Neo- and Post-Schumpeterian Contributions to Evolutionary Economics

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Paper to be presented at the
Conference on Economics and Evolution,
Arranged by the
Belgian-Dutch Association for Post-Keynesian Economics,
Utrecht, 10 November 1995

Preliminary version

October 1995

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1. Introduction

Important parts of the heterodox economics of technical change and of the more encompassing, model-building evolutionary economics have hitherto considered the relationship to the Schumpeterian heritage as a nearly self-evident fact. Empirically oriented researchers have invoked 'Schumpeter hypotheses' to delineate areas of study like the innovativeness of small and large firms (Kamien and Schwarz, 1982) and the importance of supply- and demand-side factors in innovation (Rosenberg, 1982). Theoretically oriented researchers like Nelson and Winter (1982) and Dosi (1988; 1990) have seen Schumpeter as the economist who had most clearly delineated the area that they were trying to model. For instance, Nelson and Winter (1982, 39) said that 'we are evolutionary theorists *for the sake* of being neo-Schumpeterians – that is, because evolutionary ideas provide a workable approach to the problem of elaborating and formalizing the Schumpeterian view of capitalism as an engine of change.' They also state that 'the term "neo-Schumpeterian" would be as appropriate designation for our entire approach as "evolutionary".'

Since these statements were made, a rapid expansion has taken place with respect to Schumpeterian scholarship and to evolutionary-economic modelling. Especially after the centenary celebration of Schumpeter's birth in 1983 an extensive literature has emerged, and now we have we have biographies like Swedberg (1991), bibliographies like Augello (1990), collections of papers like Wood (1991), and even an International Schumpeter Society which gives out a series of selected conference papers as well as the *Journal of Evolutionary Economics*. With respect to evolutionary approaches to economics the change has been even more significant as can be seen from, e.g., the paper collection by Witt (1993), the reference work by Hodgson, Samuels, and Tool (1994), and the review by Nelson (1995).

In this new situation it is appropriate to reconsider the sense in which the work of heterodox economists of technical change is 'evolutionary' and 'neo-Schumpeterian'. Such a study can start from challenges raised by economic methodologists. To researchers like Mirowski and Hodgson 'an evolutionary theory' is nearly synonymous with 'a theory which applies the metaphor of natural selection'. Given this view, Mirowski (1983) asks whether Nelson and Winter's work can be characterised as fully evolutionary since they mix Darwinian and Lamarckian ideas, and since they have no convincing answer to the question of units of selection.[1] Another problem is that they have a 'milk-and-water strategy' since they want to relate all kinds of heterodox economists at the same time as they claim that their book subsume the orthodox view (Mirowski, 1983, 766). The same kind of strategy can be found in Schumpeter who 'was a living, breathing contradiction' (Mirowski, 1994, 5).

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[1] Nelson and Winter's (1982, chs. 12-14) model of 'Schumpeterian competition' is unconvincing to Mirowski because the demand side is modelled as purely non-evolutionary and because the supply side lacks a convincing analogy of genes: the production routines are not precisely defined and 'there are no stable "species" in the Nelson and Winter-style "evolution".' (Mirowski, 1983, 763)

Hodgson (1993, ch. 10) emphasises the differences between the evolutionary modellers and Schumpeter. Schumpeter's milk-and-water strategy brought him so far from evolutionary thinking in the modern sense that 'the invocation of Schumpeter's name by the new wave of evolutionary theorists in the 1980s and 1990s is both misleading and mistaken.' (p. 149) The invocation seems to build on 'superficial similarities' and ignore that 'at a deeper theoretical level there is a complete divergence.' While the new evolutionary modellers from Nelson and Winter to Dosi and Silverberg base their models on a selection mechanism which is analogous to biological selection, Schumpeter 'eschewed the natural selection analogy for economics and adopted an entirely different conception of evolution ... more economic revolution than economic evolution' (Hodgson, 1993, 149 f.).[2] This difference and several other distinctions seem to demonstrate that the evolutionary ideas of the new modellers 'have much more to do with Veblen and the "old" institutionalism than with Schumpeter himself.' Thus the designation 'neo-Schumpeterian' is mistaken because it ignores that Schumpeter was not an evolutionary theorist in the modern sense; it is misleading because it draws the attention away from more fruitful relationships.

The immediate response of most evolutionary modellers is probably to ignore Mirowski's and Hodgson's arguments. These arguments sound too much as en attempt to raise an intra-evolutionary Battle of Methods with some similarities to the *Methodenstreit*, which hindered the development of economics in the German-speaking world around the turn of the century. Like then an overemphasis on methodology might force modellers to legitimise their work *ex ante* rather than when they have obtained and demonstrated interesting results. Instead they agree with Schumpeter that basis issues of methodology should not be discussed in an *a priori* fashion: 'Not the first, but the last chapter of a [scientific] system should deal with methodology.' (Schumpeter, 1908, xi; my transl.)

But the challenge of Mirowski and Hodgson can also be confronted in a more positive fashion. In this respect the reaction will be part of a debate which has already been started by researchers who are often considered to be neo-Schumpeterians themselves. For instance, Rosenberg (1986, 197 f.) has remarked that the 'Schumpeterian renaissance ... has, so far, been an excessively partial one. That is, it has confined itself to a rather restricted portion of a much larger body of thought. ... [M]any of Schumpeter's contributions to economic and social thought remain neglected – even by people who would not shrink from the label "Neo-Schumpeterians".' Furthermore, Freeman (1990, 28) that there is a major difference with respect to Schumpeter's strategy of relating to

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[2] Hodgson's judgement is to some extent based on his (1993, ch. 3) classification of evolutionary theories as being developmental (development in stages according to an implicit plan), ontogenetic (evolution of the economic system as an organism without any selection process), or phylogenetic (evolution governed by a selection process). Only the last type is considered to be evolutionary in the modern sense. In Hodgson's interpretation of the taxonomy, Schumpeter is primarily placed as an ontogenetic theorist because his core model is formed in a way which presuppose the success of an (initial) innovation. In the present paper Schumpeter is, on the contrary, seen as a theorist who wanted to emphasise that an important aspect of the evolutionary process is that innovative entrepreneurs might determine their selection environment. Due to the insufficient analytic tools he had to drive this view to the very extreme. But he would in no way have objected to an overall model with a heavy selection pressure as long as innovative entrepreneurs are sometimes able to influence their selection environment in a radical way. This is a standard theme in neo-Schumpeterian modelling as well as in heterodox evolutionary biology.

general equilibrium theory: 'it was Schumpeter's misfortune that he attempted to marry it [the general equilibrium theory] with his own theory of dynamic destabilizing entrepreneurship.'

The present paper takes Mirowski's and Hodgson's challenges, together with the more wide-spread uneasiness, as an opportunities for rethinking the relationship between Schumpeter's evolutionary works and the model-building evolutionary economics.[3] The underlying method is inspired by Schumpeter who put much emphasis on distinction between the vision and the analysis of great economists. In this case the vision is a preliminary idea of the functioning of the process of economic evolution while the analysis in performed by means of concepts and formal tools. A basic proposition of the paper is that Schumpeter's originality and his importance to evolutionary modelling to a large extent lies in the fact that he acknowledged that he lacked relevant analytical tools for clearly expressing his vision of economic evolution and in the fact that he made a life-long search for such tools. Although the results of Schumpeter's search was not satisfactory for himself, and although Schumpeter even lacked the tools for expressing the research agenda clearly, he provides modern researchers with a rich problem area. Since present-day evolutionary modellers are to a large extent able to provide relevant tools, they should explore this area much more thoroughly than has hitherto been the case.

A core task for modellers is to delineate and clarify major difficulties and inconsistencies in Schumpeterian thinking rather than exploring a few highlights among Schumpeter's many propositions. Within the set of Schumpeterian difficulties and inconsistencies the ones relating to the Schumpeter–Walras relationship should not be overestimated, although e.g. models supporting the teaching of neo- or post-Schumpeterian analysis can be developed around this relationship. The Schumpeter–Marshall relationship represents a more latent and important set of problems for evolutionary modellers. Actually, the modellers are nearly by default neo- or post-Marshallians just as much as they are neo- og post-Schumpeterians. To acknowledge this fact and try to bridge the gap between Schumpeterian and Marshallian thinking about evolutionary phenomena are major challenges for evolutionary modelling. Alternative strategies, including Hodgson's idea of a development of evolutionary modelling in relation to Veblen's thought, are of course available. But evolutionary modellers should be allowed to apply the evolutionary strategy of 'localised search' for new opportunities (Mirowski, 1983, 766) before they make a large jump into a body of thought with less clear-cut connections to standard economics and with less acknowledgement of the tool problem of evolutionary thinking.

The propositions of a tool problem for evolutionary thought and of the ability of evolutionary modellers to overcome this problem help to clarify many of the real and apparent contradictions between Schumpeter and the model-building evolutionary economics. Section 2 examines how Schumpeter's evolutionary analysis was influenced by two factors: the anti-evolutionary context in which it was developed and the inadequate analytic tools available to him. These backgrounds help to explain many of Schumpeter's paradoxical statements as well as his affinity to Walras and his conflict with Marshall. In section 3 the core elements of the contribution of Nelson and Winter and other evolutionary modellers are treated as a potential solution to Schumpeter's tool problem and to the Schumpeter–Marshall conflict on the character of the evolutionary

[3] In this endeavour the emphasis is put on other aspects of Schumpeter's work than is done in Swedberg (1991), cf. Andersen (1993).

process. This is followed up in section 4 which presents a sketch of a combined (post-) Schumpeterian-Marshallian strategy for evolutionary modelling.

2. Schumpeter and the tool problem of evolutionary thought

In economics and in other social sciences there have been long waves in the application of evolutionary modes of thinking. Sanderson (1990, 2) has summarised one of the (very long) waves of evolutionary thinking within the social sciences: 'The heyday of evolutionism was in the second half of the nineteenth century, for it was then that the doctrines of Morgan, Tylor, Spencer, Marx, and others were produced. This "golden age" of evolutionary social science came rather suddenly to an end shortly after the turn of the century, however, and the first decades of the twentieth century represented a sort of "dark age" for evolutionism.' During this 'dark age' evolutionary thinking was 'severely criticized ... as an outmoded approach that self-respecting scholars should no longer take seriously.' However, Sanderson points out that the situation finally began to change: 'By the 1930s some scholars were beginning to take evolutionism seriously again, and by the 1940s an "evolutionary revival" was well under way.'

This summary of a long wave of evolutionary thinking helps to explain the cautious attitude of many economists working with evolutionary problems in the first half of this century. For example, it helps us to understand Schumpeter's remarks that 'the evolutionary idea is now discredited in our field' and that he does not endorse 'unscientific and extra-scientific mysticism' and 'dilettantism'. Schumpeter's conclusion is that 'we must be careful with the phenomenon [of evolution, dem Entwicklungsphänomen] itself, still more with the concept in which we comprehend it, and most of all with the word by which we designate the concept and whose associations might lead us astray in all manner of undesirable directions.' (Schumpeter, 1934, 57 f. [supplemented by Schumpeter, 1926, 88]). Read in the context of a downswing of evolutionary thought, these and other remarks of Schumpeter get a different meaning than when this context is left out of consideration (as is largely the case in Hodgson, 1993). For instance, Schumpeter emphasises wisely that although 'it may be ... that certain aspects of the individual enterprise system are correctly described as a struggle for existence, ... no appeal to biology would be of the slightest use.' (Schumpeter, 1954, 789) Behind this statement is not only the methodological distinction between the context of discovery (where any analogy or metaphor can be used) and the context of justification (where only economic facts and economic logic matters). There is also a long history of misuse of biological analogies.

One careful way of formulating the problem of evolution is to put it within a clear-cut economic setting: the Walrasian system or, rather, a radical reinterpretation of this system (Schumpeter, 1908; 1912, ch. 1). The choice of this semi- or pseudo-Walrasian setting (see Andersen, 1992) is not primarily a matter of professional tactics. It also relates to two of Schumpeter's deep-felt convictions. First, he thought that a full-fledged understanding of the process of economic evolution must include innovation as taking place in discrete steps; to implement this idea it seems a good idea to superimpose innovative entrepreneurship upon a Walrasian system reinterpreted as a routine-following set of economic agents who in some ways or another have found an equilibrium state. Second, Schumpeter's preference for the formalism of Walras is related to his theory of the development of the science of economics. Economic thought as such does not make progress, but 'economic theory is a box of tools' and the development of new tools 'poses and solves problems for which older authors

could hardly have found answers even if they had been aware of them' (Schumpeter, 1954, 15, 39). The problem for economists who have been arguing about economic evolution and even formulated 'visions' about the evolutionary process is that they have not been supported by adequate analytic tools. One of the most ambitious goals an economist can set to himself is to change this situation.[4]

In retrospect, it is obvious that Schumpeter failed in finding fully adequate set of tools for the formulation and analysis of problems related to the processes of economic evolution. Especially during his work with his book on *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process* (1939) it became clear that his early hopes concerning the formalisation of evolutionary dynamics did not succeed because their basic character made his 'theories so refractory to mathematical formulations' (Schumpeter, in Swedberg, 1991, 230). One of the consequences of this was 'that his ardent support of mathematics in economics drove his students away from the fields of intellectual endeavor that made his own work so significant, and produced many results that he considered sterile.' (Smithies, 1951, 14) On this background, it is not difficult to understand why the old Schumpeter wanted to present his ideas in terms of case studies rather than in relation to formal analyses (Schumpeter, 1949) – even though the latter was his basic ambition (dating back to Schumpeter, 1908). However, his life-long search for different ways of formulating his evolutionary vision has left a huge material for his followers. Furthermore, Schumpeter's formulation of and confrontations with the tool problem of evolutionary analysis brings us a long way in clarifying many problems, including the wave form of evolutionary thinking in economics,[5] the role of Schumpeter in the history of economic thought and analysis (only indirectly touched upon in Schumpeter, 1954), and the relationship between Schumpeter and the new model-building evolutionary economics. In short, it helps to place present-day evolutionary modelling in a broader context. In order to see this we have to consider the history of economic thought from a very different angle than we find in Schumpeter's *History of Economic Analysis* and also very different from the ones presented in more specialised accounts (like Hodgson, 1993).

To understand Schumpeter's work we have to start with Marshall's evolutionary thought which was clearly influenced by Hegel and Spencer (Groenewegen, 1995, 166 f.). Actually, large parts of his *Principles* (1949) and his *Industry and Trade* (1919) can be read as preliminary sketches of analyses

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[4] The success is such an endeavour is in no way guaranteed, but experiments with evolution-oriented tool-making seems worth a try: 'Das Faszinierende an der Wissenschaft ist im Grunde nur der Spass, den man hat, wenn man tut, was beste Autoritäten für unmöglich erklären; nur die Jagd nach solchen Gelegenheiten ist etwas wert.' (Schumpeter, 1932, 608)

[5] The present paper concentrates on the 'long wave' which includes the turn of the century. But we also find a tool problem in the early upswing in the discussion of economic evolution which include the contribution of Adam Smith (and other representatives of the Scottish Enlightenment). While Smith was in many ways treating the evolutionary-economic process, Ricardo and most of his followers concentrated on the easily formalisable but non-evolutionary part of his argument. Even Smith himself seems to some extent to have started this development. In Kaldor's (1972, 1240) stylised version of the story, Smith starts his *Wealth of Nations* with a fruitful discussion of the division of labour; but after that 'his interest gets bogged down in the question of how values and prices of products and factors are determined'. The more formalistic followers were quick to recognise which part of the argument could be supported by the available analytic tools.

of the evolutionary process. But when it came to the fulfilment of these more or less explicit promises, Marshall and most of his contemporaries tended to give up. This was the theme of a *fin-du-siècle* debate which included Veblen's (1898) famous paper: 'Why is Economics not an Evolutionary Science?' In this and other papers (1899-1900) Veblen primarily accused the formalised apparatus of marginalist economics for hindering evolutionary modes of thinking. But this is a one-sided explanation. Veblen's account ignores that the primarily problem for Marshall, Böhm-Bawerk (1921), and several others was a lack of adequate analytic tools for treating the complex processes of evolution. By keeping their references to the evolutionary process in the revised editions of their works they emphasised the research task for the new generation (Marshall, 1898) but at the same time they introduced apparent inconsistencies into the formalised parts of their comparative-static argument.

Schumpeter's first book (1908) was designed to clear up this intellectually confusing situation. His main result was a kind of impossibility theorem: the core of the neoclassical apparatus cannot treat the process of economic evolution. This conclusion neither means that neoclassical tools should be dropped (they have important applications) nor that evolutionary phenomena should be abandoned. The evolutionary phenomena was confronted in Schumpeter's second book (1912) which was designed to demonstrate that an intellectually respectable theory of economic evolution (Entwicklung) can be developed (even) if we take a (pseudo-) Walrasian economic system as the point of departure. The alternative starting points in Marshall and Böhm-Bawerk were abandoned both because the task was to overcome the confusion created by their mixed character and because Schumpeter wanted to include discrete innovations rather than a theory of incremental change (which is contrary to their incrementalist evolutionary theories). Thus the Schumpeterian theory was formulated as an explicit (but rather incomplete) alternative to the dominant 'Marshallian theory of evolution' (Schumpeter, 1954, 1165). In a certain sense this theory see economic evolution as 'organic growth' (Marshall, 1898, 42 f.) in analogy with 'the gradual organic growth of a tree' (Schumpeter, 1934, 216).[6] Schumpeter (1939, 203) considered this 'picture of a steady march of progress to be misleading' since 'evolution is lopsided, discontinuous, disharmonious by nature' (p. 102) To emphasise the essence of his own evolutionary vision, Schumpeter developed a theory which removed the gradualist and adaptive aspects from the focus of attention and (like Kuhn, 1970, with respect to scientific evolution) emphasised the incommensurability between old and new as a core characteristic of his concept of innovation. At the same time Marshall's 'manager' was transformed into a routine-following agent while the creative tasks were left to the Schumpeterian entrepreneur.

When studying Schumpeter's work we should use his own distinction between the analytic tools available to him and his evolutionary vision which to some extent became distorted by being expressed in these tools. More specifically, Schumpeter formulated his evolutionary theory in connection to a (pseudo-) Walrasian framework: a routine-based circular flow of economic life. This

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[6] Schumpeter (1954, 892 f.) has made a caricature of this evolutionary theory: '[P]opulation increases, accumulation proceeds; markets widen in consequence; and this induces internal and external economies (cost-reducing improvements in the organization and technique of production). To these effects we must add those of non-induced or revolutionary inventions that just happen ... All this does not go fundamentally beyond J. S. Mill or even A. Smith. In particular, this progress is thought of as a continuous and almost automatic process that does not harbor any phenomena or problems of its own.' This is, however, a 'definite theory of economic evolution ... the Marshall-Moore theory of organic growth' (Schumpeter, 1939, 203).

framework is first challenged by an innovative entrepreneur; then swarms of entrepreneurs forces the non-innovative entrepreneurs to adapt; finally everything settles down to a new routine-based circular flow.[7] This scheme, however, does not imply that Schumpeter thinks the new circular flow evolves directly out of the initial innovation (as Hodgson, 1993, 43, seems to suggest). Schumpeter's sole reliance on innovation rather than selection should instead be seen as reflecting the inadequate tools available to him. Given these tools (including a rough reinterpretation of Walras), Schumpeter chose to focus on an important aspect of his vision: that innovations are not (always) random variety to be selected, but (sometimes) powerful ways of restructuring the selection environment. He even chose to *define* an innovation as being successful, because in this way he was relieved from the trouble of studying all the unsuccessful innovative attempts. But this is obviously not a full demand specification for evolutionary models in the Schumpeterian tradition.

With the benefit of hindsight we can see that Schumpeter's connection to Walras and the radical split between the Marshallian approach and the Schumpeterian approach is unfortunate, not least because it tends to force the modern researcher to choose between different hypotheses which all appear to reflect aspects of the real process of economic evolution. One example is that Schumpeterian consumers have to be persuaded of the advantages of a product innovation by the Schumpeterian entrepreneurs while Marshallian decision-makers are normally able to judge the quality of a modified product or a modified process. In the Marshallian approach there is no need for a concept of innovation since economic evolution can be studied in terms of gradual quality improvements (called 'incremental innovations' by neo-Schumpeterian researchers) while the Schumpeterian approach focuses on significant innovations and leaves the realm of quality improvements to the routine-based behaviour of Schumpeterian managers.

At the time when Schumpeter (1927; 1928; 1934; 1939) presented his evolutionary ideas to an English-speaking audience, the Marshallian approach to economic evolution was under heavy attack. It was primarily Sraffa (1926) who provoked the end to the influential Marshallian blend of evolutionism and comparative-static analysis. This 'crowding out' of evolutionary perspectives from economics is an implicit but central theme in Shackle's *The Years of High Theory: Invention and Tradition in Economic Thought 1926-1939* (1967).[8] In these years Schumpeter went, once more, against the stream. On the one hand, he (e.g. 1933) welcomed and supported the new wave of formalism within the core areas of economic theory, and implicitly he probably also welcomed the disintegration of the Marshallian blend of economics. On the other hand, he stubbornly proceeded in publishing his verbose accounts of his version of the evolutionary dynamics of capitalism. This apparently paradoxical double strategy can be explained by Schumpeter's hope that one day the mathematicians and econometricians would help him in articulating a more satisfactory version of his evolutionary theory.

3. The model-building evolutionary economics and Schumpeterian competition

The above account for Schumpeter's trouble with the available tools for expressing his evolutionary vision as well as his tendency to overdramatise the gap between his own and Marshall's evolutionary theories give many

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[7] See the reconstruction in Andersen (1994, ch. 2).

[8] Parts of this process is described in Foss (1991).

suggestions for the evaluation of the relationship between Schumpeter and model-building new evolutionary economics.[9] Schumpeter's deep-felt tool problem is an obvious starting point for modern tool-makers who immediately remark that 'the intellectual coherence and power of thinking about Schumpeterian competition have been quite low, as one would expect in the absence of a well-defined theoretical structure to guide and connect research.' (Nelson and Winter, 1982, 29). The mutual recognition of the tool problem does not make such a statement an expression of hostility. On the contrary, as we saw in the quotation in section 1, Nelson and Winter (1982, 39) 'are evolutionary theorists *for the sake* of being neo-Schumpeterians'. The Schumpeter–Marshall relationship is somewhat more tricky for modern modellers. One the one hand, Schumpeter's routine behaviour and his discrete innovations are much easier to handle than Marshall's incrementalist and flexible account of business behaviour. On the other hand, the Schumpeterian entrepreneurs tend to emerge out of nowhere, so to say, while Marshallian business firms are more stable and predictable entities. The solution seems to be some sort of combination in which established firms are also able to show innovative behaviour. This solution was actually proposed by Schumpeter himself in his *Capitalism, Socialism, and Democracy* (1950) which deals with the more or less permanent innovative activities of 'big business' (without any reference to Marshall). The solution has later been known as Schumpeter Mark II, while the young Schumpeter put much emphasis on the emergence of new firms based on a single innovation (Mark I). It could just as well be called a preliminary Schumpeterian-Marshallian synthesis.

Nelson and Winter proposed a solution to the tool problem met wide-spread attention when they rewrote several earlier articles and formulated a research programme in their book on *An Evolutionary Theory of Economic Change* (1982). The core contributions of Nelson and Winter (1982, 19) and their followers are based on the assumption that the 'verbal account of economic evolution seems to translate naturally into a description of a Markov process – though one in a rather complicated state space.' At a certain point of time, t, the state of the evolutionary process of an industry is described by the capital stock and the behavioural rules of each firm. This state is used for determining the short-term behaviour of the industry as well as the new capital stock and the new behavioural rules of each firm at time $t + 1$. It is the shift in behavioural rules which gives the overall evolution the character of a stochastic Markov process. When this process of state transformation is defined, it is relatively easy to translate it into computer models and simulations. This translation is, however,

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[9] Although the relationship between evolutionary modellers and Schumpeter has been given priority, it is not the only one which can be studied. Nelson and Winter (1982) give credits to many of the authors who sticked to evolutionary perspectives during the dark ages for evolutionary thought (pp. 33-45). Schumpeter gets special attention but it is also suggested that 'our evolutionary theory is closer to the original Marshallian doctrine than is contemporary orthodoxy.' (p. 45) Furthermore, Adam Smith, Marx, Simon, Penrose, Chandler, and many others are mentioned. Only the American institutionalist economics in the tradition of Veblen and Commons are largely missing (see, however, p. 404), and this may explain why the notion of 'evolutionary economics' (invented by Veblen, 1898) is missing in the book. (However, the notion of 'evolutionary economics' pops in the index of Nelson and Winter, 1982, 432.) The recognised 'antecedents' of the Nelson-and-Winter theory are largely the more or less heterodox economists who have admitted that they faced a tool problem. The institutionalists seem largely to have been denying the need for a formal foundation of evolutionary theorising, and this might explain some of the background for Nelson and Winter's relationship to them.

not purely trivial. The reason is that the translation into a programming language makes it possible to treat some of the intricacies of evolutionary mechanisms which were not clearly dealt with (or even imagined) in the original verbal-style account of the evolutionary process. For instance, we do not have to concentrate on the fact that firms are 'naturally selected' by the economic system (as emphasised by Alchian, 1950); we can also consider many details relating to the fact that firms are influencing their own destiny by modifying their own behaviour through search for and selection of new technologies (or broader: new modes of behaviour).

Through their work Nelson and Winter demonstrate the possibility of overcoming the basic difficulty in studying evolutionary processes, namely the need to combine elements which are normally considered as belonging to quite different areas of investigation. These elements are the processes of transmission, variety creation, and selection; or more specifically: Simon's work on rule-based behaviour (Nelson and Winter, 1982, chs. 4-5), Nelson's and other Schumpeter-related work on invention and innovation (ch. 11), and Alchian's and Winter's work on 'natural selection' (chs. 6). Such a combination presupposes two opposing capabilities: an ability to cope with a wide diversity of elements, and an ability to cut out the details and integrate the elements into an initially crude conception of an evolutionary process. The computer helps to organise this synthesising exercise to the very last steps since 'the simulation format does impose its own constructive discipline in the modeling of dynamic systems: the program must contain a complete specification of how the system state at $t + 1$ depends on that at t and on exogenous factors, or it will not run.' (pp. 208 f.) By taking this process to a preliminary conclusion, Nelson and Winter provide a constructive proof of the existence of relatively interesting evolutionary-economic models. At the same time they give an explanation of the weaknesses of the informal approaches to evolutionary processes: these processes are normally so complex that it is nearly impossible to master them intellectually by means of the methods of the old evolutionary modes of thinking.

To see to which extent the Nelson-and-Winter framework helps to overcome the problem, we shall shortly consider their model of Schumpeterian competition which may be considered as their standard model type (chs. 12-14), but we could also have considered the works of some of their followers.[10] The typical Nelson-and-Winter model deals with the evolution of the production techniques and other behavioural rules of an industry producing a homogeneous product (see also Andersen, 1994, ch. 4). From the very beginning it is important to note that this model of Schumpeterian competition is just one simple example of a 'vastly larger' class of Markov models (p. 407). But Nelson and Winter claim that such a simplistic model helps to clarify some of Schumpeter's thoughts. The model describe how the state of the industry in the next period is found when the state (capital stock and productivity) of the present period is given. First, the present state is used to define a short-term economic process in the industry whereby market shares, price, and profits of firms are found.[11] The simplicity of the solution depends on the firms' use of

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[10] In the present (version of the) paper no attempt will be made to give a survey of the evolutionary modelling in the Nelson-and-Winter tradition. However, the reader may think of Winter, 1984; Silverberg, Dosi, and Orsenigo, 1988; Kwasnicki, 1992; Chiaromonte and Dosi, 1993; Silverberg and Verspagen, 1994; ...

[11] Summary of the short-term part of the model: The production capacity of each firm is physical capital times the capital coefficient. Output of each firm is decided by simple capacity utilisation rules of firms. The aggregate output of the industry faces

fixed (or evolving) rules for output determination and on the exogenous specification of the demand side of the model as well as of the factor markets. Second, the investment decision is treated in a simplified way.[12] Firms expand their capacity in relation to their profitability – partly with the help of banks. However, the expansion of firms with a particularly large market share is constrained by the fact the effect of expansion on the market price is taken into account. Third, the processes of innovation and imitation is treated somewhat more thoroughly.[13] These processes are specified along the lines of Schumpeter Mark II in which the firms are continually searching for new production techniques and for copying the production techniques of their oligopolistic competitors. The simplicity of the solution depends on the firms's use of fixed (or evolving) rules in determining the R&D expenditure, and on the fixed 'landscapes of search' (with global or localised possibilities of search). Another contribution to the simplicity comes from the assumption that an innovation can immediately be applied throughout the firm, and this gives increasing returns to the application of innovations.

In this model of Schumpeterian competition it is the combined result of innovation, imitation, and investment which determines the change in the market shares of firms during a simulation run (Nelson and Winter, 1982, chs. 12-14). The innovation behaviour tends to increase concentration while imitation and the monopolistic behaviour of large firms serve to constrain the rate of concentration. The question is, of course, how much this market process has to do with Schumpeter's work. A quick answer is that it is more designed to rethink the Schumpeter's and Galbraith's hypothesis of a concentrated market structure for rapid technological change than Schumpeter's broader ideas of a self-transforming capitalist market process. Through Nelson and Winter's analysis and simulations this Schumpeter/Galbraith hypothesis is refuted since the chain of causation runs from the exogenous conditions of R&D and firm strategies via differential performance of firms to industry structure, rather than *vice versa*. Instead Nelson and Winter expresses a preference for a broader Schumpeterian approach (of *The Theory of Economic Development*). This alternative view is developed in a paper by Winter (1984) as well as in later works in the neo-Schumpeterian tradition. Especially it is emphasised that Schumpeter thinks in terms of two modes of technical change and two

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exogenously given demand conditions which together give the market-clearing price of the product. For each firm we calculate the turnover and then find the net profit by deducting capital depreciation, variable production costs, and R&D expenditure.

[12] Summary of the investment part of the model: The only way to reduce productive capacity is through the process of physical depreciation. The firm's investment is delimited by its financial constraint which is determined by the net profit. The firm's desired net investment depends on the ratio of output price to unit costs and a target mark-up factor which is an increasing function of the firm's market share. The adjusted physical capital stock is available to the firm from the beginning of the next period.

[13] Summary of the innovation/imitation part of the model: The innovate and imitate costs are given by the R&D rules of firms. The probability of success in innovation and imitation depends on the respective search costs and the difficulty of innovation/imitation in the industry. An imitative success means that the firm gets access to the best-practice technique in the industry. The outcome of an innovative success depends on the character of technical change in the industry ('science based' or 'cumulative technology'). The attempts to improve productivity end with a comparison between the capital coefficients obtainable by the technique inherited from the last period and the outcomes of imitative and innovative search; the technique with the best productivity is chosen. If the technique is changed, it will determine capital coefficient for the next period (disembodied technical change).

corresponding types of behavioural rules. The 'entrepreneurial mode' can e.g. be specified by assuming that the search work is performed before entry to the industry. If the new firm becomes sufficiently large, it reaches a threshold which allows a basic change in behavioural rules. It enters the 'routinised-search mode' where it has succeeded in incorporating routinised search into its normal business activities.

This account can be expanded into a story of 'creative destruction' which would probably have pleased Schumpeter more than the exploration of the Schumpeter/Galbraith hypothesis. It is not least the possibility of a rough account of the exit and entry of firms which gives immediate credence to Nelson and Winter's (1982, 39) belief 'that he [Schumpeter] would have accepted our evolutionary models as an appropriate vehicle for the explication of his ideas.' There are two types of destruction of firms (Winter, 1984; and others): a firm can invest so little that it in the end fail with respect to a minimum capital stock level; and the perceived performance of the firm may fall below a critical negative level. The creation of firms which are new to the industry raises some more interesting problems. Instead of giving a full account of the Schumpeterian entrepreneur, we consider the profit-seeking activities of entrepreneurs who are not yet producing the product of the industry. The activities of these entrepreneurs can be described in terms of costly innovative and imitative search – just like the activities we find within the industry.

Taken as an aggregate, external entrepreneurs are involved in search activities (R&D) which will occasionally give sufficiently promising results with respect to the production technique of the industry under study. To study this industry from its initial creation we start the whole story with a founder, or *Gründer*, who is successful in his innovative search activities. In other words, he finds a production technique which allows him to produce a potential product, and he obtains some initial information about the potential price of the product as well as of production inputs. His decision to create the industry depends on expectation of a high profit rate (to overcome the initial costs of market creation), and if this profit rate is realised, it will induce him to make a rapid rate of expansion capacity when he has entered into the industry. For the *Gründer* and his first followers there are few incentives for costly R&D activities (Schumpeter Mark I). However, the expansion of the output of the industry will diminish profits and this will lead to negative evaluations of the performance of the firms. In the case of 'satisficing behaviour' this will lead to an increase in innovative and imitative search efforts of existing firms (Mark II). Firms who do not adapt to this change are likely to become bankrupt.

This basic study of evolutionary industrial dynamics can be related to many of Schumpeter's discussions. It can also be adapted to Marshall's (1949, 263 ff.) idea of an industry as a forest of firms where young firms struggle upwards while some older firms become dominant before they succumb because of a lack of vitality. Further possibilities are explored in the post-Nelson-and-Winter literature mentioned above (see also Nelson, 1995). These studies include the consequences for diffusion of innovation of the introduction of vintages of capital and embodied technical change, the consequences of the introduction of learning by doing in existing lines of production, the path dependency of the evolutionary processes, the shift in technological regimes and market regimes, the evolution of rules of behavioural strategies like the R&D intensity of firms, etc. Even the issues of entrepreneurial strategies of firms have been dealt with in some depths, although the basic tendency in the research has been to focus on industries or other populations of firms.

4. Delineating a model of Schumpeterian-Marshallian competition and cooperation

In the accounts of the different models of Schumpeterian competition there are frequent references to Schumpeter's works but there is, to the best of my knowledge, no evolutionary simulation model which has been solely designed to formalise and simulate Schumpeter's arguments. The reason is that the model-building work in the Nelson-and-Winter tradition has been influenced by many design criteria (see e.g. Nelson, 1994; Winter, 1991). First, evolutionary-economic models are supposed to be more realistic with respect to firm behaviour than neoclassical ones; especially, no perfect information and no perfect factor substitution should be attributed to firms. Second, models should relate to the stylised facts of industrial dynamics; for instance, the generation and diffusion of knowledge concerning new production methods should be modelled in some detail. Third, models should be as simple as possible; although the simplicity is rarely sufficient for the deduction of analytical conclusions, the model should be relatively easy to communicate and study by means of computer simulations. Fourth, models should reconstruct the verbal accounts of evolution given by older economists like Schumpeter.

It is quite natural that the fourth design criterion tends to become crowded out by the other goals. The reason is the set of design criteria form a tremendous set of constraints upon the model-building process. To make clear-cut models it is important to delimit the set of constraints. For instance, one can eliminate the propositions by Schumpeter which do not fit into the criteria of realism, empirical relevance, and simplicity. This may explain why only a few more or less Schumpeterian themes have got the bulk of the attention of the modellers. In this respect the remark by Rosenberg about the Schumpeter renaissance as 'an excessively partial one' (quoted in section 1) is still valid. But the application of a limited set of Schumpeterian propositions is clearly confronted with decreasing returns in terms of interesting modelling results. This suggests that it might be fruitful to explore other areas like the Schumpeter–Marshall relationship which have not yet been explored by the modellers.[14] In Schumpeter's work we find little direct support for this task. On the contrary, he states that Marshall's theory of economic evolution is 'unsatisfactory' and 'misleading' because Marshall has left out discrete innovations as en endogenous part of the economic process (Schumpeter, 1939, 203). A full picture of the process should, according to Schumpeter (1928, 68, 62), include the 'primary' phenomenon of the entrepreneur 'as the propelling force of the process' as well as a large number of 'secondary phenomena'. A model which includes both propellant and propelled activities would have been welcomed by Schumpeter; only the lack of sufficient analytic tools made him ignore the more or less automatic consequences of innovative entrepreneurship. However, the integration of 'primary' and 'secondary' phenomena of the evolutionary process in a model does not create a full combination of Schumpeterian and Marshallian analysis. The Marshallian notions of intra- and inter-firm division of labour and the related internal and external increasing returns to scale presuppose an interest in the details of the organisation of the process of production (and consumption) – which lead directly back to Adam Smith's analysis of the division of labour.

An evolutionary model which attempts to implement a combined Schumpeterian–Marshallian analysis can start from Nelson and Winter's theory

[14] An early example of an attempted integration between Marshallian and Schumpeterian ideas is described by Nightingale (1993).

of the firm. This theory is much more complex that can be seen from the simplified version of firm behaviour applied in the standard model of Schumpeterian competition (see section 3). According to full theory (Nelson and Winter, 1982, chs. 4-5), each firm is based on a large number of interdependent routines which are performed by the workers. The exposition of the theory of the firm follows that of Schumpeter: it starts from an 'analogue of Schumpeter's "circular flow" at the level of the individual organization' (p. 98); then the processes of change are introduced into this setting; finally the possibility of routines for making innovations is discussed. The conclusion of this analysis is 'that it is quite inappropriate to conceive firm behavior in terms of deliberate choice from a broad menu of opportunities for the organization. The menu is ... built into the firm's routines, and most of the "choosing" is also accomplished automatically by those routines.' (p. 134) For instance, the firm 'chooses' to apply its customary production technique, and it even uses routines for the determination of output, investment, and R&D expenditure.

In the Nelson-and-Winter model of Schumpeterian competition, all this intra-organisational diversity has been reduced to a single evolving production technique and a set of fixed parameters of decision-making.[15] But their own verbal account for intra-firm complexity can actually be used in the study of the creation of markets by firms which specialise as a consequence of the evolutionary process. This is the case in Marshall's (1949, 222-231) account for the emergence of 'industrial districts' – but the issue is much more general (cf. Young, 1928; Stigler, 1951). The simplest way of formalising Nelson and Winter's theory of the firm in a way which opens up for a subsequent specialisation of firms is to consider the overall task of producing the product on the firm as consisting of a series of subtasks which can either be done in parallel or in series (Andersen, forthcoming; Andersen and Lundvall, 1995). To simplify we assume that the different production tasks are performed by means of labour alone. For each task of a firm it has in each period a specific production technique which is characterised by its labour coefficient, i.e. the amount of labour needed in this task for the production of one unit of final output. The total amount of labour needed for the production of a unit of output is simple the sum of the labour coefficients of all the n tasks of production. To keep the model of Schumpeterian-Marshallian competition as close as possible to the model of Schumpeterian competition, it is assumed that the overall number of workers and thus the aggregate output of the firm is constrained by its organisational capital (which is renewed in the same way as physical capital).

The firm-level dynamics of the Schumpeterian-Marshallian model can most easily be understood by reference to Adam Smith's (1976, 14 f.) famous case of pin-making. The overall product defines the task of delivering a pin (or a package of pins). This task can be divided into numerous subtasks: the delivery of pin heads and pin bodies; the delivery of the tools of pin-making and even the innovative ideas for the improvement of pin-making. Each of these subtasks can be further divided into sub-subtasks, and this process can continue recursively. In such a task-oriented conception of production there are many possibilities of increasing returns (Vassilakis, 1987; Scazzieri, 1993), but the Schumpeterian-Marshallian model concentrates on the increasing (social) returns to the application of innovations (the given costs of an innovation are spread over a smaller or larger output). More specifically, the model deals with

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[15] One explanation for this reduction of complexity is that the environment of the industry (markets for products, factors, and finance) is highly simplified. Extra complexity with respect to the specification of firms would just make the model more confusing.

innovations which produce non-incremental increases in the labour productivity of performing individual tasks.

This apparently simple revision of the Nelson-and-Winter model of the firm is the starting point of the study of an industrial dynamics which differ radically from the standard model of Schumpeterian competition. In the standard Schumpeterian model the firms compete about exactly the same 'niche'. To avoid that only one firm will survive, several stabilisers are introduced into the model: price determination and external finance do not secure rapid elimination of weak firms; large firms deliberately restrain their expansion; imitation eases the survival of weaker firms. The introduction of such stabilisers allows an illuminating analysis of industrial concentration (section 3). But in order to understand the long-term coexistence of radically different types of economic behaviour, we have to transcend this limited model of Schumpeterian competition. The introduction of a number of different productive tasks which can be innovated individually creates a multi-dimensional system of competition which allows the survival of a larger number of behavioural variants. The reason is that firms can specialise: when a firm has made an innovation with respect to one of its tasks, it decides whether or not to specialise in pursuing this task. If it does so, it exploits the innovation on a larger scale. However, it has a problem of creating a market for the intermediate product which is the output of its innovated task.

A process in which innovations with respect to individual tasks take place repeatedly gives rise to a complex and evolving industrial network of suppliers. This process can most easily be illustrated in relation to Adam Smith's story of pin making. Assume that a large number of firms perform all the subtasks of pin making. Then a firm makes a major process innovation with respect to the production of pin heads. This firm has two possibilities: it can use the innovation in relation to the part of its production which concerns pin-head making, or it can specialise in pin-head making and supply other firms with an intermediate product (pin heads). If the firm specialise in pin-head production, it may still have a heterogeneous process of production which includes tool-making as well as the application of tools in the making of pin heads. Thus an innovation may concern the process of making tools for pin-head production rather than the application of these tools. This means that a new decision has to be made: whether to become a specialised tool-maker or to apply the innovation within a mixed process of production. In this way the process of intra-firm division of labour may go on. The formalised version of the story include discrete steps of market creation, the dynamics of intermediate industries, the interdependence of the different parts of the 'development block'[16] of pin-making, etc. It can be used in the study of the many kinds of coordination problems which emerge during the vertical disintegration and partial reintegration of such a development block.

To make it operational the Schumpeterian-Marshallian model needs much specification.[17] A few suggestions might help to explain the nature of the exercise. First of all, the probability that a firm obtains an innovation in a given period can be determined in exactly the same way as in the Nelson and Winter's Schumpeterian model, i.e. in proportion to the rule-based, overall R&D expenditure. Which of the different tasks of the firm obtains the innovation is determined probabilistically in proportion to the number of labour hours spent on the different tasks during the period. Second, the firm can apply the

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[16] To use Dahmén's (1991) concept of the interdependent dynamics of different industries.

[17] A fuller specification is found in the appendix to Andersen and Lundvall (1995).

innovation within its given production structure and increase the exploitation of the innovation by expanding its organisational capacity. This is similar to the behaviour of firms in the standard Schumpeterian model. However, the benefits from the innovation depends on the size and the production structure of the innovative firm. If the firm is small and its production activities are spread between many tasks, then a given decrease in the task-specific labour coefficient will only give small results on the overall labour coefficient. If the firm is large and highly specialised in the innovated task, then the gains will be substantial. Third, the firm can decide to specialise and thus increase the proportion of its labour force which is engaged in the innovated task. This means, e.g., that a small firm is often able to reap a large part of the benefits from an innovation (its customers get the rest). Fourth, the customer has to order and pay the intermediate product in the period before it is used. The user is thus holding an inventory of the intermediate product. In the next period he will reduce his own production with respect to the task in question, and instead apply the inventory of intermediate products in his production. The assumed flexibility of the labour force and of organisational capital means that a specialisation is reversible. Furthermore, if the inventory is too small for the current needs, the buyer can produce the rest with his own labour force (presumably at higher costs).

A simulation experiment with the Schumpeterian-Marshallian model starts with the specification of the different parameters and the initial values of the state variables. It is convenient to start in a state of the system which is steadily reproduced provided that no innovation takes place. In this steady state all the firms are performing all the tasks in-house. In this case the intra-firm division of labour could be ignored, and we would have exactly the same system as in the standard Schumpeterian model. However, as soon as an innovation occurs, it becomes obvious that Schumpeterian-Marshallian model is distinguished from other evolutionary-economic models by the production graph which describes how the individual tasks are connected in series and parallel. To simplify the description of the outcomes of the simulation, it is convenient to split tasks into equivalence classes according to the number of steps they are removed from final consumption (as the Austrian economists have suggested). The finalisation of the output of the sector is in class 1, the directly connected tasks are in class 2, and so on. During the simulation, the proportion of exchanged products which comes from each of these classes will vary. Initially, all traded products comes from firms related to class 1 where all employment is concentrated. Then proportion of employment in firms related to higher classes increases because of vertical disintegration. Finally, the employment share of class 1 firms may increase (in a modelling set-up with a fixed or declining number of firms). The reason is primarily that firms with an increasing organisational capacity (i.e. employment capacity) will need to cover more and more tasks in order to fully exploit their capacity (and profit opportunities). The change rate of the aggregate labour coefficient will more or less change in parallel with this process: an initial increase and later a possible decrease. However, the emergence of a structure characterised by larger firms increases the speed of exploitation of innovations, although it is only in extreme cases that a large-scale reintegration can function more effectively than innovation-driven specialisation.

The strength of the Schumpeterian–Marshallian model is not least based on the fact that in combines the classical approach to the division of labour with the Schumpeterian notion of discontinuous innovation. The model demonstrates how specialisation and innovation are closely connected. At the micro-level vertical specialisation is a way in which a previously unspecialised firm can

often increase the returns from its innovation. At a more aggregate level specialisation can be demonstrated to be a way of increasing the speed of the diffusion of the innovation. But the most interesting result of the (repeated) process of specialisation is the emergence of a complex inter-industrial system. This system is not only consisting of competing firms. It also implies the emergence of a system of 'species' or 'industries' – and thus it gives an answer to one of Mirowski's (1983) critiques of the model of Schumpeterian competition. The issue of the non-incremental emergence of species is closely related to Schumpeter's vision of evolution. It may imply an important step forward for evolutionary modelling which might become clearer if an comparison with the development of evolutionary biology is made: The present-day evolutionary modelling has several similarities with the formal evolutionary models by Fisher and Haldane of the 1930s. However, the practical importance and the wide-spread use of evolutionary biology came from the 1940s and onwards when a 'modern evolutionary synthesis' was made which combined formal analyses of the evolutionary micro-level with theories dealing with macro-evolutionary phenomena (Mayr and Provine, 1980). Here we need a whole new set of concepts which have some similarities with the concepts of the neo-Darwinian synthesis of evolutionary theory, genetics, and taxonomy – like 'isolating mechanisms', 'sympatric and allopatric speciation', 'founder principle', 'gene flow', 'isolate', 'stabilising selection', 'taxon', etc. The economic analogies of all these concepts include a large degree of discontinuities and they might to some degree be inspired by Schumpeter.[18]

The potential fruitfulness of the Schumpeterian–Marshallian approach is not solely described by these grand issues. It can also serve as a starting point for the study of many problems of economic coordination. One set of these problems relates to standardisation. As long as intermediate products are made as one of many production tasks within vertically integrated firms, there is no need for an economy-wide standard for how to perform the task. Thus a certain degree of heterogeneity with respect to the specification and costs is allowed to exist between the firms. When firms begin to specialise, this will disclose much of this heterogeneity. Standardisation is an evolutionary process which includes a period with alternative proposals and incremental adaptations before the emergence of a standardised solution; later this solution might be challenged by product innovation. The basic characteristics of such a process can be

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[18] These formulations is an example of how an analogy can be used as a quick way of describing an idea. The same has been the case with respect to other uses of biological analogies by evolutionary-economic modellers. However, since there are so many possibilities to make analogies within the realm of economics and social sciences, the relation to biological metaphors are not a major issue. Most modellers do not emphasise the biological analogy although they exploit the tool-making performed in biology. They tend to agree with Schumpeter as well as Freeman (1992, 123) that an analogy may be a 'fertile source of new ideas and explanations' but 'it is important not to get carried away by evolutionary analogies and to mistake the analogy for the reality'. Often they use it more as a piece of pedagogics rather than as a guide for the modelling work. Even the one who contributed most to the analogy, Alchian, emphasised in his answer to Penrose's critique of his use of the analogy: 'The theory I presented stands independently of the biological analogy. ... In my original article every reference to the biological analogy was merely expository, designed to clarify the ideas of the theory. ... Readers of an earlier draft, containing no references to the biological similarity, urged that the analogy be included as helpful to the understanding of the basic approach.' (Alchian, 1953, 601) Similarly, Winter (1987) has tried to transcend the question of biological analogies. This is the reason why this part of Hodgson's challenge has not been directly confronted in the paper.

characterised in relation to Smith's pin-making parable. Before interfirm specialisation of labour has taken place, each firm is free to choose its own way of fitting the results of the different tasks together. For instance, the necessary restriction for a feasible production process is mainly that pin heads and pin bodies fit together rather than that they individually have specified sizes. Thus each firm may have its own specification of pin heads. But as soon as pin-head producing firm starts to deliver to a customer, a problem emerges. Assuming that the pin-head specifications of the producer and the user differs, the pin-head producer has to decide whether or not to reorganise his production. This problem will be more compelling when more customers are to be supplied. Either pin heads are to be produced in several batches or the new customers must be persuaded to accept the 'standardised' specifications of pin heads.

Another set of problems relates to product innovation. 'Product differentiation plays an important role in the histories of industries; to understand this fully, we need to admit more complexity to the demand side of markets in which our evolving firms operate.' (Nelson and Winter, 1982, 408) Progress has been quite slow in this respect, although Gerybadze (1982, chs. 3-5) has made direct extensions of their model is this direction by studying the interaction of firms which sells and buys a certain type of products. The Schumpeterian–Marshallian model might change the situation. To do so, we shall be somewhat more precise in the definition of the quantity of intermediate products that we was when discussing standardisation: the unit of an intermediate product is as equal to the amount of the product necessary for the production of a unit of final output. In other words, to produce one unit of final output, one unit of each of the intermediate products is necessary; only labour coefficients can be changed. An intermediate unit can, however, be of varying quality. A product innovation is a non-incremental change in the quality of an intermediate product. Such a product innovation implies that the buying of an intermediate product will not only substitute the labour previously engaged in the task(s) taken over by the intermediate producer but also some of the labour engaged in the task which use the intermediate product. It this setting it is easy to define product innovation related to the producer and product innovation related to the user. An important coordination problem (formulated by e.g. Lundvall, 1992) emerges when the activities of the user are of potential importance for the producer's product innovation. One solution is to establish an innovative linkage between the two firms in a way which increase the productivity of the product-oriented R&D of the producer.

5. Conclusions

The relationship between Schumpeter and modern evolutionary modelling often appears to be based on a few Schumpeterian catchwords rather than a thorough examination of the Schumpeter's core problems and solutions. Beneath this superficial relationship there is, however, deeper congruence. Like the modern modellers, Schumpeter emphasised the conceptual and formal tools for expressing complex evolutionary processes, he preferred discrete to continuous change, he tried to introduce the evolutionary problems both in relation to standard economics and to a wealth of new ideas, and first and foremost he took the stand for the study of broad set of evolutionary processes at a time when the overwhelming viewpoint was that this was 'supremely intelligent after-dinner talk' (Lord Robbins, according to Elster, 1983, 112). For these and other reasons the relationship is likely to proceed for some time. However, if it continues to be based on a rather small set of topics taken from Schumpeter's most popular works, it cannot avoid decreasing returns.

Therefore, a basic issue is whether and how the relationship can be renewed. The main suggestion of the paper is to develop a model which combines elements of the Schumpeterian model of evolution with elements of the Marshallian (and broader: the classical) model of evolution. This may look as 'localized search only in the near neighborhood of orthodoxy' (Mirowski, 1983, 766). But as it has been suggested above, such a localised search might lead to major novelties.

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