted to the more recent evolutionary models of economic change, associated in particular with the names of Richard Nelson and Sidney Winter, which introduce the Schumpeterian ideas on economic evolution dynamics into a novel formal framework. Finally, in section five we round up our discussion with some views on the state of the art in this area and the challenges ahead.

To be fair to the reader we will briefly point out what we are not going to discuss in what follows (but might perhaps have been discussed had the topic been cut differently). The common theme for the contributions to be discussed here is as noted the focus on

[8] Hodgson (1983) argues that Schumpeter falls short of this requirement, and that Schumpeter in his analysis underestimates the role of novelty in social evolution.

capitalist evolution rather than on, say, evolutionary ideas more generally. Thus, although interesting in its own right, we will not discuss applications of evolutionary ideas from biology to fields of economic research that do not focus explicitly on economic evolution (as defined above), such as, for instance, game theory.[9] Nor do we intend to consider in detail the many attempts in the past or more recently to systematically compare (with the hope of some cross-fertilization) approaches across the natural and social sciences, particularly biology and economics.[10] Another topic that falls outside the scope of this paper concerns general aspects of human and cultural evolution in a very long-run perspective (typically covering thousands of years or more).[11] Moreover we will not cover the contributions from Veblen and other writers in the so-called (old) "institutionalist"

[9] So-called "evolutionary game theory" (for a survey see Mailath 1998) shares with traditional neoclassical economics and non-cooperative game theory the focus on equilibria, their existence, characteristics, stability and so forth. Hence the focus is clearly not on economic evolution as defined here. It prefers, however, to explore these equilibria by a route that allows for less strong (more realistic) assumptions on human behaviour. In this respect it shares some of the assumptions used by Nelson and Winter (1982) and other researchers in the "behaviouralist tradition" in economics and business studies, see section 3 in this paper. For an extended discussion of the relationship between this literature and evolutionary economics, see Andersen (1994, ch.5)

[10] For some recent discussions of this issue, see Hodgson (1999, chapter 5) and contributions in Ziman (2000) and Laurent and Nightingale (2001).

[11] This type of work is often inspired either by socio-biological thinking or by the "Austrian approach" in economics. For a brief discussion of evolutionary economics that also takes into account contributions from socio-biology and the Austrian approach, see Witt (1993, Introduction). See also the survey of more recent contributions on the subject by Nelson (1995). A more extended account of Austrian approach may be found in Kirzner (1997). For discussion of the contributions from Hayek, one of the leading figures in the Austrian school, see Hodgson (1993), chapter 12.

strand in economics and sociology that he helped to initiate.[12] This does not mean that we wish to deny the potential relevance that this type of work may have for the future development of evolutionary economics (Hodgson 1993, 1999). However, in practice has been little if any interaction between this "institutionalist" strand and the work on economic evolution surveyed here.[13]

2. Schumpeterian evolution

For more almost fifty years, from the beginning on the 1900s until his death in 1950, Schumpeter was the leading academic protagonist for an "evolutionary" approach to long-run economic development. His views were very often radically different from those of the great majority of academic economists and, it appears, increasingly so, so that in the years following his death he was more remembered for his insightful commentaries on the contributions from other economists (Schumpeter 1954) than for his own ideas. Although some of his ideas were taken up by others in the decades that followed, sometimes

[12] The interested reader is referred to the extensive work by Hodgson on this subject. For a survey see Hodgson (1998). See also the discussion in Hodgson (1988, 1993, 1999).

[13] There are very few references to Veblen in Schumpeter's work. For instance, in his very extensive account of the development of economic ideas (Schumpeter, 1954), there are only four references to Veblen, all very brief and none of these on evolution. Nelson and Winter (1982) do not refer to any of Veblen's works, nor do Freeman, Clark and Soete (1982). However, both books refer extensively to Schumpeter. Thus, it should be established beyond doubt that while there is a very close relationship between the three streams of literature surveyed here, it is - despite Hodgson (1993)'s enthusiasm for the subject - difficult to prove a relationship between these three streams and Veblen's work.

without reference, a real revival for Schumpeter's ideas and works had to wait until after the world economic slowdown of the 1970s. However, since then the influence of his ideas appears to have been on a steady increase, so that today he is more fashionable than ever. Even among neoclassical economists, whose basic ideas are quite different from those of Schumpeter, the term "Schumpeterian" is now readily accepted as a welcome trade-mark for certain types of theoretical applications that are well within the mainstream.

The Schumpeterian vision

Schumpeter's approach may be seen as an interesting amalgam of the main approaches that he encountered as a student in Vienna around the turn of the century, namely Marxism, the (German) historical school in economics and the (emerging) neoclassical strand . From Marx he took the dynamic outlook, from the historical school the emphasis on historical specificity (with respect to technology, industry/sector, institutions and so on) and from the neoclassicals the need for a micro-based approach, in which evolution is explained through the interaction of individual actors, rather than through some metaphysical force that works its way through history. In fact, the term "methodological individualism" was coined by Schumpeter, who used for the first time in a book in German in 1908 (Swedberg 1989, p. XII). However, although he was a great admirer of contemporary neoclassical analysis, particularly the work by Léon Walras, he did not share its vision:

> *"Walras … would have said (and, as a matter of fact, he did say it to me the only time that I had the opportunity to converse with him) that of course economic life is essentially passive and merely adapts itself to the natural and social influences which may be acting on it, so that the theory of a stationary process constitutes really the whole of theoretical economics and that as economic theorists we cannot say much about the factors that account for historical change, but must simply register them. … I felt very strongly that this was wrong, and that there was a source of energy within the economic system which would of itself disrupt any equilibrium that might be attained. If this is so, then there must be a purely economic theory of economic change which does not merely rely on external factors propelling the economic system from one equilibrium to another. It is such a theory that I have tried to build … It was not clear to me at the outset what to the reader will perhaps be obvious at once, namely, that this idea and this aim are exactly the same as the idea and the aim which underly the economic teaching of Karl Marx. In fact, what distinguishes him from the economists of his own time and those who preceded him, was precisely a vision of economic evolution as a distinct process generated by the economic system itself." (Schumpeter 1937/1989, p. 166)*

It should be clear from this lengthy quote what Schumpeter's aims were. He wanted to develop a theory about economic evolution as a complement (not substitute) to the static equilibrium theory developed by Walras and others. With evolution Schumpeter meant qualitative, economic change brought about through innovation. Or in his on words: "The changes in the economic process brought about by innovation, together with all their effects, and the response to them by the economic system, we shall designate by the term Economic Evolution" (Schumpeter 1939, vol. I, p. 86). In this attempt

Schumpeter was heavily influenced by the dynamic vision that he found in Marx' works.[14]

Technological competition

However, the dynamic vision was not the only element Schumpeter borrowed from Marx. He also took from Marx the idea that capitalist evolution is driven by technological competition between firms. In "Capital" Marx had suggested that the main way for capitalist firms to keep competitive was to increase productivity by introducing new and more efficient machinery. Firms that succeeded in introducing new and more efficient technology would see their competitive position improved (and hence be rewarded by above average profits), while those who failed, Marx argued, would be unprofitable and, eventually, driven out of the market. For the aggregate economy this would imply that capital accumulation and rising productivity would go hand in hand.[15] Schumpeter essentially adapted this argument and made it the centrepiece of his exposition of the evolutionary dynamics. For him, this (technological) type of competition was the true nature of capitalist competition, in contrast to the so-called "price competition" envisaged in traditional text-books:

> *"But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition that counts but the competition from the new*

[14] For a comparative discussion of the works by Marx and Schumpeter see Eliott (1984).

[15] Marx (1954/1956/1959) also thought that the capital-output ratio had to rise, and meant that this in the end would check the tendency for capital and, hence, productivity to grow. He therefore expected capitalism to evolve through periods of alternating booms and crises.

> *commodity, the new technology, the new source of supply, the new type of organization (…) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives. " (Schumpeter 1943, p. 84)*

This quote, although written more than half a century ago, strikes one as utterly "modern". As is evident from the quote Schumpeter extended the Marxian argument by introducing a broader notion of innovation. While Marx had limited the analysis to mechanization (i.e., process innovation) Schumpeter also included a number of other elements such as the development of new products (or new variants of such), the introduction of new types or qualities of raw materials or intermediary products, the creation or exploitation of new markets or new ways to organize business (Schumpeter 1934, 1943).

The economic reward associated with a successful innovation is according to Marx and Schumpeter transitory by nature; it vanishes as soon as a sufficient mass of imitators has successfully entered the scene. However, for Schumpeter this interaction between innovation and imitation also has effects on growth. The "swarming" of imitators that follows the introduction of a successful big innovation implies that the growth of the sector or industry in which the innovation occurs for a while will be quite high. In addition there may be derived effects in the same or related fields because one (important) innovation tends to facilitate (induce) other innovations (Schumpeter 1939, p. 131). Hence, because of such systemic interdependencies, innovations "tend to concentrate in certain sectors and their

surroundings" (ibid, p 100-101) or "clusters" that for a while will grow faster than the economy as a whole. Sooner or later, however, the growth of such a cluster will slow down. Thus, there will be a tendency towards a cyclic development of such "clusters", and - following Schumpeter – this cyclic pattern may contribute to "business cycles" of varying lengths. He even saw this as a possible contributing factor to the alleged "long waves" in economic activity, of a periodicity of half a century or so, which are commonly associated with the name the Russian statistician Kondratief.[16] He warned, however, that "long waves" "cannot be linked to a particular type of innovations as against other types carried out during the same epoch, but is the result of all commercial processes of that epoch" (ibid, p. 168). In fact, Schumpeter's discussion of "long waves" in "Business Cycles" (1939) is quite complex and blended with detailed historical analysis and, as is evident from the quote, it is not obvious that he really wished to put forward a mono-causal explanation of the phenomenon (innovation-induced long waves). Leaving this as it may, it might be noted that Schumpeter's work on this issue, to his own great disappointment, was not at all well received and attracted strong criticism for failing to prove a causal explanation of the alleged "waves" (Kuznets 1940).

Innovation and entrepreneurship

[16] See Freeman and Loucã (2001), chapter 3, for a discussion of Kondratief's "long-wave" theory.

Schumpeter also departs from Marx in making a deliberate attempt to develop a theory of how innovations are created. First of all he adds a definition of innovation (or "development" as he initially phrased it) as "new combinations" of existing resources, equipment and so on (Schumpeter 1934, pp. 65). This "combinatory" activity he labels "the entrepreneurial function", for which, he says, "the defining characteristic is simply the doing of new things or doing of things that are already being done in a new way (innovation)" (Schumpeter 1947/1989, p. 223). This activity (innovation) needs to be distinguished (he argues) from invention (discovery):

> *"As long us they are not carried out into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring entirely different kinds of aptitudes. Although entrepreneurs may of course be inventors just as they may be capitalists, they are inventors not by nature of their function but by coincidence and vice versa." (Schumpeter 1934, pp. 89)*

The reason why Schumpeter stresses this difference is that he sees innovation as a specific social activity (function) carried out within the economic sphere and with a commercial purpose, while inventions in principle can be carried out everywhere such as, for instance, in universities, and without any intent of commercialisation. According to Schumpeter the entrepreneurial function also has to distinguished analytically from the roles of other actors in the firm, such as, the capitalist/financier ("risk bearing is no part of the entrepreneurial function", Schumpeter 1939, vol. I, p. 104) or the manager (that he

tends to associate with the running of relatively simple day-to-day operations).

It is clear what Schumpeter wanted to achieve by making these distinctions. He wanted to create a vocabulary that makes it possible to focus on innovation as distinct from other, related activities. As such his approach seems to be close to that of his contemporary Max Weber who also found it helpful to develop "ideal types" of social phenomena. However, while this may be helpful as first step in exploring an issue, it does in itself not add much to our knowledge about the underlying dynamics. Take for instance the term "new combinations". It seems natural to ask what it is that is combined, and how this "new combination" relates to past and future "new combinations". Schumpeter is rather vague on these points. In later work he uses the terms "industrial mutation" and "creative destruction" for essentially the same phenomenon (Schumpeter 1943, p. 83).[17] One might be tempted to think of the "new" innovations/mutations (the creative part) as building on – and at the same time substituting for – the "old" innovations (the destructive part). In that case one might see this as an "ansatz" to a theory of how industrial knowledge evolves. But this is hardly more than a qualified guess.

There is certainly much more concern in Schumpeter's works for the related issue of the "entrepreneurial function". This is an issue

[17] He describes it as a " process of industrial mutation – if I may use a biological term – that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism" (Schumpeter 1943, p. 83).

that figures prominently both in his earlier and later works. The word "function" points to a system perspective.[18] One might think about capitalist society as a system, in which the introduction of novelty (or "new combinations") is one among several important functions. In his early work "Theory of Economic Development" (1912) Schumpeter argues that "the entrepreneurial function" is a very challenging one to perform. An important reason for this, he points out, has to do with the role played by existing knowledge, habits and beliefs:

> *"(…) knowledge and habit once acquired becomes as firmly rooted in ourselves as a railway embankment in the earth. It does not require to be continually renewed and consciously reproduced, but sinks into the strata of subconsciousness. (…) Everything we think, feel or do often enough becomes automatic (…)" (Schumpeter 1934, p. 84)*

However, "this enormous economy of force", which facilitates "the ordinary routine" at the individual as well as the collective level, at the same time implies that "every step outside the boundary of routine" appears much more difficult. This, Schumpeter argues, has partly to do with the genuine uncertainty of operating outside the routine, the need for firms to act quickly (in spite of uncertainty) and, if not in theory so at least in practice, "the impossibility of surveying all the effects and counter-effects of the projected enterprise" (ibid, p. 85). But, the routine, and the cumulated knowledge on which it is built, may also act as conservative force in itself, because it biases decision-making against the new ways of doing things:[19]

[18] Schumpeter also uses the term "economic system" when discussing "new combinations" (Schumpeter 1934, p. 68).

[19] Note the striking parallel between Schumpeter's discussion here and Kuhn (1962)'s work on the role of paradigms in science.

> *"It is not objectively more difficult to do something new than what is familiar and tested by experience, but the individual feels reluctance to it and would do so even if the objective difficulties did not exist. This is so in all fields. The history of science is one great confirmation of the fact that we find it exceedingly difficult to adopt a new scientific point of view or method. Thought turns again and again into the accustomed track even if it has become unsuitable and the more suitable innovation in itself presents no particular difficulties. The very nature of fixed habits of thinking, their energy-saving function, is founded upon the fact that they have become subconscious, that they yield their results automatically and are proof against criticism and even against contradiction of individual facts. (…) So it is also in the economic world. In the breast of one who wishes to do something new, the forces of habit raise up and bear witness against the embryonic project" (ibid, p. 86).*

To this comes the resistance at the social level such as, for instance, "legal and political impediments". Economically, Schumpeter argues, "this resistance manifests itself most of all in the groups threatened by the innovation, then in the difficulty of finding the necessary cooperation, finally in the difficulty of finding consumers" (ibid, p. 87).

In short, following Schumpeter, there are many factors, working at the individual, group and social level that make it a very challenging task to succeed in innovation. The problem is not so much with the new ideas, which may be simple enough to comprehend, as with their successful economic implementation. To overcome this strong "resistance", Schumpeter argues, more than the ordinary managerial competence is required. It is this "special quality" that he in his early work "Theory of Economic

Development" (1912) associates with individual entrepreneurs. For practical purposes he assumes (without much discussion) that this quality or talent is (normally) distributed across the population.[20] However, this does not necessarily explain why someone qualified for this difficult task should volunteer to carry it out (rather than doing something else). There is of course the economic bonus associated with successful entrepreneurship in capitalist society, which, although transitory by nature, may nevertheless amply reward those who succeed. This argument, although appealing from an economist's point of view, was according to Schumpeter not the only one and perhaps not the most important either. Instead he points to psychological attributes of successful entrepreneurs such as "the dream or will to found a private kingdom" or "dynasty" for which "industrial or commercial success is still the nearest approach (…) possible to modern man" (ibid, p. 93), "the will to conquer: the impulse to fight, to prove oneself superior to others" and finally the "joy of creating". Only the first of these three motives, Schumpeter points out, can be said to relate to "private property" (ibid, p. 94). An implication is, he argues, that in principle entrepreneurship may be taken care of by other "social arrangements" than the type of "capitalistic" economy in which he lived. How that might be done, he points out, is beyond his theme but it is "not insoluble, and may be answered by detailed observation of the psychology of entrepreneurial activity, at least for given times and places" (ibid).

[20] He compares it with the talent for "singing", see Schumpeter 1934, pp. 81 (most people can sing but some better than others).

This remark by Schumpeter is interesting. Not so much, perhaps, for the obvious flirt with contemporary socialist ideas, but for his emphasis on (1) that there may be different ways to organize the entrepreneurial function in different societies (or time periods) and (2) that such differences can only be understood with the help of historical, case-oriented research. These were ideas that Schumpeter should return to towards the end of his career, particularly in connection with his monumental study on "Business Cycles", published in 1939, and in the late 1940s when he joined a cross-disciplinary "Research Center for Entrepreneurial History" at Harvard University. In a series of papers from this period he outlined a broad, historical view of the role of the entrepreneurial function in capitalist evolution:

> *" … the entrepreneurial function need not be embodied in a physical person and in particular in a single physical person. Every social environment has its own ways of filling the entrepreneurial function. (…). Again the entrepreneurial function may be and often is filled co-operatively. With the development of the largest scale corporations this evidently become of major importance: aptitudes that no single individual combines can thus be built into a corporate personality …" (Schumpeter, 1949/1989, pp. 260-261)*

Obviously this is a much more general perspective than that advanced in his early work. He did, however, not develop a theory of corporate entrepreneurship similar to that of individual entrepreneurship. Instead he suggested that the best way to increase our understanding about the role of entrepreneurship in economic evolution would be to aim for a better integration of historical and theoretical work on the

subject (ibid, p. 271) or as he put it in another paper from this period on the same issue: "Cumulation of carefully analysed historical cases is the best means of shedding light on these things, of supplying the theorist with strategic assumptions and banishing slogans" (Schumpeter, 1947/1989, pp. 227-228). Here, in his insistence on the integration of historical and theoretical analysis, we see the lasting influence of the so-called "historical school" on his thinking. Without "detailed historic knowledge", he argued, "the study of time series must remain inconclusive, and theoretical analysis empty" (Schumpeter 1939, p. 220). The "ultimate goal" for his work on "economic change in historic time" was as he phrased it "a reasoned (=conceptually clarified) history" (ibid).

Capitalist evolution: From competitive to trustified capitalism

Schumpeter's early work has often been accused of "glorification" of the typical individual entrepreneur. Although he responded to this criticism with indignation,[21] it is nevertheless true that his main emphasis in that work was on the individual entrepreneur and that he largely ignored "corporate entrepreneurship", or organized innovative activities in large firms. Writing in the beginning of the 1900s he

[21] "…our analysis of the role of the entrepreneur does not involve any "glorification" of the type, as some readers of the first edition of this book seemed to think. We do hold that entrepreneurs *have* an economic function as distinguished from, say, *robbers*. But we neither style every entrepreneur a genius or a benefactor to humanity, nor do we wish to express any opinion about the comparative merits of the social organisation in which he plays his role, …" (Schumpeter 1934, p. 90)

might perhaps be forgiven. But it is obvious that during the decades that followed a lot changed in that regard. In later work he suggested that a distinction should be made between two types of capitalist systems, labelled "competitive" and "trustified" capitalism, with the former reflecting the traditional entrepreneur-led dynamics analysed in his early work, and the latter an emerging system in which innovation was mainly taken care of by "giant firms" that played a leading role in the economy (ibid, p. 96). But despite his general appeal to historical work and case studies, he did not himself try to analyse or discuss how innovation was carried out within such large firms.

What he did, however, was to point out that such a change might have implications of a political and a macro- economic nature. Politically because it might substantially reduce the social strata that had played the leading role in the smaller firms, and which in Schumpeter's view had played an important role in developing and sustaining democracy. Hence (he feared that) it might facilitate the transition towards "socialism" in some form. However, despite some very provocative remarks on the subject in "Capitalism, Socialism and Democracy" (1943), it turns out that what he foresaw was probably no more than a "mixed economy" of the kind that evolved in most parts of the Western world after 1950. This is, for instance, clear from his entry on "Capitalism" in Encyclopaedia Britannica from 1946 in which he talks about a "tendency toward the shifting of economic activity from the private to the public sphere, or, as we may also put it towards increasing *bureaucratisation* of economic life,

coupled with an increasing dominance of labour interests" (Schumpeter 1946/1989, p.208).

As for the economic consequences it is important to bear in mind that Schumpeter did not think of large firms as a threat against (technological) competition ("perfect competition" he had always regarded as pure fiction). For instance, in "Business Cycles" from 1939 he points out that despite the tendency towards concentration the share of the economy controlled by very large firms "is as yet not great enough to dominate the picture in any country" (p.97). He added:

> *"Even in the world of giant firms, new ones rise and others fall into the background. Innovations still emerge primarily with the "young" ones, and the "old" ones display as a rule symptoms of what is euphemistically called conservatism." (ibid)*

Hence, in Schumpeter's view, technological competition between firms should be expected to continue to drive capitalist evolution "even in the world of giant firms". What might change, perhaps, was the discontinuous (cyclical) character of this process, because in a system in which "technological research becomes increasingly mechanized and organized"(ibid, p. 109), a smoother path for innovation, and a weakening of the tendency for innovation to spur cyclic economic activity, ought to be expected.

The Schumpeterian contribution

Schumpeter is arguably the most influential evolutionary economist ever. He combined a broad evolutionary perspective focusing on the

co-evolution of technology, organizations and institutions, derived from classical political economy (Marx), with a micro-based approach inspired by early neoclassical analysis and a strong emphasis on the necessity to integrate theoretical work with historical analysis. It is probably the latter that made his work appear out of touch with mainstream economics, characterized, as it increasingly was, by an axiomatic and mathematic structure. In fact, to the extent his work was referred to at all, it was often misunderstood. This holds, for instance, for the so-called "Schumpeterian hypothesis" in industrial economics (Kamien and Schwartz, 1982), which states that large firms with market power are more innovative than small ones. Whatever the merits of this hypothesis, it is difficult to see that it has a strong basis in Schumpeter's own work. In fact, Schumpeter seemed to be much more concerned with the difference between new and old firms than between small and large firms (see, for instance, Schumpeter 1939, p. 97).

Leaving this at it may, it is important to point out that Schumpeter's main contribution to evolutionary economics was in an entirely different area. What he set out to do, and also to large extent succeeded in, was to develop an understanding of how innovation, explained as a social phenomenon, shaped economic evolution. The main contours of this theory were set out already in his early work. In that work innovation was portrayed as a the outcome of a constant struggle between devoted individuals, endowed with a vision of new and better ways of doing things, and an inert social environment with a strong preference for "business as usual". A major factor behind this

social resistance against new ideas, Schumpeter argued, was the power of the old ideas, beliefs and routines, which through repeated practice had been "as firmly rooted in ourselves as a railway embankment in the earth" as he put it. This theory, with its emphasis on the interaction between the "routine breaking" minority and its inert social surroundings, certainly goes a long way in explaining many real world phenomena. But it misses an essential point, innovation increasingly goes on in groups and other organized contexts, and this means that a theory of innovation must include the organizational dimension. Schumpeter of course at a later stage acknowledged this but did not do much to rectify it (apart from pointing to the need for more case studies and historical research, which – although commendable – does not in itself provide a theory or explanation).

If he had included the organizational dimension he might have found that there were other aspects of his approach that might be in need of revision. For instance, it is clear that in many organized contexts, such as in the large, science-based firms of today, there is a lot of invention going on as well. Hence Schumpeter's sharp distinction between invention and innovation, although relevant in some circumstances, may be questionable in many present-day contexts. However, if invention and innovation increasingly must be seen as aspects of the same phenomenon, we obviously need a theory that allows us to analyse it as such. Schumpeter, with his (almost) exclusive focus on the heroic fight between the lonely entrepreneur and his inert social surroundings, has little to offer on this point.

Another shortcoming of Schumpeter's approach, and also related to his emphasis of the importance of the role of the entrepreneur, is his deliberate neglect the role of continuous learning (minor innovations) for economy-wide economic and social change. This does not mean this his point of view is not relevant. But to understand the role of innovation in modern societies in all its complexity, what Schumpeter termed "economic evolution", we need to cast the net wider than he preferred to do.

3. Exploring the evolutionary dynamics: Lessons from the applied literature

The decades that followed Schumpeter's death constituted a low tide for evolutionary economics.[22] Instead economists gradually adapted formal, mathematical equilibrium approaches of the type that Schumpeter admired but had found to be of little value for understanding economic evolution. This applied for instance to areas such as economic growth and international trade. However, while there was very little work on going on with an explicit evolutionary foundation, evolutionary ideas soon started to prop up in applied work. The reason for this was of course, as Schumpeter would have expected, that the formal equilibrium models had very little to say about qualitative economic changes in historical time (or evolution). Hence applied researchers were forced to look elsewhere for guidance in interpreting observed developments in, for instance, economic growth and international trade. In fact, what many of them came up with were causal arguments very similar to the Marx-Schumpeter model of technological competition outlined in the previous section, though often without acknowledging the source for these ideas.

[22] Surely there was something going on. In the US, for instance, there was in the early 1950s a discussion between Alchian, Penrose and others on the use of biological analogies in economics (see the next section). In Europe the economic philosopher Hayek used evolutionary ideas to among other things discredit socialist "planning". But there was very little work on economic evolution in the spirit of Schumpeter.

The dynamics of technology, growth and trade

This holds, for instance, for much of the applied work that emerged in the 1960s trying to explore the factors behind the observed pattern of international trade. The starting point for many of these efforts was the finding by Leontief (1953) that actual patterns of trade seemed to deviate from what the equilibrium approach would predict. As a response to this challenge several authors (Kravis 1956, Posner 1961, Hirsch 1965 and Vernon 1966) came up with the suggestion that the reason had to do with the fact that innovation constantly disrupts the equilibrium forces, so that the observed patterns of international trade reflects the interaction between innovation and diffusion of technology at a global scale rather than some given distribution of natural and/or man-made assets across different countries or regions. Hence, following this so-called "neo-technological" approach, to be able to understand the evolution of international trade patterns one needs to research the factors behind innovation and diffusion processes at a global scale. This resulted in the decades that followed in a large number of empirical studies focusing on innovation, diffusion and trade in various sectors/industries.[23]

While a lot of the empirical literature that followed was quite eclectic, during the 1980s a number of contributions emerged based more explicitly on Schumpeterian logic. Much of this work initiated from the Science Policy Research Unit (SPRU) at the University of Sussex (UK), which from its inception in 1965 had been directed by

[23] Some of this literature is surveyed in Fagerberg (1996) and in greater depth in Wakelin (1997, ch. 2-3).

Christopher Freeman. Freeman himself had during the sixties, in parallel with similar research efforts elsewhere inspired by the neo-technological approach, been engaged in research on innovation-diffusion in the electronics and chemicals industries (Freeman, Fuller and Young 1963, Freeman, Harlow and Fuller 1965, Freeman et al. 1968). During the decades that followed several researchers at SPRU attempted expand and generalize this type of work to a more full-fledged theory of the dynamics of technology, growth and trade (Dosi and Soete 1983, Fagerberg 1988a, Dosi, Pavitt and Soete 1990) and to back it up with solid empirical evidence based on extensive use on data on technological activities, particularly R&D and patent statistics (Pavitt 1982, Soete 1981, 1987). This attempt was based on the Schumpeterian notion of innovation as the driving force of economic change. Hence, innovation was assumed to be the primary factor behind long-run differences in specialization patterns in international trade, trade and economic performance while other, more "conventional" factors, while relevant, were relegated to secondary position or assumed to be of a more short-term nature.

As in the case of applied research on trade, the field of applied growth research was in the 1970s in a state of flux due of the failure of the standard equilibrium approaches to cope with the observed economic phenomena (see Fagerberg 1994). Among the approaches that gained popularity during the 1970s and 1980s several had a strong "evolutionary" flavour. For instance, the economic historian Alexander Gerschenkron (1962) had on the basis of his studies of European catch-up processes suggested that growth should be

analysed as the result of interaction between endogenous, path-dependent change at the frontier and the ability of late-comers to adapt to this dynamics through adequate political, institutional and economic changes. Hence, following his view, technological and economic catch-up was a very demanding enterprise. This approach was adopted by among others Moses Abramovitz in a series of analyses of differences in cross-country growth performance over the long run (Abramovitz 1979, 1986, 1994).[24] In another effort to explain cross-country differences in growth performance, Cornwall (1977) portrayed capitalist evolution as a process of endogenous growth and "transformation" (qualitative change) driven by "dynamic economies of scale" ("Verdoorn's law"), catching up processes and the ability to mobilize resources for change (investment). The manufacturing sector plays an especially important role in this account, since it is assumed to be the centre for "dynamic economies of scale" or learning in the economy. A third approach from this period, more Keynesian in flavour (Thirlwall 1979, Kaldor 1981), puts a lot of emphasis on world demand and the "income elasticities of demand" for a country's exports and imports in determining a country's growth performance. However, as pointed out by Kaldor, such elasticities are not really exogenous but reflect "the innovative ability and adaptive capacity of

[24] Abramovitz (1994) suggested to use the concepts "technological congruence" and "social capability" to analyze the growth of latecomers. The first concept refers to the degree to which leader and follower country characteristics are congruent in areas such as market size, factor supply etc. The second points to the various efforts and capabilities that backward countries have to develop in order to catch up, such as improving education, infrastructure and, more generally, technological capabilities (R&D facilities etc.).

its manufacturers" (Kaldor 1981, p, 603), which hence need to be taken into account (Fagerberg 1988a).

Although verbally many of these writers did put a lot emphasis on innovation, their modelling approach and subsequent empirical testing did not explicitly take it (or R&D) into account. Hence these models failed to take into account a vital aspect of the evolutionary dynamics. To rectify this, Fagerberg (1987, 1988b) suggested an empirical model based on Schumpeterian logic that includes innovation, imitation and other efforts related to the commercial exploitation of technology as driving forces of growth. The model was applied to a sample of countries on different levels of economic and technological development (including so-called "newly industrializing" or "semi-industrialized" countries). It was concluded that:

> *"to catch up with the developed countries, the results obtained here suggest that semi-industrialized cannot rely only on a combination of technology import and investments, but have to increase their national technological activities as well" (Fagerberg 1988b, p. 451).*

Hence, following this approach, catch-up or convergence is by no means guaranteed. It depends on the balance of innovation and imitation, how challenging these activities are and the extent to which countries are equipped with the necessary capabilities.[25] According to Verspagen (1991), who has implemented this model into a non-linear

[25] Recent work in this area (Fagerberg and Verspagen 2002) indicates that innovation is becoming more important for growth over time, while imitation tends to be more demanding the before. Thus, the authors argue, the diverging trends are getting stronger, and they see that as related to current technological trends ("the ICT revolution").

setting that allows for both catch-up and a "low-growth trap", poor countries with a low "social capability" are the ones at risk of being "trapped".

We have under this heading emphasized how evolutionary ideas, and in particular what we have called the Marx-Schumpeter model of technological competition, have been important organizing devices for attempts to come to grips with important economic phenomena that traditional equilibrium approaches at the time could not accommodate. As a result there is now a strong applied research tradition in this area that continuously produces new insights into the workings of innovation, growth and trade.[26] However, some of the strong ambitions of the (unofficial) SPRU research program of the 1980s, most typically conveyed through Dosi et al. (1988) and Dosi, Pavitt and Soete (1990), have arguably not been met. Despite some attempts (Verspagen 1993, Dosi and Fabiani 1994, Dosi et al. 1994) to cross-fertilize the type of research discussed here with the formal evolutionary modelling to be presented later, a more general evolutionary theory of the dynamics of technology, growth and trade - whatever that might imply - is arguably still out of reach. It is possible that this has to do with the arrival in the 1990s of another theoretical strand, so-called "new growth theory", which has invigorated the equilibrium theory by incorporating some aspects of evolutionary reasoning, particularly of what we have called the Marx-Schumpeter model of technological competition (Romer 1990,

[26] See, for instance, the recent contributions by Laursen (2000) and Meliciani (2001).

Grossman and Helpman 1991, Aghion and Howitt 1992). We will return to this issue in the concluding part of this paper.

The interaction between technological and institutional change and "long waves"

With the big unexpected slump in economic activity in the Western world in the 1970s the interest in theories focusing on explaining alternating periods of growth and crises/stagnation increased sharply, and several authors presented new interpretations of long run growth based on such perspectives. Schumpeter was as noted very interested in this topic, to which he thought his work might contribute, and this interest has been shared by several other economists with an evolutionary leaning (Mensch 1979, Kleinknecht 1987, Tylecote 1992, Freman and Louca 2001). This has to do with Schumpeter's insistence of capitalist evolution as a succession of "industrial revolutions"[27] and, in particular, role played by the interaction between technological and institutional change in this process. As is well known he argued that important innovations do not occur at random but tend to cluster in certain time-periods and sectors of the economy, and that this is likely to give rise to (or contribute to) a discontinuous pattern of growth known as "long waves"[28] (Schumpeter 1939). This assertion was as previously noted received

[27] "The atmosphere of industrial revolutions – of "progress" – is the only one in which capitalism can survive" (Schumpeter 1939, p. 1033).

[28] We are for the sake of space as well as the purpose of this paper not going to survey the entire literature on long waves, much of which arguably has little to do with evolutionary economics. However, there are certain aspects of this debate that point to issues of wider relevance and which we will consider in the following.

with great scepticism in the academic community and did not receive much attention in the decades that followed. However, with the big slump of the 1970s, this part of his work suddenly became fashionable again.

A very stimulating account of long run growth (or evolution) based on Schumpeterian logic was presented by Gerhard Mensch in his book "Stalemate in Technology – Innovations Overcome the Depression" published in 1979 (German edition 1976). As Schumpeter before him Mensch argued that important ("basic") innovations come in bunches that give rise to a long period of sustained growth. Associated with this, Mensch points out, we also witness the spread of social and political thrust and support for the leading industries and their "way of doing things" and, simultaneously, increasing resistance against new, innovative ventures in other areas that do not conform well to the received pattern. But sooner or later the potential for further growth in the leading industries becomes depleted, and as a result overall growth slows down and, eventually, depression occurs. One effect of depression is however to weaken the public thrust in the old – and resistance against new – ideas. This is assumed to facilitate the emergence of a new cluster of innovations that – the book suggests – overcomes the economic depression. Mensch argued that this interpretation of Western economic history is consistent with observed peaks and slumps in innovative activity.

This interpretation of events was, however, questioned by Freeman, Clark and Soete (1982). They argued that the sample of

innovations considered by Mensch was biased and that a more even-handed reading of the evidence would lead to other conclusions. Although it was true, the authors admitted, that innovations tended to come in bunches, such bunches could be shown to occur in booms as well slumps. Moreover, they criticized the assumptions of causality implicit in Mensch' account:

> *"What matters in terms of major economic effects is not the date of the basic innovation (important though this may be for other purposes); what matters is the diffusion of this innovation – what Schumpeter vividly described as the "swarming" process (…) In fact, it may often be delayed by a decade or more until profitability is clearly demonstrated or other facilitating basic and organisational innovations are made, or related social changes occur. Once swarming occurs it has powerful multiplier effects in generating additional demand (…). This in turn induces a further wave of process and applications innovations. It is this combination of related and induced innovations which gives rise to expansionary effects in the economy as whole" (Freeman, Clark and Soete 1982, p. 65).*

Hence, in Freeman, Clark and Soete (1982) the focus is deliberately shifted from dating of individual innovations to a system perspective in which the process of innovation-diffusion is studied as an inter-related whole. Within such a perspective diffusion ceases to be seen as a passive, mechanical process in which a given technology is gradually spread to a population of potential adopters, as has indeed often been the case in diffusion research, and is instead approached as an inter-active, creative process in which the technology itself may change quite radically and other, related innovations be induced. The authors suggest the term "new technology (or technological) system"

for such "constellations of innovations which are technically and economically interrelated" (Freeman 1991, p. 223). As an example of such a system Freeman mentions the cluster of (inter-related) innovations that gained force from the 1930s onwards in petrochemicals, synthetic materials and plastics machinery (ibid).

Such "technological systems" need not lead to "long waves" but may do so if a system is very large and of long duration or if "the bandwagons" of several different systems "roll" together (Freeman, Clark and Soete 1982, p. 67), the latter generally being seen as the most probable alternative. This, however, raises the quite intricate question of what mechanism could possibly contribute to the coordination of the life-cycles of a set of technological systems in a way that would lead to such "long waves". An evolutionary scheme developed to explain such simultaneous "rolling", suggested by Carlota Perez (1983, 1985), has received wide attention and has recently been applied to historical evidence by Freeman and Louca (2001) in their very extensive account of capitalist evolution. The basic assumption in Perez' scheme is the emergence of a "key factor",[29] a cheap, almost universally available input, characterized by rapidly falling costs, that potentially can be used in many sectors of the economy and therefore may have very pervasive effects.[30] One may think of examples such as electricity, oil/gas and microelectronics. The industries that produce this input and those that

[29] Freeman and Louca (2001, p. 147) suggest the term "core input" instead of "key factor".

[30] The idea of such "core inputs" is very similar to the idea of "general purpose technologies" suggested more than ten years later by Bresnahan and Trajtenberg (1995). See also Helpman (1998).

uses it intensively – so called "carrier branches" - grow very fast as the "key factor" become more widely diffused. Moreover there will be induced effects in a number of other industries such, as for instance, services. The diffusion process is also likely to give rise to a number of innovations in how to manage and organize processes using the new input. Gradually, through trial and error, new "common sense" ways of managing and organising the new technology will emerge. Perez uses the terms "new technological styles" – or alternatively "new techno-economic paradigms" – for these new ways to manage and organise economic life (which eventually may influence almost all kinds of activities). However, the new style of management and organisation that is emerging is likely to come into conflict with existing ways to organise and mange the economic activities (based, in fact, on older technologies), and this may substantially delay the diffusion of the new key factor and slow down growth. Thus, following this view, the degree of "match" – or "mismatch" between the technological dynamics on the one hand and social, organisational and institutional conditions on the other, enters as an important determinant of economic evolution.

The point raised by Perez is an important one. Technological dynamics has its own logic and it needs not correspond to the internal logic of other social subsystems. Freeman and Louca (2001) suggest analysing capitalist evolution as the interplay (co-evolution) between five different systems (science, technology, economy, culture, politics), each with its own dynamics, and this paves the way for a whole range of issues related to "match" and "mismatch" of such

systems. However, whatever the merits of these insights, it is difficult to see why such interaction (or lack of such) between different social subsystems should give rise to so-called "long waves" in economic activity (as is sometimes suggested). That there may be booms and slumps of various lengths is clear enough. But the "wave" analogy requires something more than that, a strong regularity, and this has not been proven. In fact the empirical basis for assuming that "long waves" in the GDP of the world economy actually exist, is weak (von Tunzelmann 1995). Moreover, there is a strong "mechanistic" flavour of this "long wave" literature that is arguably quite alien to the evolutionary approach. Economic evolution, at least as described in this paper, is about qualitative changes in production, organizational forms, institutions etc. in historical time, not about cycles that repeat themselves century after century at constant pace.

Systems of innovation

Even though the public interest in the "long waves" debate soon faded some of the underlying ideas, based on Schumpeterian logic, continued to be very influential in applied research. In particular, during the 1980s and 1990s many researchers came to embrace the Schumpeterian idea that the process of innovation and diffusion of technology has a strong systemic character. The starting point for much of this was a growing interest among applied researchers for Schumpeter's insistence on the cumulative and path-dependent character of innovation (Dosi

1988), [31] and the finding from applied innovation research (Kline and Rosenberg 1986) that the various stages of the innovation process tended to be filtered together in a web of feedbacks and loops (rather than as a linear procession). From the end of the 1980s a series contributions emerged focusing on the systemic aspects of innovation-diffusion and the relationship to social, institutional and political factors.[32] However, although some social, institutional and political factors may be of a global relevance, most are quite tightly knit to the national or sub-national (regional) level. Thus with the integration of social, institutional and political factors into analysis the territorial dimension of innovation-diffusion naturally followed.

Thus, a central theme in this literature has been how to link technological and territorial dynamics. One strand in this literature, initiated by Freeman (1987) and followed up by Nelson (1993), has focused on the national level and the "national system of innovation", defined as "the networks of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman 1987, p. 4). In practice what

[31] As originally suggested by Schumpeter, a radical (or "revolutionary") innovation tends to define certain paths for further exploration, including what questions to ask, how to search for solutions etc. Sahal (1985) used the term "technological guideposts" to characterize this phenomenon, while Dosi (1982) – inspired by Thomas Kuhn's work on "scientific revolutions" (Kuhn 1962) – suggested the term "technological paradigm" to characterize such systemic interdependencies. He proposed the notion "technological trajectories" for the paths defined by these paradigms. Nelson and Winter (1982) similarly use the term "natural trajectories" for such paths.

[32] For an overview, see Edquist (1997), ch. 1 and the collection of papers on the subject edited by Edquist and McKelvey (2000).

many of these contributions do is, for each particular country, to try to identify and de scribe the most important private and public actors, organizations and institutions that take part (or influence) R&D and innovation in the country.[33] According to Freeman (1995) who was the first to publicly use the term "national system of innovation" (Freeman 1987), the inventor of the term was not himself but Lundvall (1988, 1992). However, Lundvall's approach differs from that of Freeman and Nelson in several respects.

While Freeman and Nelson take a macro-view, and focus on the big national players in R&D, Lundvall's approach is more "micro" and based on a particular view of how learning occurs in economic systems. Innovation, he argues, should be seen as a new combination of knowledge drawn from different sources (Lundvall 1992, p. 8). But in contrast to Schumpeter Lundvall sees no reason for focusing solely on "big" innovations. The cumulated impact of small "routine"-type innovations may be just as great. Moreover, while Schumpeter mainly focused on the person who performs the new combination and the feedback from the economic environment, Lundvall particularly emphasizes the access to the different types of knowledge that take part in the combinatory dynamics. The sources for this knowledge, he argues, are to a large extent to be found in the interfaces between the firm and its surroundings, particularly in the interaction with customers and suppliers. Hence, an innovation system in Lundvall's

[33] The initial study by Freeman focused on Japan while the later contributions from Nelson and others included studies of 15 different countries on different levels of development. More recently the OECD has carried out a large comparative project on national systems of innovations that is in the process of being published (OECD 2001).

sense is an economic system characterized by dense and enduring relationships between firms, customers and suppliers.

But why should such systems be national? Lundvall gives at least two different reasons. The first has to do with history: The economic structure of a country has evolved slowly through time and – although subject to change – has strong enduring character. So, if the major industries and firms of a country happen for historical reasons to be closely knit together, as seems to be the case in many small, advanced countries, the probability that the innovation dynamics of the country has a strong national aspect would be high. The second has to do with common culture, language and institutions, which arguably facilitates interaction between firms and their environments and, hence, affects learning positively. However, although there are many examples of countries that fit this description on both points, many don't. For instance, some countries may for historical reasons be integrated in the economies of neighbouring countries. Moreover, some countries may be multi-lingual, or be culturally divided, or have a federal structural that allows for considerable diversity in institutions and policies and so on. Hence it seems clear that the degree of "systemic-ness" of a country's innovation activities may differ a lot across countries. In fact, Fagerberg (1995), in a rare attempt to test some aspects of this "systemic-ness", found that there were marked differences across countries in this regard. While some countries such as Japan, the Nordic countries and some others appeared to fit the theory quite

well, some European countries (particularly Austria, France and the UK) did not.

This raises the question of how to define the boundaries of innovation systems. Several authors have in fact pointed out that boundaries of such systems cannot be assumed a priori to follow national borders (Carlsson and Stankiewicz 1991, Cooke et al. 1997, Edquist 1997). Carlsson and Stankiewicz (1991), in particular, have argued that the territorial dimension of innovation systems may differ from one technological area to another. They prefer, therefore, to use the notion "technological systems", which they define as "a dynamic network of agents interacting in a specific, economic/industrial under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology" (ibid, p. 93).[34] Their approach is also characterized by a much stronger focus on the "economic competence" of the agents (which they identify largely with firms). Economic competence, as they see it, is a "scarce and unequally distributed resource" (ibid, p.94), which is critical for the ability expand "the economic opportunity set" and unleash the potential of a given network into a fully-fledged "technological systems". Such systems, they argue, often (but not always) have a spatial dimension, sometimes national but often regional (or local):

> *"it is important to emphasize that high technological density and diversity are properties of regions rather than countries. They are the result of local agglomeration of industrial, technological and scientific activities. At the heart of such agglomerations one usually*

[34] Their view of the "technological system" as "a dynamic network" is, as the authors themselves point out, closely related to Erik Dahmén's work on "development-blocks" (Dahmén 1970).

> *finds a "knowledge industry" consisting of universities, engineering schools, R&D laboratories of large companies, small R&D firms, government laboratories, a variety of consulting firms, and other forms of activities whose primary output is knowledge or competence. These local agglomerations of industrial and technological activity constitute dense nodes in a web of local and distant contacts maintained by the actors involved" (ibid, p. 115).*

The central role played by the interaction between universities, firms and governments in regional and local knowledge agglomeration has also been emphasised by Etzkowitz and Leydesdorff (2000) in their so-called "triple-helix" approach. That innovation systems often have a regional basis has also been noted by Braczyk et al. (1997) who suggest to use the notion "regional innovation systems" for such systems. The point that there are large and persistent differences in the way innovation and diffusion occurs across different industries and sectors has recently been emphasised by Breschi and Malerba (1997). They have coined the term "sectoral systems of innovation" to characterise this phenomenon, which has also acquired a lot of attention in formal evolutionary modelling (see the next section).

The innovation-systems literature is a relatively new and rapidly growing field of research. It has had a large impact, not least on policy-makers, by discrediting the so-called "linear model of innovation" (basically a "production function" approach), which used to be the basis for much policy thinking. In its place we have got a more holistic perspective that focuses on the interdependencies among the various agents, organisations and institutions that take part in the (innovation) system. While the traditional approach has mainly

been used to legitimate subsidies to public and private sector R&D (due to its alleged public-good nature), the innovations-systems approach leads to a stronger focus on the economic system's capacity for taking new technologies into use (its "carrying capacity") and on the ability of the various actors to interact in the creation of new technology. Despite these achievements, the innovation systems approach – based as it is on mixture of theoretical conjectures and generalisations from empirical research – has not yet generated a theory and/or methodology that is sufficiently well developed to allow for systematic empirical work. Arguably, to achieve this it would need to substitute its current vague appeal to "system-thinking" with a more precise theoretical analysis of how these systems actually work. One way to do this might be to aim for some cross-fertilization with the more formal evolutionary theories to be considered in the following section.[35]

[35] See Niosi et al. (1993) and Freeman and Louca (2001) for interesting discussions of the relationship between innovation-systems and evolutionary theorizing.

4. Modelling evolution

The attempts to develop formal models of economic evolution date back to the 1970s to a series of papers by Nelson and Winter, summarised in their 1982-book "An Evolutionary Theory of Economic Change". Nelson and Winter share with Schumpeter the focus on "capitalism as an engine of change". What they do, it is argued, is elaborate and formalize his view: "Indeed the term "neo-Schumpeterian" would be as appropriate a designation for our entire approach as evolutionary" (Nelson and Winter 1982, p, 39). There is something to this argument. However, what Nelson and Winter and Schumpeter have in common is primarily the focus on technological competition as the driving force of capitalist development. This was as previously shown an idea that Schumpeter had borrowed from Marx, so in a sense Nelson and Winter's modelling efforts resemble Marx' work. As in Marx' (and Schumpeter's) account the firms in Nelson and Winter's models compete by reinvesting their profits in new and more productive technology and/or equipment. Those that succeed are rewarded by high profits, and hence grow faster than others, while those who fail fall in the background, and risk being eliminated altogether.

This being said there are also some major differences between Nelson and Winter's approach and that of Schumpeter (and Marx before him). First, as noted, Nelson and Winter clearly recognize the link between from evolutionary theorizing in biology and their own

work, while Schumpeter was highly critical to attempts to apply theories from natural sciences into economics. However, also Nelson and Winter denounce pursuing biological analogies for their own sake or for the purpose of constructing a general evolutionary theory applicable to both natural and social sciences (Nelson and Winter 1982, p. 11). Their explicit theoretical strategy is to pick and choose whatever they find useful in the explanation of economic change and leave behind what does not suit their purpose independent of how important it may be in other evolutionary approaches (sciences).[36] Second, building on earlier work by Herbert Simon and others, they add a much more elaborate theoretical perspective on how firms behave, based on the idea of "procedural" or "bounded" rationality. Third, through their modelling efforts they open up for greater diversity in firm behaviour (and strategies) and industry characteristics, and allow for a clearer distinction between the technological activities of firms and the actual outcome of these activities (which, they argue, has a strong stochastic element). And finally they downplay the importance of major discontinuities in economic evolution, a point that was essential for Schumpeter. For better or for worse Nelson and Winter's work has a much more "gradualist" flavour.

[36] "We are pleased to exploit any idea from biology that seems helpful in the understanding of economic problems, but we are equally prepared to pass over anything that we find awkward, or to modify accepted biological theories radically in the interest of getting better *economic* theory …" (Nelson and Winter, 1982, p. 11)

Cognitive foundations: "Bounded" or "procedural" rationality

In designing the micro fundament of their approach Nelson and Winter embrace the common criticism of traditional neoclassical economic theory for basing itself on a completely unrealistic view on what humans are able to do (Simon 1959, 1965, Cyert and March 1963).[37] Humans, it is argued, are simply not able to calculate the consequences of all possible actions and choose between them in the way neoclassical economists usually assume. The world is too complex, the mass of information too large and the cognitive abilities of humans (and even large scale computers) too limited to allow for this type decision-making. What humans actually do, following this view, is to practice a simpler and less demanding type of decision-making called "bounded" or "procedural" rationality, a main form of which is so-called "satisficing" behaviour. "Satisficing" is based on the idea that actors will stick to a behavioural rule as long as it leads to a satisfactory outcome. Only when this is clearly not the case any longer the actor will start to search for alternatives. This will continue until he is satisfied, i.e., found a rule that complies with his (given) criteria.

These ideas may be – and have been – exploited in different ways. For Simon this led among other things to his work on "artificial intelligence", that is computer-mediated problem solving of complex problems (Andersen 1994). Cyert and March (1963) in their book "A

[37] See Andersen (1994) for a more elaborated treatment of the relation between Nelson and Winter's work and the work of Simon and the behaviouralists.

behavioural theory of the firm" used this perspective to analyse decision-making within the firm. It was Alchian (1950) that in his classic paper "Uncertainty, evolution and economic theory" introduced this perspective to the analysis of competition between firms.[38] What matters, Alchian argued, is not motives but results. Actors may (and will) follow all kind of rules but only those that lead to a successful outcome, i.e., are profitable, will in the long run survive the competitive struggle. In Alchian's view, the possibility to imitate successful rules also greatly enhanced the efficiency of this selection process. This perspective, he admitted, was much closer to evolutionary biology than to traditional economics but many of the implications of the latter was still supposed to hold. He summed it up as follows:

> *"All the preceding arguments leave the individual economic participant with imitative, venturesome, innovative, trial-and-error adaptive behaviour. Most conventional economic tools and concepts are still useful, although in a vastly different analytical framework – one which is closely akin to the theory of biological evolution. The economic counterparts of genetic heredity, mutations and, and natural selection are imitation, innovation and positive profits." (Alchian 1950, pp. 219-220)*

Selection, multiple solutions and path-dependence

Although Alchian's analogies with biological evolution proved controversial at the time (Penrose 1952), his approach was embraced

[38] However, in developing this view, Alchian does not refer to Simon's work.

by Friedman (1953) who turned the argument that only profitable firms would survive the competitive struggle into a defence of the neoclassical assumption of maximizing behaviour (that Alchian actually had critized): "unless behaviour of businessmen in some way or other approximated behaviour consistent with the maximation of returns, it seems unlikely that they would remain in business for long" (Friedman 1953, p 22). This way of reasoning was criticized by Winter (1964, 1971) who pointed out that the crucial thing about evolution (and selection) is that it takes time. Hence, Winter argued, to explain how one type of behaviour come to dominate one needs a theory that allows for different types of behaviour to persist (reproduce) through time, something akin to role of genetic inheritance in evolutionary biology. Which type of behaviour, if any, that would eventually come to dominate, cannot not be identified without knowing the characteristics of the different types of behaviour and the relevant market conditions (selection environment). Different market conditions can easily lead to different types of behaviour being selected (Winter 1971, p. 244-5).

Winter's argument points to an important aspect of evolutionary theorizing: that outcomes generally are uncertain, that there may be many different outcomes (with widely different characteristics) and that which one will in the end succeed (be selected) may depend a lot on the concrete circumstances (including the initial conditions). This is especially so, as pointed out by Arthur (1994), if there are increasing returns involved, as he thinks often (but not always) is the case. Increasing returns, whether resulting from indivisibilities (f.i. in

R&D investments), learning by doing, using and so forth or network externalities, may lead to a situation in which small differences in initial conditions determine long-run outcomes. Any technology, firm or location that happen to get an initial advantage may in the presence of increasing returns come into a situation in which these advantages are amplified though time, while those that initially were at a disadvantage risk being marginalized or driven out of the market. This may happen even if the latter technology, firm or location actually had a potential for performing better had it received the support given to the former (i.e., "selected" early on). Hence in the presence of increasing returns there is no guarantee that the solution "selected" by market forces will in any sense be "optimal". Arthur discusses several examples of this, for instance the QWERTY keyboard, initially introduced to slow down typing in order to avoid "jamming" of types on mechanical typewriters, see also David (1985). The QWERTY standard has survived (and prospered) long after this problem ceased to exist, and despite the fact there has been more efficient keyboards on the market. Arguably, this is a typical example of how network externalities and associated "switching cost" may lead to selection of an inferior technology.

Arthur makes a valid point when he emphasizes the possibility of multiple equilibra and the importance of initial, historical conditions in the presence of increasing returns. However, as pointed out by Andersen (1994), as long as there is no creation of variety, agents "will always end up (…) bound to a particular (optimal – suboptimal) behaviour" (Andersen 1994, p.150). Thus, the problem,

following Andersen, is not so much to explain why "lock-in" to a specific path may occur as to explain how such path-dependent processes may be checked (and changed).[39] Arthur does not allow for conscious innovation activities in his models but he does consider learning (see Arthur 1994, chapter 8). The model, based on Holland's "classifier systems" (Holland and Miller 1991), is calibrated on data generated by psychological experiments. Arthur arrives at the conclusion that

> *"If exploitation outweighs exploration, learning may converge too rapidly on promising-looking actions. What is crucial then to the emergence of the optimal action is a slowing down of the speed of convergence, so that learning has time to explore less promising alternatives. The data – not the algorithm – show that in human learning such slowing down does not occur. I would therefore expect the result that human learning is path-dependent, nonpredictable and not necessarily optimal to be validated …" (Arthur 1994, p. 150-1).*

The Nelson-Winter model

Nelson and Winter (1982) follow Alchian (1950) in applying the principle of "bounded" rationality to the behaviour of firms (rather than individuals). Generally, Nelson and Winter tend to look at firms (or organizations) as quite "conservative" (resistant to change):

> *"We think of organizations at being typically much better of the tasks of self-maintenance in a constant environment than they are of major change, and much better in changing in the direction of "more of the*

[39] Arthur does not discuss in any detail how such path-dependent processes may be checked, apart from the possible impact of heterogeneity of preferences (Arthur 1994, p. 61).

> *same" than they are at any other kind of change"(Nelson and Winter 1982, p. 9-10).*

The firms are assumed to follow decision rules (or "routines"), and it is these routines that are the "social equivalent" of genes in biology. Routines determine behaviour (together with impulses form the environment), are heritable (as part of the "organizational memory"[40] of the firm) and selectable (through the fate of the firms that apply them). However, despite the strong inertia emphasised by Nelson and Winter, routines may also change (the equivalent of mutation in biology). Following Cyert and March (1963) Nelson and Winter (1982) try to take this into account by introducing a hierarchy of routines, in which routines at a higher level govern the modification of routines at a lower level. Hence, in Nelson and Winter's approach, the process that leads to routine change is also governed by routines. They use the term "search" for such "routine-guided, routine changing processes" (Nelson and Winter 1982, p. 18).

Although most firms may be quite satisfied with how they are doing things, some firms will at any point of time be engaged in search for new and more efficient routines. The outcome of such search is uncertain, there is no guarantee that the search will result in a more efficient routine than the one actually in place. Only if it by comparison is found to be superior, the firm will adopt the new routine. A firm can do search in two different ways, through

[40] Organizational memory is according to Nelson and Winter kept alive through practicing: "… organizations "remember" a routine largely by exercising it" (Nelson and Winter, 1982, p. 99).

developing a new routine itself from scratch (innovation) or adapting an already existing routine in use elsewhere (imitation). Innovation is assumed to be more demanding than imitation, but also potentially more rewarding. In both cases there are search costs, R&D expenses being the most typical example, and these costs rise with the difficulty of the search. The probability of finding a better routine will in any case strongly depend on how much the firm spend on R&D and other search costs.

How much a firm is willing to invest in search (and what types) is given by the character of its search routines and its ability and willingness to finance such investments. The ability to finance search will to a large extent depend on how profitable the firms is, since Nelson and Winter assume that investments are financed through retained profits.[41] Since large firms can afford to spend more on R&D than small firms, they are also more likely to find a better routine. Large firms also get more out of the introduction of a new and better routine since they have a higher volume of production (to which the new routine may be applied). Hence, large firms tend to be at a competitive advantage in Nelson and Winter's models, and this is also confirmed by simulations that consistently show that in the course of time an initially dispersed industry will tend to dominated by one or a few firms. To counteract this tendency Nelson and Winter introduce the (somewhat controversial) assumption that large firms (with more market power) have a higher profit target (price/cost ratio) than

[41] External finance, to the extent that is allowed, is also assumed to depend on profitability, so this does not introduce any qualitative change in the working of the model.

smaller firms, so that in the end the large firms will show some "restraint" in driving the small ones out of business.[42] An alternative way to keep competition alive, suggested by Winter (1984), would be to allow for entry by firms from the "outside world".

The models suggested by Nelson and Winter are generally too complex to allow for analytical solutions. The dynamics are therefore best explored through simulations. This also has the advantage that one may vary the value of key parameters to reflect different assumptions on how the dynamics vary across different countries, industries firms and time periods. A number of different simulations are presented in the book. One of these focuses on the long run growth of the US economy, using a data set first explored by Solow (1957). It was shown that the model can be calibrated to reproduce the historical data quite well. Although the authors were quite satisfied with this result, one might side with Silverberg and Verspagen in the quest for more added value of such exercises: "… a more "positive approach" to scientific development would require an evolutionary theory to provide fresh results of its own and not only benchmark itself against neoclassical results …" (Silverberg and Verspagen 1998, p. 249).

Other simulations explore differences in "industrial dynamics" between different "innovation regimes". For instance, they distinguish between an "innovation regime" in which the technological frontier (growth of "latent" productivity) is assumed to progress independently of firm's own activities (the "science based" regime),

[42] See Andersen (2001) for a discussion of this assumption.

and another in which technological progress is more endogenous and depend on what the firms themselves do (the "cumulative" regime). They also vary the ease/difficulty of innovation and imitation and how "aggressive" large firms are in exploiting their advantages vis-à-vis the smaller firms. Different combinations of these assumptions may give rise to different scenarios. However, overall the tendency towards industrial concentration (one or a few large firms dominating) appears strong, especially if large firms pursue their advantages aggressively. There is also a tendency towards large imitating firms doing relatively well at the expense of innovators and smaller firms. In the case with endogenous technological progress it was shown that this may lead to a situation in which productivity is substantially below what it could have been (had the industrial structure been more diversified).[43]

Further work

Nelson and Winter's seminal contributions in this area have spurred further work along several different dimensions, of which we will we mention three.[44] First there is a large and growing body of work related to firm behaviour, particularly the role of knowledge in firms, to which Nelson and Winter's analysis of the role of routines, skills, "organizational memory" and tacit and codified knowledge in firms is

[43] In such a case, Nelson and Winter argue, "The hidden hand has throttled the goose that lays the golden eggs" (Nelson and Winter 1982, p. 348).

[44] See also the survey by Nelson (1995). That survey is, however, mostly about how evolutionary ideas have developed (in biology for instance) and diffused into various aspects of social science, including law, sociology and economics. It also discusses socio-biology.

recognized as an important contribution. We shall not discuss this theme in detail here, although we will revisit it briefly in the concluding section. However, this may very well end up as the most important long-run impact of their work. In a citation analysis of Nelson and Winter's book Meyer (2001) shows that the book is heavily cited (and increasingly so) but mainly in journals devoted to management/organisation. In fact of the ten journals that cited the book most frequently six fell in this category. Of the remaining two were explicitly "evolutionary" (Journal of Evolutionary Economics and Journal of Economic Issues) and two were specialised journals for which the topics of Nelson Winter's work were especially relevant ("Research Policy" and "Journal of Economic Behaviour and Organization"). The lack of the large mainstream economics journals on this list is noteworthy.

Second, Nelson and Winter's attempt to model evolution has led to the appearance of a variety of formal growth models exploring the evolutionary dynamics. Some of these, such as Iwai (1984 a,b), Conlisk (1989), Metcalfe (1994, 1998) and Andersen (2001), aim at illustrating the central mechanisms through mainly analytical methods. According to these contributions the heart of the evolutionary dynamics is the principle, known as Fisher's theorem of natural selection, that "selection improves average fitness in the population, and that the rate of improvement in average fitness is equal to the variance of fitness" (Metcalfe 1998, p.61).[45] Hence,

[45] Fisher was as English geneticist who discovered the basic principle of "evolutionary dynamics: that change is driven with respect to rate and direction by variety of behaviour evaluated within a common environment" (Metcalfe

growth is in these models driven by variety. But selection continually improves the average performance so that if there are no new injections of variety into the system, in the end all actors in a given environment will perform equally well. Thus, thus as Andersen puts it, "the selection process uses up its own fuel" (Andersen 2001, p.17). It follows therefore that the creation of new variety is of paramount importance in evolutionary growth models (without which endogenous growth would simply vanish). However, this is an issue on which many of the evolutionary theorists have relatively little to say.

One approach, adopted by Iwai (1984 a,b), is simply to assume that there is some exogenous force (invention) that allows the potential for innovation to grow (as in Nelson and Winter's "science-based" regime), and that it is a matter of chance whether firms will succeed or not in exploiting this potential to make an actual innovation.[46] In Conlisk (1989) technological progress is (as in Nelson and Winter's "cumulative" regime) modelled as incremental improvements in existing technologies and dependent on firms' own efforts (investments). Hence growth is more "endogenous" in the latter case than in the former. Both approaches are of course highly stylised and offer few if any original insights into the determinants of innovation. Metcalfe on his part concedes that he "discuss innovation without saying anything of substance about the origins of

1998, p.61). The standard reference is Fisher (1930).

[46] Iwai models the occurrence of innovations as a Poisson process, see Iwai (1984 a), p. 174 and (1984b), p. 399. For a discussion of Poisson processes in an evolutionary context, see Silverberg and Lehnert (1994).

innovations" and adds that "whether this process of endogenous innovation is capable of being understood in all but its broad outlines seems to me to be doubtful" (Metcalfe 1998, p.7). He therefore confines himself to the task of analysing the selection process as coordinated by the market environment for given levels of variety.

Other formal models in this tradition do in various ways extend the perspective outlined above by considering other factors not sufficiently taken into account so far such as product innovation, demand, labour markets, several production sectors, vintage-capital, a financial sector, learning etc. Since this generally greatly complicates the models, such extensions are in most (though not all) cases analysed with the help of simulations (as in the original Nelson and Winter approach).[47] The analysis presented in Nelson and Winter (1982) was based on a one-sector approach that only allowed for process innovation. Saviotti (2001), building on Pasinetti (1981) and earlier work by himself (Saviottti 1996), suggests a novel (analytical) framework that also may allow for the inclusion of product innovation and demand. An improved modelling of how new investments are financed, in the tradition from Kalecki (1954) and Wood (1975), is developed by Possas et al. (2001) in a (simulation) model, which also – following Silverberg, Dosi and Orsenigi (1988) – includes "learning by doing" as a complement to search processes of the type initially suggested by Nelson and Winter (1982). A richer representation of how innovation and learning occur, that also allows

[47] Silverberg and Verspagen (1998) present an overview and discussion of selected models including some of the technical aspects involved.

for firms to change their R&D strategies on the basis of received feedback, is suggested by Silverberg and Verspagen (1994 a,b). This is shown to allow for successive "stages of development" characterized by different combinations of market structure, R&D intensity and growth. Silverberg and Lehnert (1993, 1994) emphasize the importance of dating of investment (a vintage structure) for evolutionary models. In fact it is shown that this factor alone is capable of generating "long waves" of economic behaviour quite independently of what happens to innovation.

Third, as is evident from the above, Nelson and Winter's approach naturally lends itself to exploration of differences in dynamics across different types of "regimes" or industries/sectors. In a paper entitled "Schumpeterian competition in alternative technological regimes" Winter (1984) presented a version of the model aimed at explaining the differences between Schumpeter's "entrepreneurial" and "routinised" modes of innovation as he put it, the first being characterised by a multitude of small, entreprenurial firm and the second by a few, big firms with a lot of organized R&D. This distinction, which is more or less identical to what is elsewhere often labelled "Schumpeter Mark I" and "Schumpeter Mark II", is commonly associated with the so-called "Schumpeterian hypothesis" (Kamien and Schwartz 1982)[48] that the latter (more concentrated) "regime" should be expected to be more conducive to innovation than the former. In modelling this difference Winter also opened for entry

[48] As pointed out in section 2 of this paper, it is not obvious that this view was adhered to by Schumpeter (despite his name being used as a label for this hypothesis).

by new firms (drawing to a large extent on the external sources of knowledge) and for (small, adaptive) changes in the innovation strategies of firms. He suggested that the difference between the two regimes had to do with differences in the role played by external and internal sources of technology (or knowledge), with the former (leading to a lot of new entry) playing the leading role in the "entrepreneurial" regime and the latter (favouring industrial concentration and discouraging entry) being of most importance in the "routinised" one. Hence the difference in market structure commonly associated with "the Schumpeterian hypothesis" is here explained as the combined result of differences in knowledge bases, entry conditions and selection.[49] More recently, Nelson, Winter and others have argued that such modelling efforts, to be really useful, need to be more tightly linked to findings and "problems" identified by empirical research (Malerba et al. 1999). Following this programmatic statement, Nelson and Winter have recently engaged themselves in attempts to add more historical realism to their modelling approach by adapting it to the evolution of the post-war computer industry (Malerba et al. 1999) and a similar attempt has also been made for the pharmaceuticals industry.[50]

[49] There have also been some other attempts to explore how market structures develop though time with the help of evolutionary models, see in particular Silverberg and Verspagen (1994a), and the survey by Silverberg and Verspagen (1998). However, Silverberg and Verspagen appear to arrive at the opposite conclusion of Winter (see Winter 1984, p. 315, Figure 8.) when they conclude that "a highly competitive regime and high R&D activity emerge jointly" (Silverberg and Verspagen 1994 a, p. 218).

[50] See Malerba and Orsenigi (2001).

The contribution from formal modelling

What has the contribution of formal models of economic evolution been? Although the ideas date back to the early 1950s, formal models of economic evolution did not start to appear before the 1970s. The book "An Evolutionary Theory of Economic Change" by Nelson and Winter, published in 1982, was a milestone. In the years that followed a number of new contributions in this area emerged. However, while some of the initial contributions in this area appeared in mainstream US economics journals, such as American Economic Review and Quarterly Journal of Economics, authors in this area report that they have found it increasingly difficult to get their work accepted in these forums. Although many of the contributors in this area lived in the US, many of the most important contributions were actually published in European journals, particularly Economic Journal, and – increasingly – in specialized journals such as Research Policy, Journal for Evolutionary Economics, Industrial and Corporate Change etc. Hence it is difficult to avoid the conclusion that the evolutionary modelling does not appear to have been accepted as welcome addition to the discipline by hardcore mainstream economics (particularly in the US).

We may, however, phrase the question a bit more narrowly and instead ask what the contribution of this "new wave of evolutionary theorists", as Hodgson (1993) puts it, to the evolutionary agenda has been. Then it becomes clear that this literature has helped to clarify several issues that are central on this agenda today. First, a much

clearer focus has been put on the importance of "population thinking" for understanding economic phenomena. In contrast to traditional neoclassical economics, which aims at understanding macro-phenomena by extrapolating the characteristics of a "representative agent" to the entire population (so-called "typological thinking"), evolutionary economics – and in particular the formal literature - looks at the social and economic consequences of interaction within populations of heterogeneous actors. Arguably, many of the economic phenomena that we observe may be better understood as the outcome of such interaction processes (in historical time) than by reference to the characteristics of a supposedly "representative agent". Take, for instance, the long debated issue of the hypothesis that large firms are more innovative than small ones. Rather by trying to explain this relationship by exploring the special characteristics of, say, large firms, a "population thinking" perspective to the issue would mean looking at the evolutionary process behind the observed pattern. Then one might for instance find that in a world driven by technological competition, selection will make innovative firms grow and less innovative ones shrink. The likely result of such a process is, of course, that innovative firms become large and non-innovative firms small just as hypothesised. This, however, has nothing to do with the special characteristics of firms of different sizes but is entirely explained by the evolutionary "population dynamics".

Another issue that the "new wave of evolutionary theorists" has helped to clarify is the important role played by variety in economic evolution. As shown by several contributions in this area variety is the

source of growth in evolutionary models. However, selection by definition reduces variety. So unless there are some new injections of variety in the system (endogenous) growth will disappear and the system will converge towards a stationary state. This is essentially the explanation of the much-debated phenomena of "lock-in" and "path-dependency". If there is no new variety created, or selection becomes "too strong" and variety creation "too weak", the system will be locked into a particular path/state. Thus, creation of new variety – or innovation – is absolutely essential for economic evolution. Hence the question of what influences innovation emerges as a very important point on the evolutionary agenda. This is, however, a topic on which the evolutionary modellers have had relatively little to say, and some of them even appear to be quite comfortable with that. Metcalfe (1998), for instance, argues that "the population perspective does not require a theory of how variety is generated" (p. 24) and that "we are interested in the evolution of populations, not in the change of individual entities which make up these populations" (p. 25). It is difficult, however, to see how such a position can be defended, given that in the absence of variety creation there will be no evolution.

The question of how new variety is generated is closely linked to the issue of how the actors think, learn and act. This is, of course, the very issue on which Nelson and Winter made their most original contribution. What they did was to apply the ideas of "procedural rationality" and "satisficing behaviour", initially developed for individual actors, to the actions of entire firms. Hence firms' actions – included search for new or improved routines if necessary – became

entirely routine-based. However, routines are also allowed to change through the interplay between search processes (with stochastic outcomes) on the one hand and selection processes on the other hand. The formulation of this approach was clearly an important scientific achievement that has yet to receive the academic recognition it arguably deserves. Still one might argue that there are questions that have not been satisfactory dealt with so far. The most basic and important is arguably what role remains for purposive human actions in all this? Is there a built-in bias against devoted “routine-breakers” in this approach as one might suspect? In that case there may be an important source of new variety that is overlooked.

5. Conclusions

Are the different strands of analysis discussed in this paper sufficiently similar to be grouped together under the same heading? Is there a common core? This is a matter of considerable controversy. Hodgson, in particular, argues that

> *"the invocation of Schumpeter's name by the new wave of evolutionary theorists is both misleading and mistaken. (..) These authors make repeated claims that that their work is in a "Schumpeterian" or "neo-Schumpeterian mould. There are superficial similarities (..) But at a deeper level there is a complete divergence."(Hodgson 1993, p. 149-50).*

Andersen (1994) similarly observes that "large parts of the theoretically oriented new evolutionary economics (…) have (…) a loose empirical orientation and a weak relationship to the old evolutionary economics" (Andersen 1994, p. 186).

These writers are of course correct in pointing out that there are differences between what Andersen calls "the old evolutionary economics" – which he largely associates with Schumpeter's work – and what Hodgson has labelled "the new wave of evolutionary theorists" (Nelson and Winter onwards). Moreover there are different perspectives within "the new wave" as well. However, such differences do not exclude a common core. In contrast to Hodgson we going to argue that many of these differences are in fact relatively superficial and that there at a deeper level is a well-defined common core that ties these different strands together. This core consists of

three interrelated arguments that together define the evolutionary dynamics. The first of these specifies the evolutionary driving forces, the second defines a set of strong regularities of evolutionary processes and the third is concerned with the relationship between evolution, cognition and action.

Although the terminologies of "old" and "new" evolutionary economics differ somewhat, the basic argument that innovation is the main factor behind long run economic development is the same. The more innovation, the higher the degree of variety and the more dynamic the economy will be. Without innovation, the economy will settle down in a well-defined state characterized by little or no growth. This is the first argument. The second argument states that evolutionary processes are characterized by strong regularities (Dosi 1988). For instance, there is the sequence of innovation and imitation, i.e., that innovators are amply rewarded at first but that these advantages will vanish when imitators succeed in entering the scene. Another important regularity concerns the role of innovation as a pointer to further change, i.e., that an important innovation opens up "a window of opportunity" that primarily facilitates the development of certain types of applications in certain types of contexts, and leads to links between innovations or technologies sharing the same context ("clustering"). Related to this is the important role of learning (incremental innovations) - based on accumulated experience - along the path set out by an important innovation. Still another has to do with the influence of users (and other parts of the "selection environment") in inducing, improving and selecting innovations.

The third argument is concerned with the role actors (and cognition) in the evolutionary process. At a first glance one might perhaps get the impression that this is the point where the Schumpeterian tradition and the more recent stream of thought (Nelson and Winter and others) part from each other. However, by closer scrutiny it is easy to see that there is a lot of common ground. For instance both strands basically look at economic knowledge as a set of routines (for action) that are reproduced (remembered) through practice. The arguments are also the same: The combined effect of the unpredictability of the future (the open-ended character of evolution) and the potential complexity of economic decision-making ("the impossibility of surveying all the effects and counter-effects", Schumpeter 1934, p. 85) forces firms to abandon the ideal of "rational man" and go for a more "economic" (realistic) strategy.

The problem, of course, is how to allow for sufficient change, or creation of novelty, within such an environment. Although evolutionary theorists have approached this question in different ways, their suggestions have always been based on the assumption of heterogeneous agents. The early Schumpeter simply assumed a population of individuals with different talents and/or psychological attributes, some of which would be more inclined towards innovation than others. Later he acknowledged that much innovative activity was embedded in organisations (firms) but without providing a framework for analysing this phenomenon. Nelson and Winter, in contrast, explicitly focuses on innovation as an organisational phenomenon, which, however, is unequally distributed across the population of

firms. The reason is, they argue, that firms differ in their inclinations. Hence, what Nelson and Winter do is to apply Schumpeter's principle of heterogeneous agents to the firm level (rather than to individuals). This, however, raises many new questions, that we can only briefly touch upon here. For example, what is the relationship between individual cognition and collective cognition? How do firms "think"? These and similar issues are currently are at the forefront of research in both business studies and evolutionary economics (which increasingly appear as strongly linked fields of research).[51]

How different is evolutionary economics from other strands of research? We have already mentioned that the boundaries between evolutionary economics and business studies/management are increasingly blurred. Another strand that arguably has imported many ideas from evolutionary economics is the so-called "new growth theory". There are two mechanisms of growth that are highlighted by this literature, incremental learning and investments in R&D (innovation). The first, advocated by among others Lucas (1988, 1993), is to some extent similar in spirit to some of the ideas of Arthur discussed above and leads to similar conclusions in terms of "path dependency" etc. The second, pioneered by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), explains growth through the combined private and public aspects of investments in R&D. Basically what these latter theories do is to take into account is the well-known fact that knowledge may be at least partly

[51] For an example of this trend, see the influential management book by Nonaka and Takeuchi (1995).

"excludable" through the use of intellectual property rights (patents etc.). This, in the view of these authors, provides the necessary economic incentive to innovation since the innovator, by exercising his intellectual property rights, may retain some of the rents accruing to an innovation. But some of it also spills over to rest of the economic system by increasing the social pool of public knowledge, which helps foster new innovations and, hence, allows growth to go on. This line of reasoning resembles some of the arguments from Schumpeter and the innovation systems literature, particularly their emphasis on the cumulative aspects of technology. However, by closer scrutiny the differences appear more striking.

First, while the evolutionary literature focuses on a population of heterogeneous, "boundedly rational" agents that try to find their way through trial and error (in an environment characterized by radical uncertainty), in the new growth theory this is reduced to one "representative", "perfectly rational" agent endowed with perfect information etc. Second, in the evolutionary approach economic knowledge is analysed as a distributed phenomenon that to a large extent resides in firms in the form of shared "routines" that are reproduced through practice. New growth theorists, in contrast, look at knowledge as a "public good", or a stock of publicly available information, that is potentially available free of charge for anyone had it not been for certain legal arrangements that limit this somewhat. Hence, the two streams of thought, while agreeing on the importance of innovation for long run economic development and some of the implications, actually look at the world through very different lenses.

One might argue, however, that each approach focuses only a subset of the economically relevant knowledge, and that further theoretical and empirical research on the implications of the different forms of economic knowledge for economic change is needed to arrive at a more comprehensive understanding of the role of knowledge in economic evolution. Such a discussion is actually already well under way (Cowan et al. 2000, Ancori et al. 2000).

The many unresolved issues illustrate the essentially "open" character of this area of research. Obviously there is a lot of unfinished business here. This also implies that one cannot draw very firm conclusion on policy matters. For what it is worth, however, evolutionary economics provides a different perspective on policy than the one advocated by neoclassical economics. As is well known the latter has its main emphasis on the alleged failure of competitive markets to deliver socially needed public goods, to which "knowledge" is assumed to belong, that hence needs to be subsidized or provided by the state. The evolutionary approach, however, downplays the public-good aspect of much economic knowledge and hence puts a question mark on policy prescriptions that are solely based on public-good assumptions. Moreover, from an evolutionary perspective there is no such thing as an "optimal" rate of growth. Hence it is left to politics to decide whether or not the economic system is performing in a satisfactory way. If it needs to be invigorated there are two main mechanisms that follows form evolutionary reasoning. The first would be to attempt to increase the economic system's ability to generate new variety. For instance,

rather than subsidizing R&D in well-established firms in traditional sectors, one might put the resources into new types of activities or actors, not necessarily with the expectation that these would do extremely well, but because the entire system (including the traditional sectors) might benefit from such increased diversity. The second would be to focus on the economic system's capacity to absorb innovations, what in evolutionary theory is often called the system's "carrier capacity". This would for instance mean to find ways to overcome the inertia, or "resistance to new ways" as Schumpeter phrased it, that according to evolutionary thinking is characteristic for economic and social systems.[52]

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[52] Such policies need not be limited to the private sector but could equally well focus on the sectors in which the government is in charge such as, for instance, education, health, social security and so on. Fagerberg et al. (1999) suggest the term "diffusion-oriented policies centred around social needs" for such initiatives. The purpose of such initiatives would, of course, not be expected to invigorate the public sector only but have consequences for the entire economic system.

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