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Schumpeter and the revival of evolutionary economics: an appraisal of the literature*

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Abstract. During the last two decades we have seen a revival of interest in the works of Joseph Schumpeter and "evolutionary" ideas in economics more generally. A professional society honouring Schumpeter's name has been founded, and linked to it we have had for more than fifteen years now a professional journal devoted to this stream of thought. However, it has been argued that, despite these developments, the link between Schumpeter's own work and the more recent contributions to evolutionary economics is in fact rather weak. This paper considers this claim. Based on an analysis of Schumpeter's contribution to economics the paper presents an overview and assessment of the more recent literature in this area. It is argued that although there are important differences between Schumpeter's work and some of the more recent contributions, there nevertheless remains a strong common core that clearly distinguishes the evolutionary stream from other approaches (such as, for instance, so-called "new growth theory").

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1 Introduction

For more almost fifty years, from the beginning on the 1900s until his death in 1950, Joseph Schumpeter was the leading academic protagonist for an "evolutionary" approach to long-run capitalist development. His views were very often radically different from those of the great majority of academic economists and, it appears, increasingly, 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 others took some of his ideas up in the decades that followed, a real revival for Schumpeter's ideas and works had to wait until after the world economic slowdown of the 1970s. Since then we have seen a surge of interest in the works of Schumpeter and "evolutionary" ideas in economics more generally. A professional society honouring Schumpeter's name has been founded and linked to it we have had for more than fifteen years now a professional journal – Journal of Evolutionary Economics – devoted to fostering this stream of thought.

However, despite these developments it has been argued that the link between Schumpeter's own work and the more recent contributions to evolutionary economics is in fact rather weak. 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, pp. 149–150).

Andersen similarly points out 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). This raises the important question of how "similar" the different strands that are commonly classified under the evolutionary heading really are. Is there a common "core"? And – if so – how should it be defined? Or are the differences on closer scrutiny larger than commonly assumed, as asserted by Hodgson? The purpose of this paper is to make a contribution to the discussion of these issues, with the hope that this may also help to improve our ability to analyse capitalist dynamics (or evolution). We pursue this by making a thorough assessment of the three streams of evolutionary thought that we consider to be the most relevant: Schumpeter's own contribution,[1] the (mostly applied) "neo-schumpeterian" literature attempting to use Schumpeterian concepts and theories to understand the working of the capitalist economy, and the more formal literature on "evolutionary modelling" associated with the names of Richard Nelson and Sidney Winter. On the basis of this assessment, we raise questions of how much the different contributions considered actually have in common, and what the differences and similarities are when

[1] Since we primarily focus on Schumpeter's contribution to evolutionary economics, and not on his life or the context in which he developed his ideas, many of the issues traditionally raised in the secondary literature on Schumpeter will not be central here. Interested readers may consult one of the biographies on Schumpeter (Allen, 1991; Stolper, 1994; or Swedberg, 1991). See also the very stimulating interpretation of his work by Shionoya (1997).

compared to other approaches (such as, for instance, the so-called "new growth theory").

Although an effort was made to take the most central contributions into account, it goes without saying that a single paper cannot do full justice to such a vast area of research. This is particularly true for the applied neo-Schumpeterian literature that has expanded very considerably in recent years. What we did was to focus on some selected areas of research (at the expense of others[2]) that we believe convey some of the general lessons. Furthermore, although the three strands of research considered here clearly are the most important for the issues under discussion, the term "evolutionary" is also used in other contexts in economics and social science, and it would clearly have been interesting to explore the connections. Unfortunately, space considerations preclude discussing the relationships between the different types of research that use the evolutionary label here. However, in many cases there seems to be a considerable difference in focus compared to the contributions discussed in this paper. For instance, while the contributions considered all share the Schumpeterian focus on capitalist evolution as an open-ended process of qualitative change (driven by innovation), others often use the term to signal an affection for theoretical approaches or techniques borrowed from (evolutionary) biology (something to which Schumpeter was very critical[3]). Moreover, many of these other users do not share Schumpeter's keen interest in capitalist dynamics, but focus instead on totally different topics such as, for instance, game theory,[4] human and cultural evolution in very long perspective (covering thousands of years or more)[5] or methodological issues arising from comparisons between natural and social sciences.[6] A strand that sometimes uses the evolutionary label, and which arguably is closer in spirit to the literature discussed here, is the so-called (old) "institutionalist" strand in economics and sociology associated with Veblen's works.[7] However, although we do not wish to deny the potential relevance that this type of work might have for the future development of evolutionary economics (Hodgson, 1993, 1999), in practice there has been very little (if any) interaction between this "institutionalist" strand and the work on economic evolution discussed in this paper, and we are not going to pursue this comparison further here.[8]

[2] For instance, the rapidly growing literature on the dynamics within specific industries, sectors or technological fields, to a large extent based on Schumpeterian logic, will not be systematically covered here. For some recent contributions see Mowery and Nelson (1999) and the Special Issue (August 2002) of *Industrial and Corporate Change* on Industrial Dynamics.

[3] Schumpeter (1934), p. 57

[4] 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. 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.

[5] For a discussion of some of these issues see Witt (1993, Introduction) and Nelson (1995).

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

[7] For a survey see Hodgson (1998). See also the discussion in Hodgson (1988, 1993, 1999).

[8] 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), the few references to Veblen are all

2 Schumpeterian evolution

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[9] 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 at the level of the overall economy (or nation). In fact, the term "methodological individualism" was coined by Schumpeter, who used it 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 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

very brief and none of these is on evolution. As for the more recent literature considered here, Nelson and Winter (1982), for example, do not refer to any of Veblen's works nor do Freeman, Clark and Soete (1982). However, the two latter books refer extensively to Schumpeter confirming the close links between his works and subsequent writings.

[9] The "German historical school" is shorthand for a widely diffused approach to economics in Germany from the mid nineteenth century onwards. Writing in a period of rapid industrialization and economic and social change, many of its proponents advocated the need for industrialization to be accompanied by adequate social policies (reforms) by the state. This put them in opposition to the liberal ("laissez-faire") approach often associated with the classical (and later neo-classical) schools. Advocates of the historical school (with Gustav von Schmoller as the leading figure) criticised the deductive basis of such policy recommendations and emphasized the need for theorizing to be based on insights derived from detailed, case-oriented, historical research (which they pursued with great vigour). They also held the classical/neoclassical conception of (economic) man to be much too narrow and emphasized the plurality of (economic) motives and the need for a broad (multidisciplinary) approach. It has been argued that a long-lasting influence may be found in the development of American institutionalism (Schinzinger, 1987) but this interpretation is controversial (Hodgson, 1993, p. 291). Reinert (2002) argues that the historical school influenced the case-oriented methodology still taught at Harvard and other business-schools. For treatments of Schumpeter's relationship to the historical school, see Shionoya (1997), Ebner (2000) and Freeman and Louçã (2001, chapter 2).

> 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 of economic evolution[10] as distinct from the static equilibrium theory developed by Walras and others. Yet he was, as noted, a great admirer of Walras and neoclassical equilibrium theory. In fact, in the early phase of Schumpeter's career, fellow German economists generally regarded him as an advocate of the (emerging) neoclassical perspective (Shionoya, 1997). This combination of high esteem for neoclassical equilibrium theory, while simultaneously doing everything to break away from (or to transcend) it, has often been characterized as paradoxical (Allen, 1991; Freeman and Louçã, 2001). However, the explanation seems to be the very simple one that Schumpeter from the very start was a methodological pluralist who believed different approaches to be relevant for different problems (Shionoya, 1997):

> "I am convinced that the contentions of almost all "schools" and of all individual authors are *correct*, most contentions are *true in ways* for which they are meant and *for the purposes intended.* (. . . .) Each method has its concrete areas of application, and it is useless to struggle for its universal validity." (Schumpeter, 1908, pp. *vi* and 7, cited after Shionoya, 1997, p. 96.)

Hence, Schumpeter saw the neoclassical equilibrium theory as an elegant illustration of the power of the equilibrating forces in the economy, abstracting as it did from any qualitative changes that might occur. These equilibrating forces were in his view real and strong and would, in the absence of qualitative change (innovation), force the economy into a stationary state. But in the real world such a stationary state would never (or only occasionally) be reached because such equilibria would constantly be disrupted by innovation. To study such processes of qualitative change through time, Schumpeter argued, a different approach, more dynamic and historical in nature, was required and it was this he set out to develop.

Technological competition

Schumpeter was, as noted, heavily influenced by the dynamic vision he found in Marx' works.[11] But this 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

[10] 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).

[11] The main reference is Capital (3 vols.), see Marx (1954/1956/1959). For a comparative discussion of the works by Marx and Schumpeter see Eliott (1984).

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 that 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. Schumpeter essentially adopted 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 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 and new ways to organize business (Schumpeter, 1934, 1943).

The economic reward associated with a successful innovation is, according to Marx and Schumpeter, transitory in 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 will, for a while, 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, pp. 100–101) or "clusters" that may for a while 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, commonly associated with the name of the Russian statistician Kondratief.[12] 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

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

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, 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).

Innovation and entrepreneurship

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". Innovation, he argues, needs to be distinguished from invention (discovery). The reason 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 be 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 (whom he tends to associate with the running of relatively simple day-to-day operations).

The notion of "entrepreneurial function" points to a system perspective.[13] 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[14] work *Theory of Economic Development* 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

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

[14] First German edition 1911, second, revised edition 1926. Published in English in 1934.

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:[15]

> "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 by 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, for instance, "legal and political impediments".

In short, following Schumpeter, there are many factors, working at the individual, group and social level, that make success in innovation a very challenging task. 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 *The Theory of Economic Development* associates with individual entrepreneurs. For practical purposes he assumes (without much discussion) that this quality or talent is (normally) distributed across the population.[16] 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 in 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 the 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,

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

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

he points out, is beyond his scope 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).

This remark by Schumpeter is interesting. Not so much, perhaps, for the obvious flirt with contemporary socialist ideas, but for his emphasis on the possibility (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 understood with the help of historical, case-oriented research. These were ideas Schumpeter would return to towards the end of his career, particularly in connection with his monumental study *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 not, however, develop a theory of corporate entrepreneurship similar to that of individual entrepreneurship. Instead he suggested that the best way to increase our understanding of 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, "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 on his thinking of the "German historical school" in economics.

Capitalist evolution: From competitive to trustified capitalism

Schumpeter's early work has often been attacked as "glorification" of the typical individual entrepreneur. Although he responded to this criticism with indignation,[17] it is nevertheless true that the main emphasis in that work was on the individual entrepreneur, and that he largely ignored "corporate entrepreneurship" and organized innovative activities in large firms. Writing in the beginning of the 1900s he might perhaps be forgiven. But it is obvious that, during the decades that followed

[17] "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)

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, the former reflecting the traditional entrepreneur-led dynamics analysed in his early work, and the latter referring to an emerging system in which innovation was mainly taken care of by "giant firms" that played a leading role in the economy (Schumpeter, 1939, p. 96). 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. In terms of politics, the change 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. 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.[18] 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* 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.

[18] This is, for instance, clear from his entry on "Capitalism" in Encyclopaedia Britannica from 1946 in which he writes about a "tendency toward the shifting of economic activity from the private to the public sphere, or, as we may also put it, toward increasing *bureaucratisation* of economic life, coupled with an increasing dominance of labour interests" (Schumpeter, 1946/1989, p.208).

The Schumpeterian contribution

Schumpeter is generally recognized as the most influential evolutionary economist of all times.[19] 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. What he set out to do, and also to a large extent succeeded in doing, was to develop an understanding of how innovation, explained as a social phenomenon, shapes economic evolution. The main contours of this theory were set out already in his early work. In that work, innovation was portrayed as 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". This theory, with its emphasis on the interaction between the "routine breaking" minority and its inert social surroundings, certainly goes a long way to explaining many real world phenomena. But it misses an essential point, namely that 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). 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.

3 Exploring the evolutionary dynamics: lessons from the applied literature

The decades that followed Schumpeter's death constituted a low tide for evolutionary economics. Economists gradually adopted formal, mathematical equilibrium approaches of the type that Schumpeter admired but had found to be of little value for understanding economic evolution. While there was very little work going on with an explicit evolutionary foundation, evolutionary ideas soon started to appear in applied work. The reason for this was, as Schumpeter would have expected, that the formal equilibrium models had very little to say about qualitative economic changes in historical time (or evolution). Applied researchers were forced to look

[19] 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 anti-neoclassical as people sometimes imply, it is as demonstrated in this paper not correct that he overlooked the role of continuing novelty in economic evolution (see also Foster, 2000).

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 (Fagerberg, 2002).

The dynamics of technology, growth and trade

This holds 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 (Posner, 1961; Hirsch, 1965; and Vernon, 1966) suggested that the reason had to do with the fact that innovation constantly disrupts the equilibrium forces, so that the observed patterns of international trade reflect 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. This resulted, in the decades that followed, in a large number of empirical studies focusing on innovation, diffusion and trade in various sectors/industries.[20]

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 Christopher Freeman. Freeman himself had, during the sixties, 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 to expand and to 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 of 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. Innovation was assumed to be the primary factor behind long-run differences in specialization patterns, trade and economic performance, while other, more "conventional" factors, while relevant, were relegated to a 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, 2002). Among the approaches that gained popularity during the 1970s and 1980s, several had a strong "evolutionary" flavour. For instance, the economic historian

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

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. Following his view, technological and economic catch-up was a very demanding enterprise. This approach was adopted by, among others, Abramovitz in a series of analyses of differences in cross-country growth performance over the long run (Abramovitz, 1979, 1986, 1994). 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), placed 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 its manufacturers" (Kaldor, 1981, p, 603), which hence need to be taken into account (Fagerberg, 1988a).

Although many of these writers did place much emphasis on innovation, their modelling approaches 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 included innovation, imitation and other efforts related to the commercial exploitation of technology as driving forces of growth. Following this approach, catch-up or convergence is by no means guaranteed, but 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. According to Verspagen (1991), who implemented this model into a non-linear 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 in attempting to come to grips with important economic phenomena that traditional equilibrium approaches 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.[21] 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

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

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.

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 had been, 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 Louçã, 2001). This has to do with Schumpeter's insistence that capitalist evolution represents a succession of "industrial revolutions" and, in particular, the 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 randomly, 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"[22] (Schumpeter, 1939). This assertion was received with great scepticism in the academic community (Kuznets, 1940) 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 Mensch in his book *Stalemate in Technology – Innovations Overcome the Depression* published in 1979 (German edition 1976). As did 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 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 to weaken the public trust in the old – and resistance against new – ideas. This is assumed to facilitate the emergence of a new cluster of innovations that 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). Although it was true, the authors admitted, that innovations tended to

[22] 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. Economic evolution, we will argue, is about qualitative changes in production, organizational forms, institutions etc. in historical time, not about cycles that repeat century after century at a constant pace. However, there are certain aspects of this debate that point to issues of wider relevance and which we will consider in the following.

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 does start 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 the 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 may 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 Perez (1983, 1985), has received wide attention and has recently been applied to historical evidence by Freeman and Louçã (2001). The basic assumption in Perez' scheme is the emergence of a "key factor",[23] 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.[24] One may think of examples such as electricity, oil/gas and microelectronics. The industries that produce this input and those that use it intensively – so called "carrier branches" – grow very fast as the "key factor" becomes more widely diffused. Moreover there will be induced effects in a number of other industries, such as, for

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

[24] 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).

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 manage 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.[25] Thus 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.[26] Following this view, technological dynamics has its own logic, and this needs not correspond to the internal logic of other social subsystems. Freeman and Louçã (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.[27]

This literature has made several important contributions to evolutionary economics. First, it has developed the systemic approach to innovation inherent in Schumpeter's work and applied it to historical processes, so that we now have a much better understanding of the dynamics of subsequent generations of "technological systems". Second, and probably of even greater importance, this literature represents the first serious attempt to link technological dynamics with social, organizational and institutional features. While Schumpeter tended to see such features as constraining, this literature points out that social, organizational and institutional factors may in fact *enable* innovation. Moreover, as pointed out by Mensch, Perez and others, such factors are not constant, but change over time, to some extent endogenously. However, despite these obvious merits, it is difficult to see why interaction (or lack of such) between different social subsystems should give rise to so-called "long waves" in economic activity (as is sometimes suggested). 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 certain "mechanistic" flavour in much of the "long wave" literature that is arguably quite

[25] Note the striking parallel to the arguments by Mensch (1979).

[26] This argument has a certain Marxian flavour. Marx saw capitalist development as characterized by an increasing mismatch between economic and technological progress and social and institutional factors (so-called "relations of productions"). However, while for Marx this tension was assumed to lead to a transition from capitalism to socialism, in long-wave analyses of the Mensch-Perez type it marks the transition from one capitalist wave (or "technological revolution") to another. A related perspective, also emphasizing the possibility of mismatch between the economic dynamics and social and institutional factors ("regulation") at the other, has been advanced by authors belonging to the so-called French "regulation school" (Aglietta, 1979; Boyer, 1988). For a brief discussion of the relationship between the two different perspectives, see Fagerberg 2002, Introduction.

[27] The financial system also merits attention in this context, see Perez (2002) for a recent attempt to take this more thoroughly into account.

alien to an evolutionary approach. To avoid being trapped in an overly mechanical "wave" analogy many writers now prefer other terms such as "industrial" or "technological revolutions" (von Tunzelmann, 1995; Perez, 2002).

Systems of innovation

Even though public interest in the "long waves" debate 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),[28] 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 of contributions emerged focusing on the systemic aspects of innovation-diffusion and the relationship to social, institutional and political factors.[29] 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 the analysis, the territorial dimension of innovation-diffusion naturally followed.

Hence, 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 many of these contributions do is, for each particular country, try to identify and describe the most important private and public actors, organizations and institutions that take part in or influence R&D and innovation in the country.[30] However, according to Freeman (1995) who was the first to use the term "national system of innovation" (Freeman, 1987), the inventor of the term was not himself but Lundvall (1988, 1992). While Freeman and Nelson took a macro-view, and focused on the big national players

[28] 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.

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

[30] 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 carried out a large comparative project on national systems of innovations that is in the process of being published (OECD, 2001).

in R&D, Lundvall's approach was more "micro" and based on a particular view of how learning occurs in economic systems. Following Schumpeter, he argued that an innovation should be seen as a new combination of knowledge drawn from different sources (Lundvall, 1992, p. 8). But in contrast to Schumpeter, Lundvall saw 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 emphasized the access to the different types of knowledge that take part in the combinatory dynamics. The sources for this knowledge, he argued, 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 sense is an economic system characterized by dense and enduring relationships between firms, customers and suppliers.

But why should such systems be national? Lundvall gave at least two different reasons. The first has to do with history: The economic structure of a country evolves slowly through time and – although subject to change – has a 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 factors such as a common culture, language and institutions, which arguably facilitate interaction between firms and their environments and, hence, affect learning positively. However, although there are many examples of countries that fit this description on both points, many do not. 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 structure 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 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 system", which they define as "a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology" (ibid, p. 93).[31]

[31] 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).

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 to expand "the economic opportunity set" and to unleash the potential of a given network into a fully-fledged "technological system". 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 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 and 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). That innovation systems often have a regional basis has also been pointed out by Braczyk et al. (1997), who have suggested 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 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 a mixture of theoretical conjectures and generalisations from empirical research – has yet to generate 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.[32]

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*, which continues to be the central contribution within this strand of research. Nelson and Winter share with Schumpeter the focus on "capitalism as an engine of change". What they do, is to 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). What Nelson and Winter and Schumpeter have in common is primarily the focus on technological competition as the driving force of capitalist development. 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 into the background, and risk being eliminated altogether.

This being said, there are also some important differences between Nelson and Winter's approach and that of Schumpeter (and Marx before him). First, Nelson and Winter clearly recognize the link between evolutionary theorizing in biology and their own work, while Schumpeter was highly critical of attempts to apply theories from the natural sciences to economics. However, Nelson and Winter also denounced pursuing biological analogies for their own sake or for the purpose of contructing a general evolutionary theory applicable to both natural and social sciences (Nelson and Winter, 1982, p. 11). Their explecit theoretical strategy was to pick and choose whatever they found useful in the explanation of economic and social change and leave behind what did not suit their purpose. Second, building on earlier work by Simon and others, they added 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 allowed for greater diversity in firm behaviour (and strategies) and industry characteristics, and for a clearer distinction between the technological activities of firms and the actual outcomes of these activities (which, they argued, has a strong stochastic element). Finally, they downplayed 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.

Cognitive foundations: "Bounded" or "procedural" rationality

In designing the micro fundament of their approach, Nelson and Winter embraced the common criticism of traditional neoclassical economic theory of basing itself

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

on a completely unrealistic view on what humans are able to do (Simon, 1959, 1965; Cyert and March, 1963).[33] 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 will the actor 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 to, among other things, his work on "artificial intelligence", that is, computer-mediated problem solving (Andersen, 1994). Cyert and March (1963) in their book *A behavioural theory of the firm* used this perspective to analyse decision-making within the firm. However, it was Alchian (1950) who in his classic paper "Uncertainty, evolution and economic theory" introduced this type of reasoning to the analysis of competition between firms. Nelson and Winter (1982) followed Alchian in applying the principle of "bounded" rationality to the behaviour of firms (rather than individuals). Generally, Nelson and Winter tended 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 same" than they are at any other kind of change"(Nelson and Winter, 1982, pp. 9–10).

The firms are assumed to follow decision rules (or "routines"). Routines determine behaviour (together with impulses form the environment), are heritable (as part of the "organizational memory"[34] 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. Following Cyert and March (1963), Nelson and Winter (1982) tried 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. They used the term "search" for such "routine-guided, routine changing processes" (Nelson and Winter, 1982, p. 18).

The Nelson-Winter models

Although most firms may be quite satisfied with the way in which they are doing things, some firms will at any point in time be engaged in a search for new and

[33] 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.

[34] 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).

more efficient routines. The outcome of such a search is uncertain, that is, 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, will the firm adopt the new routine. A firm can search in two different ways, through developing a new routine itself from scratch (innovation) or by 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 spends 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 a search will, to a large extent, depend on how profitable the firm is, since Nelson and Winter assume that investments are financed through retained profits.[35] 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. To counteract this tendency, they introduced the (somewhat controversial) assumption that large firms (with more market power) have a higher profit target (price/cost ratio) than smaller firms, so that in the end the large firms will show some "restraint" in driving the small ones out of business.[36] 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 as to 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 the firm's own activities (the "science based" regime), and another in which technological progress is more endogenous and de-

[35] 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.

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

pends 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.

Post Nelson and Winter

Nelson and Winter's seminal contributions in this area have spurred further work along several different dimensions, of which we will mention three. 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 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.[37]

Second, Nelson and Winter's attempt to model evolution has led to the appearance of a variety of formal growth models exploring 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 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). Hence, 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, as Andersen put 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 (1984a,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. 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

[37] In a citation analysis of Nelson and Winter's book, Meyer (2001) shows that it is heavily cited mainly in journals devoted to management/organisation. In fact, of the ten journals that cited the book most frequently six fell in this category. The lack of the large mainstream economics journals on this list is noteworthy.

course highly stylised and offer few if any original insights into the determinants of innovation. Metcalfe, for his part, conceded that he "discuss innovation without saying anything of substance about the origins of innovations" and added 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 confined 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, 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).[38] 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 his own earlier work (Saviottti, 1996), suggested a novel (analytical) framework that may allow for the inclusion of product innovation and demand. An improved model of how new investments are financed was developed by Possas et al. (2001), which – 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 allow 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) emphasized the importance of dating of investment (a vintage structure) for evolutionary models. Here 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 firms, and the second by a few, big firms with a great deal of organized R&D. This distinction, which is more or less identical to what is elsewhere labelled "Schumpeter Mark I" and "Schumpeter Mark II", is commonly associated with the so-called "Schumpeterian hypothesis" (Kamien and Schwartz, 1982) that the latter (more concentrated) "regime" should be expected to be more conducive to innovation than the former. In modelling this difference Winter also allowed for entry 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

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

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 most important in the "routinised" regime. 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.[39] 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.[40]

Selection, multiple solutions and path-dependence

Another important aspect of evolutionary theorizing is 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. 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 happens 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 discussed several examples of this, for instance the QWERTY keyboard, initially introduced to slow down typing in order to avoid "jamming" in types on mechanical typewriters (see also David, 1985).

Although some of the examples Arthur has used to support his argument have proved to be controversial (Liebowitz and Margolis, 1990, 1995), he 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. The seemingly innocent suggestion that such paths need not be "optimal" is more difficult to

[39] 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).

[40] See Malerba and Orsenigi (2001).

accommodate from an evolutionary point of view, since the concept of optimality generally plays no role in evolutionary economics. Moreover, 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).[41]

The contribution from formal modelling

What has been the contribution of formal models of economic evolution? Although the ideas date back to the early 1950s, formal models of economic evolution did not start to appear before the 1970s. *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. Hence it is difficult to avoid the conclusion that evolutionary modelling does not appear to have been accepted as a welcome addition to the discipline by hardcore mainstream economics (particularly in the US).

We may, however, phrase the question a bit differently and instead ask what has been the contribution of this "new wave of evolutionary theorists", as Hodgson (1993) puts it, to the evolutionary agenda. 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 than 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 more 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,

[41] 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).

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 if selection becomes "too strong" and variety creation "too weak", the system will be locked into a particular path/state. Thus, the 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.

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. Firms' actions – including search for new or improved routines if necessary – became entirely routine-based. The question arises, however, as to the role for purposive human actions in this approach. Is there a built-in bias against devoted "routine-breakers", 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, as shown by the interventions of Hodgson (1993) and Andersen (1994).[42] 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 – as shown above – different perspectives within "the new wave" as well. However, such differences do not exclude a common core. In contrast to Hodgson, we shall argue that many of these differences are in fact relatively superficial and that there is at a deeper level a well-defined common core that ties these different strands together. This core consists of three interrelated arguments that 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

[42] Of course, these authors could not have foreseen the rapid growth in the research in this area, particularly applied, during the last decade or so, and it is possible that today they may view this issue differently.

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 to 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., innovators are amply rewarded at first, but these advantages vanish when imitators enter the scene. Another important regularity concerns the role of innovation as a pointer to further change, i.e., 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) play in the evolutionary process. At 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. However, closer scrutiny shows 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 did not provide a framework for analysing this phenomenon. Nelson and Winter, by contrast, explicitly focused on innovation as an organisational phenomenon, which, however, is unequally distributed across the population of firms. The reason for this, they argue, is 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, which 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 at the forefront of research in both business studies

and evolutionary economics, which increasingly appear as strongly linked fields of research.[43]

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 take into account the well-known fact that knowledge may be at least partly "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. Nonetheless, some of it spills over to rest of the economic system and increases the social pool of public knowledge, which helps foster new innovations and, hence, allows growth to continue. 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, upon closer scrutiny, the differences appear more striking.

First, while the evolutionary literature focuses on a population of heterogeneous, "boundedly rational" agents who 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, by contrast, look at knowledge as a "public good", or a stock of publicly available information, which would have been freely available to everybody, hat it not been for certain legal arrangements that serve to limit this availability. 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 on 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 conclusions on policy matters. For what it is

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

worth, however, evolutionary economics provides a different perspective on policy than the one advocated by neoclassical economics. As is well known, the latter places its main emphasis on the alleged failure of competitive markets to deliver socially needed public goods, to which "knowledge" is assumed to belong, and which need to be subsidized or provided by the state. The evolutionary approach, however, downplays the public-good aspect of much economic knowledge and puts a question mark on policy prescriptions based solely on public-good assumptions. Moreover, from an evolutionary perspective, there is no such thing as an "optimal" rate of growth. 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 follow from evolutionary reasoning. The first is 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 serve to find ways to overcome the inertia, or "resistance to new ways" as Schumpeter phrased it, that according to evolutionary thinking is characteristic of economic and social systems.[44]

References

Abramovitz M (1979) Rapid growth potential and its realisation: the experience of capitalist economics in the postwar period. In: Malinvaud E (ed) Economic growth and resources, Vol 1. The major issues, pp 1–30. Macmillan, London

Abramovitz M (1986) Catching up forging ahead and falling behind. Journal of Economic History 46: 386–406

Abramovitz M (1994) The origins of the postwar catch-up and convergence boom. In: Fagerberg J, Verspagen B, von Tunzelmann N (eds) The dynamics of technology trade and growth, pp 21–52. Edward Elgar, Aldershot

Aglietta M (1979) A theory of capitalist regulation The US experience. NLB, London

Alchian AA (1950) Uncertainty evolution and economic theory. Journal of Political Economy 58: 211–222

Allen RL (1991) Opening doors: the life and work of Joseph Schumpeter, 2 vols. Transaction Publishers, New Brunswick

Aghion P, Howitt P (1992) A model of growth through creative destruction. Econometrica 60: 323–351

Ancori B, Bureth A, Cohendet P (2000) The economics of knowledge: the debate about codification and tacit knowledge. Industrial Dynamics and Corporate Change 9: 255–287

Andersen ES (1994) Evolutionary economics post-Schumpeterian contributions. Pinter, London

Andersen ES (2001) Towards a multiactivity generalisation of the Nelson-Winter model. Paper presented at the 2001 Nelson-Winter Conference organized by DRUID June 12–15, 2001, Aalborg Denmark

[44] 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. Such initiatives would, of course, not be expected to invigorate the public sector only, but have consequences for the entire economic system.

Arthur WB (1994) Increasing returns and path dependency in the economy. The University of Michigan Press, Ann Arbor
Boyer R (1988) Technical change and the theory of regulation. In: Dosi G et al. (eds) Technical change and economic theory, pp 67–94. Pinter, London
Braczyk HJ et al. (1998) Regional innovation systems. UCL Press, London
Bresnahan TF, Trajtenberg M (1995) General purpose technologies: engines of growth. Journal of Econometrics 65: 83–108
Breschi S, Malerba F (1997) Sectoral innovation systems: technological regimes, Schumpeterian dynamics and spatial boundaries. In: Edquist C (ed) Systems of innovation: technologies institutions and organizations, pp 130–156. Pinter, London
Carlsson B, Stankiewicz R (1991) On the nature function and composition of technological systems. Journal of Evolutionary Economics 1: 93–118
Conlisk J (1989) An aggregate model of technical change. Quarterly Journal of Economics 104: 787–821
Cornwall J (1977) Modern capitalism: its growth and transformation. St Martin's Press, London
Cowan RP, David A, Foray D (2000) The explicit economics of knowledge codification and tacitness. Industrial Dynamics and Corporate Change 9: 211–253
Cooke PM, Uranga G, Etxebarria G (1997) Regional innovation systems: institutional and organisational dimensions. Research Policy 26: 475–491
Cyert RM, March JG (1963) A behavioural theory of the firm. Prentice-Hall, Englewood Cliffs NJ
Dahmén E (1970) Entrepreneurial activity and the development of Swedish industry 1919–1939. American Economic Association Translation Series, Homewood
David P (1985) Clio and the economics of QWERTY. American Economic Review 75: 332–337
Dosi G (1982) Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. Research Policy 11: 147–162
Dosi G (1988) Sources, procedures and microeconomic effects of innovation. Journal of Economic Literature 26: 1120–1171
Dosi G, Fabiani S (1994) Convergence and divergence in the long-term growth of open economies. In: Silverberg G, Soete L (eds) The economics of growth and technical change: technologies, nations agents, pp 119–146. Edward Elgar, Aldershot
Dosi G, Fabiani S, Aversi R, Meacci M (1994) The dynamics of international differentiation: a multi-country evolutionary model. Industrial Dynamics and Corporate Change 3: 225–241
Dosi G, Freeman C, Nelson R, Silverberg G, Soete LG (eds) (1988) Technical change and economic theory. Pinter, London
Dosi G, Soete L (1983) Technology gaps and cost-based adjustment: some explorations of the determinants of international competitiveness. Metroeconomica 35: 357–382
Dosi G, Pavitt K, Soete LG (1990) The economics of technical change and international trade. Harvester Wheatsheaf, London
Ebner A (2000) Schumpeter and the Schmollerprogramm: integrating theory and history in the analysis of economic development. Journal of Evolutionary Economics 10: 355–372
Edquist C (ed) (1997) Systems of innovation: technologies, institutions and organizations. Pinter, London
Edquist C, McKelvey M (2000) Systems of innovation: growth, competitiveness and employment, 2 vols. Elgar, Cheltenham
Elliot JS (1980) Marx and Schumpeter on capitalism's creative destruction. Quarterly Journal of Economics 94: 45–68
Etzkowitz H, Leydesdorff L (2000) The dynamics of innovation: from national systems and mode 2 to a triple helix of university-industry-government relations. Research Policy 29: 109–123
Fagerberg J (1987) A technology gap approach to why growth rates differ. Research Policy 16: 87–99
Fagerberg J (1988a) International competitiveness. Economic Journal 98: 355–374
Fagerberg J (1988b) Why growth rates differ. In: Dosi G et al. (eds) Technical change and economic theory, pp 432–457. Pinter, London
Fagerberg J (1994) Technology and international differences in growth rates. Journal of Economic Literature 32: 1147–1175
Fagerberg J (1995) User-producer interaction, learning and comparative advantage. Cambridge Journal of Economics 19: 243–256

Fagerberg J (1996) Technology and competitiveness. Oxford Review of Economic Policy 12: 39–51
Fagerberg J (2002) Technology, growth and competitiveness: selected essays. Edward Elgar, Cheltenham
Fagerberg J, Guerrieri P, Verspagen B (eds) (1999) The economic challenge for Europe: adapting to innovation-based growth. Edward Elgar, Aldershot
Foster J (2000) Competitive selection, self-organisation and Joseph A. Schumpeter. Journal of Evolutionary Economics 10: 311–328
Freeman C (1987) Technology policy and economic performance: lessons from Japan. Pinter, London
Freeman C (1991) Innovation, changes of techno-economic paradigm and biological analogies in economics. Revue Économique 42: 211–232
Freeman C (1995) The 'National System of Innovation' in historical perspective. Cambridge Journal of Economics 19: 5–24
Freeman C, Clark J, Soete LG (1982) Unemployment and technical innovation: a study of long waves and economic development. Pinter, London
Freeman C, Curnow RC, Fuller JK, Robertson AB, Whittaker PJ (1968) Chemical process plant: innovation and the world market. National Institute Economic Review 45: 29–57
Freeman C, Fuller JK, Young A (1963) The plastics industry: a comparative study of research and innovation. National Institute Economic Review 26: 22–62
Freeman C, Harlow CJ, Fuller JK (1965) Research and development in electronic capital goods. National Institute Economic Review 34: 40–97
Freeman C, Louçã F (2001) As time goes by: from the industrial revolutions to the information revolution. Oxford University Press, Oxford
Gerschenkron A (1962) Economic backwardness in historical perspective. The Belknap Press, Cambridge MA
Grossman GM, Helpman E (1991) Innovation and growth in the global Economy. The MIT Press, Cambridge, MA
Helpman E (ed) (1998) General purpose technologies and economic growth. MIT Press, Cambridge, MA
Hirsch S (1965) The US electronics industry in international trade. National Institute Economic Review 34: 92–107
Hodgson GM (1988) Economics and institutions: a manifesto for modern institutional economics. Polity Press, Cambridge
Hodgson GM (1993) Economics and evolution: bringing life back into economics. Polity Press, Cambridge
Hodgson GM (1998) The approach of institutional economics. Journal of Economic Literature 36: 166–192
Hodgson GM (1999) Evolution and institutions: on evolutionary economics and evolution of economies. Edward Elgar, Aldershot
Iwai K (1984a) Schumpeterian dynamics I: an evolutionary model of innovation and imitation. Journal of Economic Behavior and Organization 5: 159–190
Iwai K (1984b) Schumpeterian dynamics II: technological progress firm growth and economic selection. Journal of Economic Behavior and Organization 5: 321–351
Kamien M, Schwartz N (1982) Market structure and innovation. Cambridge University Press, Cambridge
Kaldor N (1981) The role of increasing returns, technical progress and cumulative causation in the theory of international trade and economic growth. Economie Applique (ISMEA) 34: 593–617
Kleinknecht A (1987) Innovation patterns in crisis and prosperity: Schumpeterian long cycles reconsidered. Macmillan, London
Kline SJ, Rosenberg N (1986) An overview of innovation. In: Landau R, Rosenberg N (eds) The positive sum strategy: harnessing technology for economic growth, pp 275–304. National Academy Press, Washington, DC
Kuhn T (1962) The structure of scientific revolutions. Chicago University Press, Chicago
Kuznets S (1940) Schumpeter's business cycles. American Economic Review 30: 257–271
Laurent J, Nightingale J (2001) Darwinism and evolutionary economics. Edward Elgar, Cheltenham
Laursen K (2000) Trade specialization and economic growth: theory and evidence from advanced countries. Edward Elgar, Cheltenham
Leontief W (1953) Domestic production and foreign trade: the American capital position re-examined, pp 332–249. Proceedings of the American Philosophical Society, September

Liebowitz SJ, Margolis SE (1990) The fable of the keys. Journal of Law and Economics 33: 1–26
Liebowitz SJ, Margolis SE (1995) Path dependence, lock-in and history. Journal of Law Economics and Organization 11: 205–226
Lucas RE (1988) On the mechanisms of economic development. Journal of Monetary Economics 22: 3–42
Lucas RE (1993) Making a miracle. Econometrica 61: 251–272
Lundvall BÅ (1988) Innovation as an interactive process: from user-producer interaction to the national system of innovation. In: Dosi G et al. (eds) Technical change and economic theory, pp 349–369. Pinter, London
Lundvall BÅ (1992) National systems of innovation: towards a theory of innovation and interactive learning. Pinter, London
Mailath GJ (1998) Do people play Nash equilbrium? Lessons from evolutionary game theory. Journal of Economic Literature 36: 1347–1374
Malerba F, Nelson RR, Orsenigo L, Winter SG (1999) History-friendly models of industry evolution: the computer industry. Industrial Dynamics and Corporate Change 8: 1–36
Malerba F, Orsenigo L (2001) Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: towards a history-friendly model. Paper presented at the 2001 Nelson-Winter Conference, organized by DRUID, June 12–15, 2001, Aalborg, Denmark
Marx K (1954/1956/1959) Capital: a critique of political economy, (3 vol). Moscow: Progress Publishers (originally published in 1887/1893/1894)
Meliciani V (2001) Technology trade and growth in OECD countries – does specialization matter? Routledge, London
Mensch G (1979) Stalemate in technology. Ballinger, Cambridge, MA
Metcalfe JS (1994) Competition, Fisher's principle and increasing returns in the selection process. Journal of Evolutionary Economics 4: 327–346
Metcalfe JS (1998) Evolutionary economics and creative destruction. Routledge, London
Meyer M (2001) Nelson's and Winter's evolutionary theory – a citation analysis. Paper presented at the 2001 Nelson-Winter Conference organized by DRUID, June 12–15, 2001, Aalborg, Denmark
Mowery DC, Nelson RR (eds) (1999) Sources of industrial leadership: studies of seven industries. Cambridge University Press, Cambridge
Nelson RR (ed) (1993) National systems of innovation: a comparative study. Oxford University Press, Oxford
Nelson RR (1995) Recent evolutionary theorizing about economic change. Journal of Economic Literature 33: 48–90
Nelson RR, Winter SG (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge, MA
Niosi J, Saviotti P, Bellon B, Crow M (1993) National systems of innovation: why they are important and how they may be measured and compared. Technology in Society 15: 207–227
Nonaka I, Takeuchi H (1995) The knowledge creating company. Oxford University Press, Oxford
OECD (2001) Dynamising national innovation systems DSTI/STP/TIP(2001)15
Pasinetti LL (1981) Structural change and economic growth: a theoretical essay on the dynamics of the wealth of nations. Cambridge University Press, Cambridge
Pavitt K (1982) R&D, patenting and innovative activities: a statistical exploration. Research Policy 11: 33–51
Perez C (1983) Structural change and the assimilation of new technologies in the economic and social system. Futures 15: 357–375
Perez C (1985) Micro-electronics, long waves and world structural change. World Development 13: 441–463
Perez C (2002) Technological revolutions and financial capital: the dynamics of bubbles and golden ages. Edward Elgar, Cheltenham
Posner MV (1961) International trade and technical change. Oxford Economic Papers 13: 323–341
Poussas M, Licha AL, da Costa Oreiro JL, Koblitz ACV, Dweck E (2001) A sectoral evolutionary model. Paper presented at the 2001 Nelson-Winter Conference, organized by DRUID, June 12–15, 2001, Aalborg, Denmark
Reinert ES (2002) Schumpeter in the context of two canons of economic thought. Industry and Innovation 9: 23–29

Romer PM (1990) Endogenous technological change. Journal of Political Economy 98: S71–S102
Sahal D (1985) Technological guideposts and innovation avenues. Research Policy 14: 61–82
Saviotti PP (1996) Technological evolution variety and the economy. Edward Elgar, Cheltenham
Saviotti PP (2001) Variety, growth and demand. Journal of Evolutionary Economics 11: 119–142
Schinzinger F (1987) German historical school. In: Eatwell J, Milgate M, Newman P (eds) The new Palgrave: a dictionary of economics, Vol 2, pp 516–518. MacMillan, London
Schumpeter J (1908) Das Wesen und Hauptinhalt der theoretischen Nationalökonomie. Duncker and Humblot, Leipzig
Schumpeter J (1934) The theory of economic development. Harvard University Press, Cambridge, MA
Schumpeter J (1937) Preface to the Japanese edition of Theorie der Wirtschaftlichen Entwicklung. Reprinted in: Schumpeter J (1989) Essays on entrepreneurs, innovations, business cycles and capitalism (edited by Clemence RV), pp 165–168. Transaction Publishers, New Brunswick, NJ
Schumpeter J (1939) Business cycles: a theoretical historical and statistical analysis of the capitalist process (2vol). McGraw-Hill, New York
Schumpeter J (1943) Capitalism, socialism and democracy. Harper, New York
Schumpeter J (1946) Capitalism. In: Encyclopaedia Britannica, Vol IV, pp 801–807. Reprinted in: Schumpeter J (1989) Essays on entrepreneurs, innovations, business cycles and capitalism (edited by Clemence RV), pp 189–210. Transaction Publishers, New Brunswick, NJ
Schumpeter J (1947) The creative response in economic history. Journal of Economic History 7: 149–159. Reprinted in: Schumpeter J (1989) Essays on entrepreneurs, innovations, business cycles and capitalism (edited by Clemence RV), pp 221–271. Transaction Publishers, New Brunswick, NJ
Schumpeter J (1949) Economic theory and entrepreneurial history. Change and the entrepreneur, pp 63–84. Reprinted in Schumpeter J (1989) Essays on entrepreneurs, innovations, business cycles and capitalism (edited by Clemence RV), pp 253–271. Transaction Publishers, New Brunswick, NJ
Schumpeter J (1954) History of economic analysis. Allen & Unwin, New York
Shionoya Y (1997) Schumpeter and the idea of social science. Cambridge University Press, Cambridge
Silverberg G, Dosi G, Orsenigo L (1988) Innovation, diversity and diffusion: a self-organization model. Economic Journal 98: 1032–1054
Silverberg G, Lehnert D (1993) Long waves and evolutionary chaos in a simple Schumpeterian model of embodied technical change. Structural Change and Economic Dynamics 4: 9–37
Silverberg G, Lehnert D (1994) Growth fluctuations in an evolutionary model of creative destruction. In: Silverberg G, Soete L (eds) The economics of growth and technical change: technologies nations agents, pp 74–108. Edward Elgar, Aldershot
Silverberg G, Verspagen B (1994a) Learning, innovation and economic growth: a long-run model of industrial dynamics. Industrial Dynamics and Corporate Change 3: 199–223
Silverberg G, Verspagen B (1994b) Collective learning, innovation and growth in a boundedly rational evolutionary world. Journal of Evolutionary Economics 4: 207–226
Silverberg G, Verspagen B (1998) Economic growth and economic evolution: a modeling perspective. Selbstorganisation – Jahrbuch für Komplexität in den Natur- Sozial and Geisteswissenschaften 9: 239–264
Simon HA (1959) Theories of decision making in economics. American Economic Review 49: 253–283
Simon H A (1965) Administrative behaviour, 2nd edn. Free Press, New York
Soete L (1981) A general test of technological gap trade theory. Weltwirtschaftliches Arkiv 117: 638–660
Soete L (1987) The impact of technological innovation on international trade patterns: the evidence reconsidered. Research Policy 16: 101–130
Solow RM (1957) Technical change and the aggregate production function. Review of Economics and Statistics 39: 312–320
Stolper WF (1994) Joseph Alois Schumpeter: the public life of a private man. Princeton University Press, Princeton
Swedberg R (1989) Introduction to the transaction edition. In: Schumpeter J (1989) Essays on entrepreneurs, innovations, business cycles and the evolution of capitalism (edited by Clemence RV), pp vii-xxxix. Transaction Publishers, New Brunswick, NJ
Swedberg R (1991) Joseph Schumpeter: his life and work. Polity Press, Cambridge
Thirlwall AP (1979) The balance of payments constraints as an explanation of international growth rate differences. Banca Nazionale del Lavoro Quarterly Review 32: 45–53

Tylecote A (1992) The long wave in the world economy: the present crisis in historical perspective. Routledge & Kegan Paul, London
Vernon R (1966) International investment and international trade in the product cycle. Quarterly Journal of Economics 80: 190–207
Verspagen B (1991) A new empirical approach to catching up or falling behind. Structural Change and Economic Dynamics 2: 359–380
Verspagen B (1993) Trade and knowledge spillovers in an evolutionary model of growth rate differentials. In: Wagner A (ed) Dezentrale Entscheidungsfindung bei Externen Effekten, pp 189–218. Franke Verlag, Tübingen
von Tunzelmann GN (1995) Technology and industrial progress: the foundations of economic growth. Edward Elgar, Aldershot
Wakelin K (1997) Trade and innovation: theory and evidence. Edward Elgar, Cheltenham
Winter SG (1984) Schumpeterian competition in alternative technological regimes. Journal of Economic Behavior and Organization 5: 287–320
Witt U (ed) (1993) Evolutionary economics. Edward Elgar, Aldershot
Ziman J (ed) (2000) Technological innovation as an evolutionary process. Cambridge University Press, Cambridge