BUSINESS ECOSYSTEM

A CONCEPTUAL MODEL OF AN ORGANISATION POPULATION FROM THE PERSPECTIVES OF COMPLEXITY AND EVOLUTION

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FOREWORD BY THE DIRECTOR OF TIP RESEARCH PROGRAMME

The aim of the TIP research program (Knowledge and Information Management in Knowledge Intensive Services) is to examine competitiveness, activities, and development opportunities of knowledge-intensive service organisations from the perspective of knowledge management. The projects in the program explore theories of complex adaptive systems and their various interpretations and apply them to the study of socio-economic systems. Based on this, the projects create better understanding of the subject matter and develop knowledge management procedures for firms, other organisations, and business ecosystems comprising them. In addition, the research program aims to increase general understanding in the field of knowledge management. In the course of the program, a research group has formed that excels through thorough research work and international networking. While the research program has started international cooperation with selected universities, firms, and other organisations, the research group has also produced numerous reports, conference articles, and other publications and lectures in the research field of the program, as well as material for teaching.

The TIP research program began by an investigation of the present state in the research field in 2003. The program itself constitutes of three stages that span the years 2004-2006. The first stage (2004), during which this report has been prepared, consists of a conceptual analysis based on an extensive literary review. A total of eleven researchers and a research program coordinator have taken part in the investigation and the first stage of the program. In the second stage (2005-2006), an empirical study on selected enterprises and public administration organisations will be carried out within each project. In the third stage (2006), the focus is on the institutional framework of knowledge management in knowledge-intensive service organisations. The Institute of Business Information Management at Tampere University of Technology is responsible for coordinating the research program.

Individual researchers in the program have had opportunities to build international connections through conferences, workshops, and personal connections. We are grateful especially to Ron Sanchez from Copenhagen Business School and Eve Mitleton-Kelly from London School of Economics for their excellent presentations and tutoring sessions. We would also like to thank all the other experts, firms, public administration organisations, and others who have offered their time and help for the research program during its first stage or promised to participate during the second stage. A special thank you goes to the research program steering group, as well as to research professor Matti Rimpelä from Stakes. We are also grateful to the Director of the Institute of Business Information Management Prof. Mika Hannula for providing the projects with an enabling environment, and to all our colleagues at Tampere University of Technology for cooperation.

We would also like to thank all the financiers. Without their support the research work carried out during the program would not have been possible. The pre-investigation was financed by Sitra, while the Finnish Technology Agency (Tekes), Professia Ltd., and eBRC (e-Business Research Center) financed the first stage of the program.

As the director of the TIP research program, I would especially like to thank the author of this report for successful and high-quality research work and excellent cooperation.

Tampere, January 20th 2005
Marjatta Maula
Professor

ABSTRACT

PELTONIEMI, MIRVA: **Business ecosystem: A conceptual model of an organisation population from the perspectives of complexity and evolution**

Keywords: ORGANISATION POPULATION, COMPLEXITY, EVOLUTIONARY ECONOMICS, BUSINESS ECOSYSTEM, KNOWLEDGE-INTENSIVE SERVICE ORGANISATION

The objective of this study is to construct a conceptual model of the behaviour and development of an organisation population of which knowledge-intensive service firms form an important part. Attention is directed towards the assumptions, on which the behaviour of organisations and populations that constitute of them is based. In addition, the importance and value of knowledge in business, and especially in knowledge-intensive service organisations, is taken into account.

This research is conducted in an explorative manner as a literature review and conceptual analysis. The material for this study - books, journal articles and conference papers - has been gathered through library databases and by attending some international conferences. The research problem "*How can the behaviour and development of an organisation population, of which knowledge-intensive service firms form a part, be modelled at the conceptual level?*" has been approached in an interdisciplinary way from the fields of complexity, evolutionary economics and business ecosystem. In addition, some assumptions of neoclassical economics, and their implications to the modelling problem at hand, are reviewed.

The conceptual model constructed in this research emphasises the dynamics that follow on the one hand from conscious choice and limited knowledge of an individual organisation and on the other hand from the interconnectedness and feedback loops of an organisation population. Conscious choice is an important observation since it differentiates economic evolution from biological evolution. Limited and local knowledge is assumed since no organisation can be perfectly aware of the present state, not to mention the future. This leads to profit motivated striving and not to optimisation as neoclassical economics would suggest. An organisation population is interconnected through competition and cooperation that can be present simultaneously. This results in feedback loops that carry triggers that can induce change in the behaviour of the organisations. Thus, a change in the behaviour of an organisation can induce another organisation to change its behaviour which in turn will encourage the initial organisation to change its behaviour again. These triggers consist essentially of knowledge. Conscious choice, limited knowledge, interconnectedness and feedback loops result in a nondeterministic, nonlinear and unpredictable future constructed by the organisations.

ACKNOWLEDGEMENTS

The research for this report has been done during the year 2004. In the beginning many of the concepts of this research, such as complexity and business ecosystem, were not familiar to me. It was a great challenge to gain understanding of them, and as I found out, the only productive solution is hard work.

Since the field of this research is fairly new there are not many experts in Finland with whom I could have discussed my research. Luckily, I got to meet some foreign scholars, such as Eve Mitleton-Kelly, John Casti, Stanley Metcalfe, John Foster and Peter Allen, in conferences and workshops during the year. From them I received ideas and inspiration, but most importantly they assured me that applying complexity to socio-economic systems is a rational and important effort.

As a part of TIP research group I got to participate in conversations and debates with my fellow researchers. Without them and the support of the group it would have been virtually impossible to find out about complexity science within such a tight schedule. The driving force of TIP research group, Professor Marjatta Maula, showed her commitment by spending far more time tutoring me than thesis supervisors usually do.

Finally, I would like to thank the National Technology Agency of Finland, Professia Ltd. and e-Business Research Center for funding this research.

Tampere, March 2nd 2005

Mirva Peltoniemi

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1 INTRODUCTION

1.1 Background

This research report is a literature review and conceptual analysis about modelling an organisation population that knowledge-intensive service firms are a part of. This research report is a part of the first phase of TIP research programme[1]. The main objective of this study is to build a framework, theoretical basis, for the author's empirical research project that is to be conducted during the second phase of the research programme.

This study is inspired by the rise of the new knowledge-based economy and increasing importance and growth of knowledge-intensive services. The growing significance of knowledge as a factor of production has implications to the way that economic life should be understood. These changes pose new challenges for theory formation and may even render some existing theories of economic development obsolete.

1.2 New economy and knowledge-intensive service firms

According to Liedtka (2002) the term "new economy" is often used but seldom defined. She states that in the United States the change of economy from old to new is characterised by the dominance of technology, financial services and media/entertainment instead of the former giants; manufacturing and oil (Liedtka 2002, p. 2). Thus, the source of business success has moved from valuable tangible products to technology and knowledge. This is noted also by Cooke (2002, p. 189) who states that throughout the OECD area the investment in R&D has risen three times as fast as manufacturing output during 1975-1995. This is a clear sign of the rise of the new knowledge-based economy. New economy has implications towards national competitiveness and economic development (Cooke 2002). The growing importance of knowledge, information, communication and learning are major challenges for many nations, but can also offer unforeseen opportunities. The importance of the amount of available capital as denominator of success is decreasing and moving to people and their knowledge and learning capabilities.

One feature of the new economy is the large number of high technology firms and high technology workers (Liedtka 2002, p. 3). It can also be stated that there is a fundamental change in the capabilities that an organisation must posses in order to survive in the new economy. According to Liedtka (2002, p. 3) these capabilities include the ability to cope with the important role of technology and its catalysing effect, and to take full advantage of the new possibilities of communication. But first of all, the new economy is about "the growing value of knowledge". This

[1] TIP Research Programme, Knowledge and Information Management in Knowledge Intensive Services, Tampere University of Technology. (TIP-tutkimusohjelma, Tietointensiivinen palvelutoiminta tietojohtamisen näkökulmasta, Tampereen teknillinen yliopisto).

is because knowledge is the only way to resist the commoditisation of goods and services. Knowledge, especially tacit knowledge, can not be transferred the way that a product design and its manufacturing methods can be, through reverse engineering for example.

According to Kelly, the distinguishing characteristics of the new economy are ideas, information and relationships (in Liedtka 2002, p. 3). Thus, the difference between the old and the new economy is in the requirements that a firm faces. The key is in a firm's "capacity for managing knowledge and relationships to produce innovation" (Kelly in Liedtka 2002, p. 3). Thus, the emphasis is on both knowledge and its creation. Kuusisto and Meyer (2003, p. 2) state that the importance of services is a sign of major shift in the business world. "In the evolving knowledge economy, the role of services is so prominent that their full acknowledgement is long overdue." The interest in services, however, is directed pronouncedly towards knowledge-intensive services. This is the way firms can gain knowledge and knowledge can be turned into business opportunities.

Kemppilä and Mettänen (2004) claim that knowledge-intensive service sector is characterised by fast growth compared to other industries. In addition to knowledge-intensive service sector's ability to advance innovation, it is also a major growth area in developed economies (Kuusisto & Meyer 2003). It is unlikely that noteworthy growth can be achieved in manufacturing in countries of high labour costs. This is why the growth of knowledge-intensive services is essential in order to maintain our living standard.

Kemppilä and Mettänen (2004) argue that knowledge is important in many organisations but its importance is highlighted in knowledge-intensive services. They also state that the rise of the knowledge economy is characterised by the importance of knowledge-intensive services. This is noted also by Kuusisto and Meyer (2003, p. 1) who state that the role of knowledge-intensive services in the "creation and commercialisation of new products, services and processes" is decisive. Knowledge-intensive services function as carriers, shapers and creators in the innovation process. These knowledge-intensive services can be both technological and managerial in nature. (Kuusisto & Meyer 2003, p. 1) This is how knowledge-intensive services can catalyse innovation and the development of other industries.

In relation to technological knowledge-intensive services, the concept of "technology broker" has been developed (see e.g. Hardagon & Sutton 1997). The basic idea is that a knowledge-intensive service firm with many different clients takes advantage of its position as the hub of a network structure combining existing knowledge and technology from many industries in order to create something new. Thus, a knowledge-intensive service firm can have a major role in catalysing innovation and creation of new knowledge in many industries. It can function as a vital member in a population of organisations that aims at delivering innovative, high technology products. The diverse tasks of knowledge-intensive services are listed in figures 1 and 2.

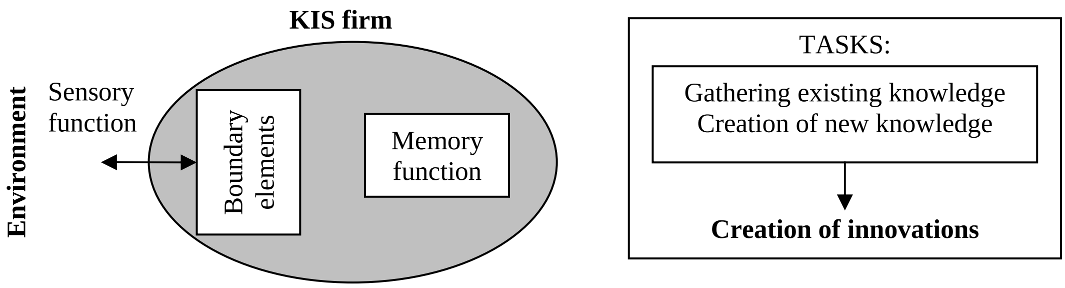

Figure 1. The tasks of knowledge-intensive service firm from the perspective of creation of innovations inside the KIS firm (Memory function – Boundary elements – Sensory function conceptualisation from Maula (2000, p. 159), tasks by the author).

A knowledge-intensive service (KIS) firm can be seen as a living (self-producing, autopoietic) system that has memory function, boundary elements and sensory function (Maula 2000). Memory inside the firm is continuously changing and adapting in an autonomous way. According to its internal rules and existing knowledge the firm interprets triggers (perturbations) from the environment by using its sensory function and boundary elements. This process is, however, a two-way flow in a sense that the firm also can have an effect on its environment. New knowledge is created in the interaction of memory and sensory functions. This is how the firm gathers existing knowledge, creates new knowledge and creates innovations.

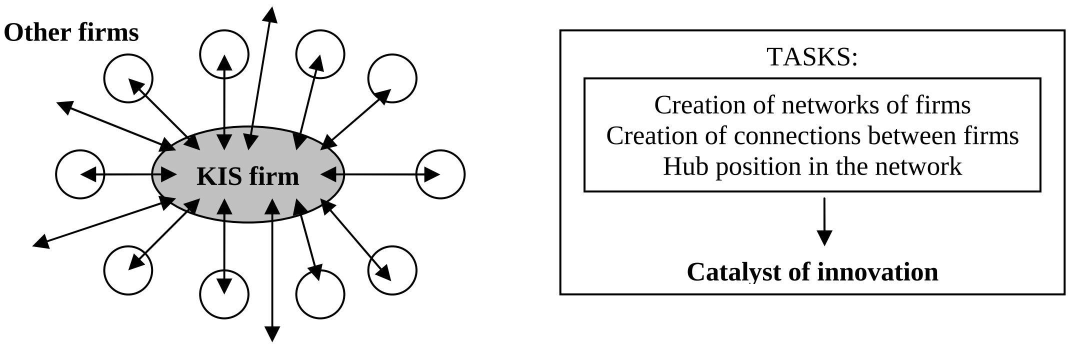

Figure 2. The tasks of knowledge-intensive service firm from the perspective of catalysing innovations.

In the network model the hub position in the knowledge creation and innovation process of the knowledge-intensive service (KIS) firm among other firms is presented. Since a knowledge-intensive service firm has this position, it can create networks consisting of other firms and it can create individual interconnections between firms. Thus, a knowledge-intensive service firm functions as a creator of knowledge and innovations, as well as, as a creator of relationships and ways of communication. This is how it can catalyse innovation.

However, these perspectives are limited and limiting since it restricts the examination to the level of individual knowledge-intensive service firm, its functions and tasks, and its affect on other firms and on the innovation process. It lacks examination of a population of organisations with both competitive and cooperative relationships, rich interaction and communication, high-technology orientation, growth, but also uncertainty. What is needed is a holistic approach to the development of this kind of an entity, that knowledge-intensive service firms are an important part of.

1.3 Phenomenon under study: The development of an organisation population

The models presented in the preceding chapter take the point of view of individual knowledge-intensive service firm. In this research the emphasis is not on individual knowledge-intensive service firms, but on a population of different kinds of organisations of which some are knowledge-intensive service firms. The phenomenon under study is the development of a population of firms and other organisations that form an interacting entity. There is interaction also among the entity and its environment. Figure 3 presents this kind of an entity.

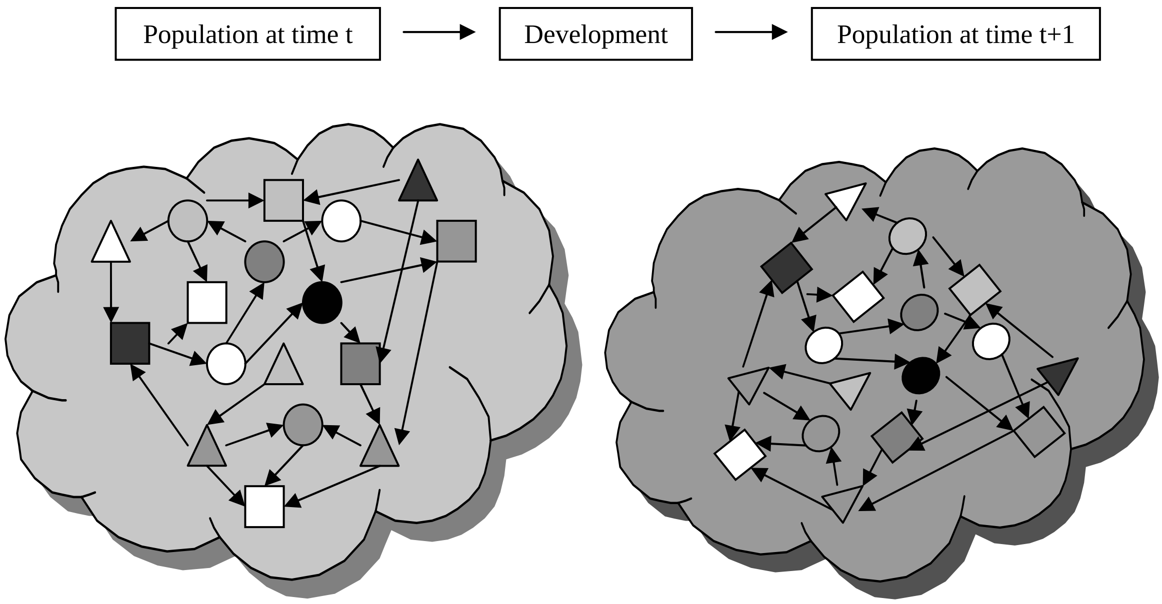

Figure 3. Preliminary conceptualisation of a population of different kinds of organisations and their interactions with each other in their environment and the development of that population in process of time.

An example of this kind of a population is companies related to the airline business. Airline companies themselves form a vast network where both competition and cooperation are present simultaneously (Gummesson 2004). Although all airlines are competing they still form alliances in order to offer connections for their passengers and possibilities to reach airports that no one company can profitably keep servicing. A part of the alliances is also the possibility of the passengers to gather points from all the members of the alliance to receive “bonus flights” as a reward for frequent travelling. In relation to airline companies, there are also other actors involved. Airports with their shops, restaurants and hotels are competing for flights and thus for passengers. Since airline activities are regulated by law, there is also major public sector intervention. Thus, this population includes many kinds of actors with different ways to compete and make profit. The development of the entity is dependent on each actor's choices and decisions.

Another example of a population of firms and other organisations are science parks or technology villages. These kinds of organisations have administrative centres that aim at knowledge agglomeration and resource sharing in order to accelerate business development (Phan et al. 2005). These administrative centres offer different kinds of knowledge-intensive services for the members of the science park and also enable the formation of network relationships. The goal is to catalyse the development of new successful businesses based on high technology and, on the other hand, the formation of new jobs. This kind of a population has many kinds of actors that both compete and cooperate. They can even cooperate by sharing resources while competing in the same industry.

The phenomenon under study is the behaviour and development of such populations because it is of great importance to understand the dynamics related to it. The significance of knowledge, learning, relationships and communication is growing which makes the development of firm populations faster, but it also increases unpredictability associated with economic evolution. This is why the problem of organisation population development must be approached from an open-minded and holistic perspective.

1.4 Research problem and objectives of the research

The research problem of this study is stated as follows:

> How can the behaviour and development of an organisation population, of which knowledge-intensive service firms form a part, be modelled at the conceptual level?

This research is essentially concentrated on the modelling problem since the objective is to create a theoretical framework that is suitable to the special features that this kind of an organisation population possesses. The criteria for the theoretical framework include:

1. realistic assumptions concerning the behaviour of individual organisation
2. realistic assumptions concerning the behaviour of an organisation population which is induced by organisation level behaviour
3. acknowledgement of knowledge as an important factor of production
4. suitability of the framework for analysing knowledge-intensive service industry.

The mainstream solution to the modelling of population level behaviour would be derived from neoclassical economics. This is why the basic assumptions of neoclassical economics are reviewed and their suitability to the modelling problem at hand is assessed. Also some criticism of neoclassical economics is reviewed.

A new emerging paradigm of complexity and concepts related to it are introduced. In this study the examination of complexity is mainly limited to the study of socio-economic systems as complex adaptive systems. Complexity science includes concepts, theories and ideas that are often contrary to those of neoclassical economics, and can perhaps offer a more realistic description and understanding of the behaviour of the new economy.

Related to complexity, some ideas of evolutionary economics are reviewed in order to create a richer picture of the population level behaviour. Complexity and evolutionary economics share many fundamental propositions. Some[2] refer to complexity as a feature of evolutionary economics while others[3] see complexity and evolutionary economics sharing concepts and areas of study. In this research the perspective is not limited to any one approach.

The concept of business ecosystem has been developed in recent managerial literature based on complexity and evolutionary economics. It draws an analogy between biological ecosystem and a population of organisations. Phenomena observed in nature, such as competition, cooperation and evolution, can also be found in socio-economic systems. Business ecosystem analysis aims at describing and understanding the behaviour of an organisation population.

This report is restricted to the analysis of organisation population behaviour and development at the conceptual level. The term “model” is here understood as conceptual model. Computational or mathematical modelling, such as agent-based modelling and simulation, are not examined. This exclusion is made because other reports[4] produced within the research programme will concentrate on those aspects of modelling.

1.5 Methods

The study has been conducted as a literature review and conceptual analysis. No empirical findings are included in the study. Since the subject at hand has not been widely examined in Finland or in the organisational literature in general, this research is conducted in the form of exploration.

Explorative research method is described in Olkkonen (1994, pp. 46-47). According to him, explorative research method should be used when the research problem is not well-structured, the approach is not clear and theory base does not support the kind of analysis. It is typical that the

[2] See e.g. Potts (2000)
[3] See e.g. Lesourne & Orlean (1998)
[4] Vuori (2005) and Vainio (2005)

results of explorative research are based on ideas and interpretations of the researcher. The results can serve as the basis for further research.

The method of systematic review is abandoned since it would require strict definitions from the beginning in order to find suitable search words. This is not possible in this research because its design and limitations have been evolving during the project. When the subject at hand is not well-established it is impossible to decide in advance which terms and concepts will dominate the research.

The material for the research has been gathered from library databases, such as EBSCOhost, Compendex and JSTOR, which include journal articles and conference papers. On many occasions relevant articles have induced search with new words. Reference lists have also been a valuable source of information about available material and about interesting authors. This has often been the way that relevant books have been found. Books have also been searched through amazon.com, which offers a wide variety of also academic literature.

Participation in conferences has been an important source of information and inspiration. During the year 2004 the author has participated in the following conferences.

- Autonomous Agents and Multi Agent Systems Conference. Columbia University, New York, 17-23rd July 2004.

- “Organisations, Innovation and Complexity: New Perspectives on the Knowledge Economy”. University of Manchester, 9-10th September 2004. Conference organised by NEXSUS, The Complexity Society and CRIC Centre for Research on Innovation and Competition.

- eBRF eBusiness Research Forum. Tampere, 21-22nd September 2004. Conference organised by eBusiness Research Center.

In addition, the research topic has been discussed in tutoring sessions with foreign professors. In these sessions the author has received valuable comments and insights to clarify the research topic. The tutoring sessions have been the following.

- Prof. Ron Sanchez, 31st May and 21st September, Tampere.

- Prof. Eve Mitleton-Kelly, 11th November, Helsinki.

The conferences and the tutoring sessions have all been sources of interesting material and have thus benefited this research greatly. They have also been sources of information about concepts, authors and previous research that could never have been reached by structured review or by autonomous literature review alone.

1.6 Structure of the report

The structure of the report is described in figure 4. First, assumptions of neoclassical economics and their implications to the modelling of the behaviour and development of an organisation population are reviewed in chapter 2. An organisation population model based on neoclassical economics is constructed and assessed according to the criteria presented in chapter 1.4.

Since neoclassical economics is concluded to be an unsuitable framework for the problem at hand, the modelling problem is approached with the emerging theories of complexity (chapter 3), followed by the assumptions and propositions of evolutionary economics (chapter 4) and finally reviewing how the concept of business ecosystem can contribute to this kind of analysis (chapter 5). These three fields are discussed individually and an organisation population model based on each of them is presented and assessed in respective chapters.

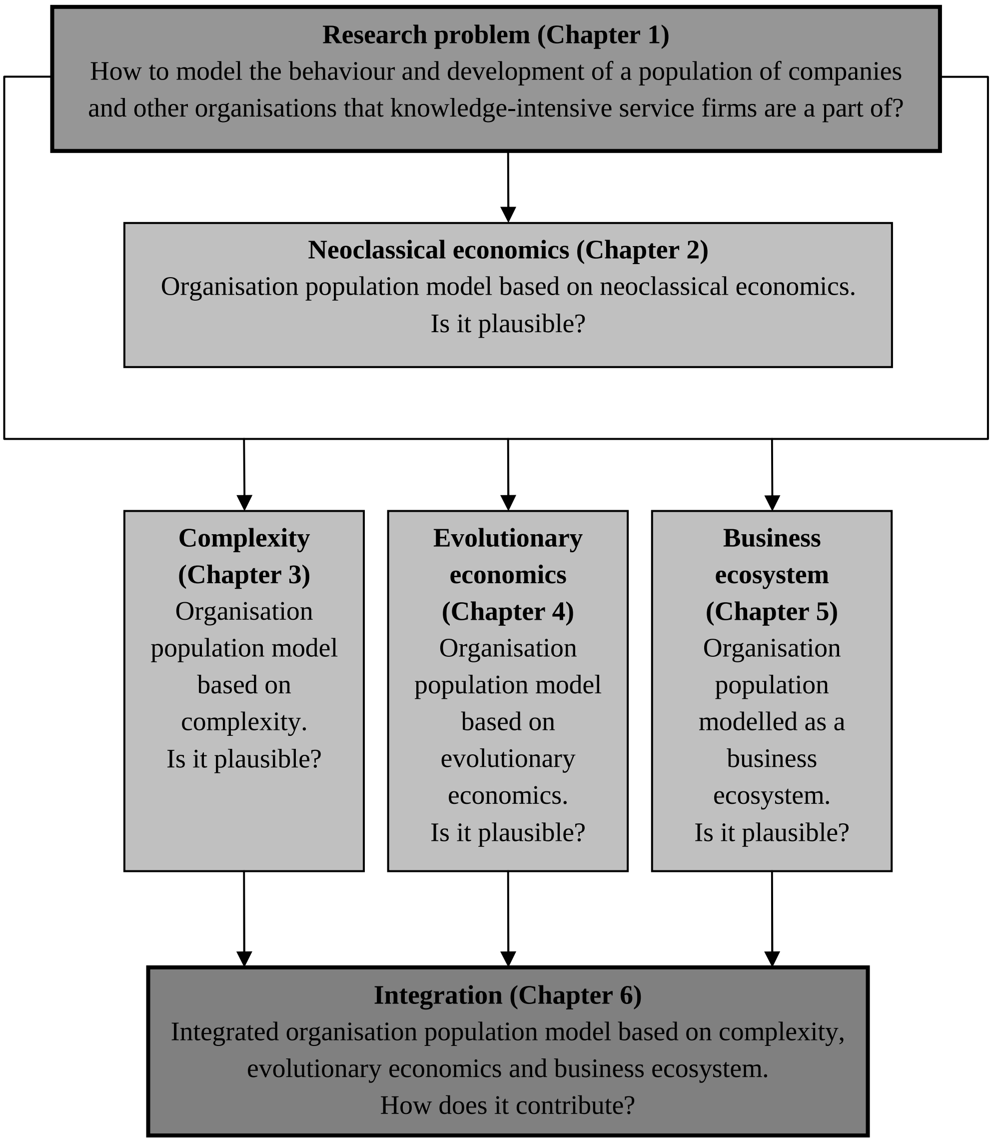

Figure 4. Structure of the study.

In the concluding chapter an integrated organisation population model based on complexity, evolutionary economics and business ecosystem is constructed and presented. It is a conceptual model that comments on both organisation and population level behaviour and development. Finally, it is discussed how this model can contribute in the analysis of the behaviour and development of an organisation population that consists of many kinds of firms, including knowledge-intensive service firms, and public sector organisations.

2 THE ASSUMPTIONS OF NEOCLASSICAL ECONOMICS IN MODELLING AN ORGANISATION POPULATION

"Economics is popularly viewed as a discipline that has departed from reality – more like a branch of philosophy or mathematics rather than a science."
(Foster 2004, p. 2)

Neoclassical economics is a well established field and offers straightforward assumptions and principles that can serve as the basis for modelling an organisation population. Maximisation, rationality and equilibrium are basic concepts of neoclassical economics. These concepts and their implications to the modelling problem at hand are reviewed in this chapter. Also, some critique of neoclassical economics is presented. Finally, the conceptual organisation population model based on neoclassical economics is presented, evaluated and rejected.

2.1 The assumption of maximisation and rationality

Maximisation and rationality are important assumptions in neoclassical economics. With these assumptions, the behaviour of all actors becomes explicit. When there are choices to be made, the actor always knows the results of each alternative and takes the one that is the absolute best.

This view of maximisation is described in Nelson & Winter (1982, p. 12). "In orthodox theory, firms are viewed as operating according to a set of decision rules that determine what they do as a function of external (market) and internal (such as available capital stock) conditions… The rules reflect *maximizing* behaviour on the part of the firms. This is one structural pillar of orthodox models." Thus, in orthodox models firms are seen maximising according to the constraints that the environment poses at them.

Rationality, on the other hand, is discussed in (Sargent 1993, pp. 2-3). "Rational expectations imposes two requirements on economic models: individual rationality, and mutual consistency of perceptions about the environment." Thus, each actor in the economic system would be acting totally rationally, and each actor would see the environment around him the same way.

These assumptions are contradicted by, for example, Geoffrey Hodgson. He states that "organizations 'satisfice' rather than maximize: they find niches to protect themselves from competition" (Hodgson 1994, p. 29). The idea of a firm making the absolute best possible choices at all times is, at least, questionable. It is not easy to find a firm who would have made the best possible choices at all times, not to mention all firms functioning this way. Hodgson claims that just by existing, the act of learning rules out this kind of behaviour (Hodgson 1994, p. 4). If the organisations are constantly learning, how could they have perfect knowledge at all times? If there is some information to be learned, it can not have been common knowledge before the actual act of learning.

Foster and Metcalfe's work on firm as a knowledge-based system suggests that a firm does not function totally rationally searching for efficiency, but it concentrates on constructing the future. This is where knowledge takes an important role. "From a self-organization perspective, knowledge-based systems are autocatalytic: knowledge feeds on itself to generate more knowledge in quite unpredictable ways." (Foster & Metcalfe 2001, p. 4) This kind of a process is hard to predict since the process itself transforms its own future. If the process is unpredictable, then the notions of rationality, maximisation and optimisation become meaningless. "Thus the crucial attribute of economic agents is not a rational search for efficiency but rather the imaginative construction of future, alternative economic worlds." (Foster & Metcalfe 2001, pp. 4-5) The key here is knowledge. Any economic actor can base its decisions only on the knowledge that it possesses. When there is no perfect knowledge, there can be no perfect decisions.

Neoclassical economics suggests perfect rationality on the part of the organisations. This should be based on perfect knowledge, since in order to be perfectly rational one must be aware of all alternatives and their future repercussions. This would lead to optimisation in such a way that the organisations would always make the absolute best decisions. However, this contradicts the notion of learning, and especially the fact that we can be certain only of things that have already happened. Thus, in order to reach perfect rationality an organisation should possess knowledge of the future.

2.2 The concept of equilibrium

Schumpeter starts the description of economic equilibrium with opportunity cost. "Cost as an expression of value of other potential employment of means of production constitute the liability items in the social balance sheet. This is the deepest significance of the cost phenomenon. From this expression the value of producer's goods must be distinguished. For it represents the – *ex hypotesi* – higher total value of the actually created product." (Schumpeter 1951, p. 29) Thus, opportunity cost is defined in the value of a certain product compared to some other product.

From this he goes on to define economic equilibrium as the optimum position. "But at the margin of production, according to the above, both quantities are equal, because these costs rise to the height of the marginal utility of the product, therefore also of the participating combination of productive means. At this point emerges that relatively best position which is usually called the economic equilibrium, and which, as long as the given data are maintained, tends to repeat itself in every period." (Schumpeter 1951, p. 29) Thus, equilibrium position is reached when people make rational choices based on opportunity cost.

These statements basically summarise the concept of economic equilibrium. It implies that when optimal decisions, based on opportunity cost, are carried out, the economy reaches the position where the maximum satisfaction of needs happens. The assumption is that each firm's profit reaches the best possible level and each individual's material satisfaction is at the highest possible level, under constraints though.

Foster describes this kind of thinking as constrained optimisation. "Standard economic theory centres upon constrained optimization in the allocation of resources, factors of production and goods/services in the face of scarcity. It is theory that deals with outcomes, mainly point equilibria that can be deduced analytically." (Foster 2004, p. 5) His criticism arises from the fact that this kind of analysis places emphasis only on the outcome, and not on the processes which would lead to equilibrium. (Foster 2004, p. 6)

Nelson and Winter comment on economic models that are used for equilibrium analysis. "The other major structural pillar of orthodox models is the concept of *equilibrium*. This is an extremely powerful and flexible concept; a full equilibrium in an orthodox model may be an equilibrium in two or three distinguishable senses relating to a number of different components or variables within the model's overall structure." (Nelson & Winter 1982, p. 13) It is obvious that the model used for defining equilibrium can only incorporate a few distinct variables. Thus, any mathematically derived equilibrium can be defined as an equilibrium only in relation to those variables that are taken into account in the model.

There is a distinction between the roles of maximisation and equilibrium in economic analysis. It can be noted that maximising behaviour leads to equilibrium. "The role and result of all these equilibrium conditions is to generate within the logic of the model conclusions about economic behaviour itself – as distinguished from conclusions about the *rules* of behaviour that are generated by the maximization analysis." (Nelson & Winter 1982, p. 13) While maximisation defines the rules of behaviour, equilibrium analysis generates conclusions about the economic behaviour.

Schelling highlights that equilibrium is only a result and should not be given the kind of significance that is not well grounded. "The point to make here is that there is nothing particularly attractive about an equilibrium." (Schelling 1978, p. 26) An equilibrium is simply a result that the process leads to and perhaps even achieves. Schelling (178, p. 26) states that the basic idea of equilibrium is the acknowledgement of the existence of some adjustment processes. Schelling compares reaching equilibrium to dust settling. "Unless one is particularly interested in *how* dust settles, one can simplify analysis by concentrating on what happens after the dust has settled." (Schelling 1978, p. 26) Basically, there is adjustment and after that the system has reached a defined state.

One important assumption behind the idea of equilibrium is diminishing returns. This basically means that production of any product gets less and less profitable the more the products are produced. The logic comes from two complementing phenomena. Firstly, production operations face increasing costs and difficulties the more is produced. Acquiring materials, settling with less than optimal production sites and other related effects cause the costs to go up. Secondly, consumers are willing to pay less and less when the amount of certain product in the market increases. Thus, in order to charge a premium, the product must be rarely available.

This phenomenon is described by Brian Arthur. "Conventional economic theory is built on the assumption of diminishing returns. Economic actions engender a negative feedback that leads to a predictable equilibrium for prices and market shares. Such feedback tends to stabilize the economy because any major changes will be offset by the very reactions they generate." (Arthur 1994b, p. 1) Thus, negative feedback makes the economy predictable and equilibrium-seeking.

Arthur claims that this might have been the case in the past but today economies work under increasing returns. The agreeable picture of diminishing returns is often not consistent with the reality. He states that in many parts of the economy such stabilising forces, or negative feedback, can not be observed. "Instead positive feedback magnifies the effects of small economic shifts; the economic models that describe such effects differ vastly from the conventional ones." (Arthur 1994b, p. 1) His criticism goes also towards the assumption of only one potential equilibrium. Diminishing returns imply a single equilibrium which is the best possible state. Increasing returns, on the other hand, leads to positive feedback and to a variety of different possible equilibrium points. When a particular equilibrium point is selected there is no guarantee that it is the best one of the alternatives. (Arthur 1994b, p. 1) Thus, increasing returns are also a factor preventing optimisation in economic development.

But not all the old-timers in economics have favoured rigid equilibrium analysis. Both Marshall and Schumpeter saw the concept of equilibrium as a rough approximation to be used with great caution in connecting the principles of economic logic with historical facts (Foster 2000, p. 321). This means that while analysing the past it is not always plausible to explain all events by forces directing the system towards equilibrium.

Schumpeter saw equilibrium as a state towards which the system is going at, but it may never be reached. This results from the idea that the equilibrium is determined by current data, and when the data changes the equilibrium changes also. According to Schumpeter an economic system adapts to economic data which can be observed as a tendency towards an equilibrium state. Since the economic data changes the equilibrium state changes also. The ideal state of equilibrium is continuously striven after but never attained. (Schumpeter 1951, p. 62) Thus, there is continuous adaptation to changing data which makes it impossible to reach any optimum position.

This idea has some resemblance with the thoughts of Ilya Prigogine, Nobel laureate in chemistry in 1977. He writes of "far-from-equilibrium systems" that never return to some fixed state. There is continuous change and the system is always becoming something else. Prigogine thought that theory should move "from being to becoming". (in Merry 1995, p. 31) Thus, the emphasis is not on the state that the system is at the moment or on the state that the system is pursuing, but on the process that the system is going through. Prigogine's thoughts have given inspiration to many post-Schumpeterian economists.

Kirman divides economists into two classes. There are those who put equilibrium at the centre of the analysis. They see individuals learning relatively rapidly to behave optimally and they also see the economic environment changing slowly. This leads to the individuals not having to continue learning and adapting as time passes. Then, there are those who apply the principles of complexity to economic systems. They see economy as a complex adaptive system where learning and adaptation, as well as the consequences of that adaptation generate complicated dynamics. It may be impossible to model this process consistent of standard equilibrium analysis. (Kirman 1997, p. 496)

Foster and Metcalfe argue that the fundamental properties of economic systems make it impossible for the system to reach any kind of equilibrium. This is because in any economic system the amount of information that circulates the system, and has an affect on decisions, is so large that it causes the system to behave in a restless manner. "The distinctive, complex, evolutionary property of economic and social systems is that they are knowledge based and that the primary interactions within them are exchanges of information." (Foster & Metcalfe 2001, p. 4) Information flow is active and creative, and it leads to restlessness in the system. This view of economic life, at the very least, does not favour the idea of economic equilibrium.

It is one of the cornerstones of neoclassical economics to assume that organisations optimise and pursue their own self-interest, and by functioning this way lead the economic system to an equilibrium state that can be defined as the best possible. This kind of analysis is elegant and quite straightforward but does not offer many insights about the behaviour of the organisations. It neglects the organisations' abilities to learn and adapt. It also gives a notion of some optimum state that the economic system is supposedly aiming at, but does not mention any state of any real economic system as the equilibrium finally reached.

2.3 Critique of neoclassical economics

One of the best known critics of neoclassical economics is Brian Arthur, who is an active figure within the economics programme at Santa Fe Institute. He finds mainstream economics simplistic and machine-like, since the analysis concentrates on equilibrium which is derived from the actions of identical and rational actors whose economic actions eventually face diminishing returns. Waldrop (1992, pp. 37-38) lists Arthur's theses of what the "new economics" consists of compared to the "old economics" in table 1.

Besides increasing returns, Arthur bases his ideas of economics on biology. While old economics is based on equilibrium, stability, and deterministic dynamics of 19th century physics, new economics finds inspiration from the concepts from biology, such as structure, pattern, self-organisation and life cycle. In old economics people are presumed to be identical in a sense that in the same situation every person acts the same way. In the new economics people are seen as individuals. In the old economics there are no real dynamics since everything is presumed to be at equilibrium which makes the object under study structurally simple. In the new economics, on the other hand, there is continuous change which makes the behaviour of the system inherently complex.

Table 1. Arthur's theses of new economics versus old economics (in Waldrop 1992, pp. 37-38).

Old economics	**New economics**
Each operation faces diminishing returns.	Increasing returns are acknowledged.
Economics is based on the 19th century physics (equilibrium, stability, and deterministic dynamics).	Economics is based on biology (structure, pattern, self-organization, and life cycle).
People are assumed to be identical.	Focus is on individual life. People are seen as separate and different.
If only there were no externalities and all had equal abilities, we would reach Nirvana.	Externalities and differences become driving force. There is no Nirvana. System is constantly unfolding.
Elements are quantities and prices.	Elements are patterns and possibilities.
No real dynamics in the sense that everything is at equilibrium.	Economy is constantly at the edge of time. It rushes forward, structures constantly coalescing, decaying, and changing.
Sees subject as structurally simple.	Sees subject as inherently complex.
Economics is comprehended as soft physics.	Economics is comprehended as high-complexity science.

Arthur's work during the last two decades is not, however, the first criticism to mainstream economics. Already in 1898 Thorstein Veblen wrote an article titled "Why is economics not an evolutionary science?". Veblen states that traditional economics is not an evolutionary science, since it does not trace the "cumulative working out of the economic interest in the cultural sequence" or take into account the process or community dimensions of economic life. (Veblen 1898, p. 394) In this article it is acknowledged that there can be alternatives to neoclassical economics and that evolutionary theory can be one of them.

Later critics include John Foster, for example. According to him, neoclassical economics consists of simplistic theorising and constrained optimisation. This kind of analysis is ahistorical and outcome focused. (Foster 2004) He sees, that it is a tremendous setback for economic analysis that it is not taken seriously in public sector decision making. "Significantly, the public at large and policymakers seem to be much less enthusiastic about modern economics than they were in the days when it was less sophisticated." (Foster 2004) Basically, Foster claims that sophisticated mathematical models do not serve the purpose if they do not have a link to the real world. "Economics is popularly viewed as a discipline that has departed from reality – more like a branch of philosophy or mathematics rather than a science." He states that neoclassical economics is often seen as a useful way of thinking and not a scientific representation of actual economic behaviour.

It is acknowledged that there are alternatives to neoclassical economics in portraying economic life. The criteria for a viable alternative arise from its ability to depict reality with sufficient accuracy. In all kinds of models approximations must be made but their plausibility must be thoroughly assessed. However, a model, no matter how elegant it may be, can not contribute if it fails to depict the essential parts of reality with sufficient accuracy.

2.4 Solution to the modelling problem based on neoclassical economics

If the organisation population is modelled with neoclassical economics then the model is based on the basic propositions, such as rationality, perfect knowledge, maximisation, diminishing returns, and equilibrium-seeking behaviour. Rationality implies that each actor inside an organisation, and thus each organisation, functions rationally in every situation. This kind of rationality – in the sense of neoclassical economics - can only be attained when there is perfect knowledge among all the actors.

Rationality and perfect knowledge are preconditions to maximisation. Thus, each organisation possessing perfect knowledge of its environment and functioning rationally based on that knowledge leads to maximising behaviour of the organisation. This means that each organisation optimises in its behaviour within the constraints that the environment poses at it. This is presented in figure 5.

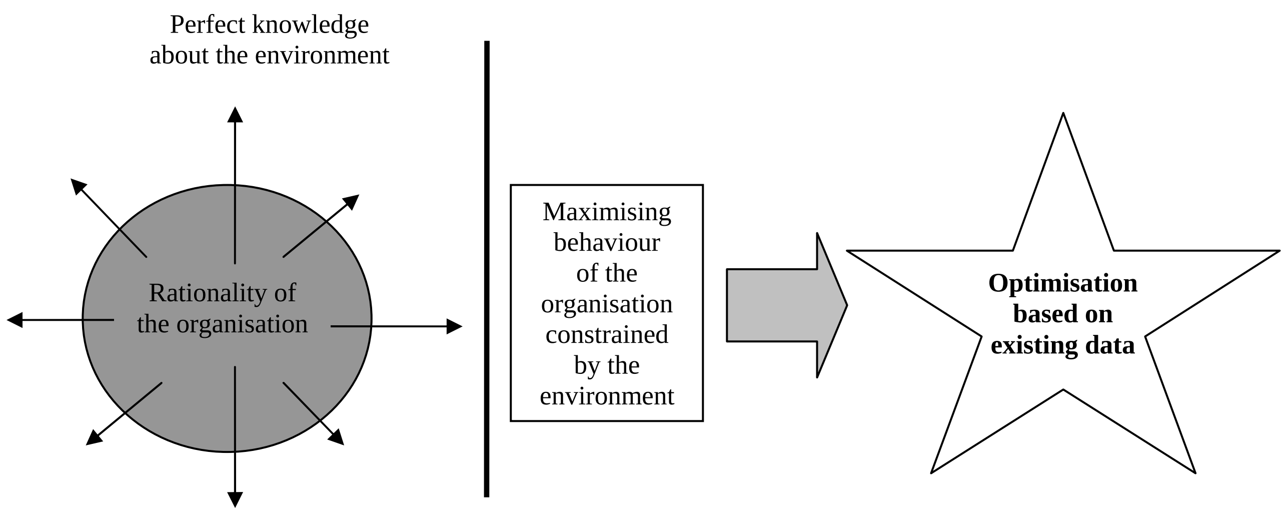

Figure 5. Organisation level behaviour based on neoclassical economics.

At the population level each organisation's optimising behaviour faces diminishing returns. Thus, the more is produced the less is gained per unit. This leads to a specific equilibrium state that is optimal. That means that at the equilibrium position material satisfaction is at its best possible level. This is presented in figure 6.

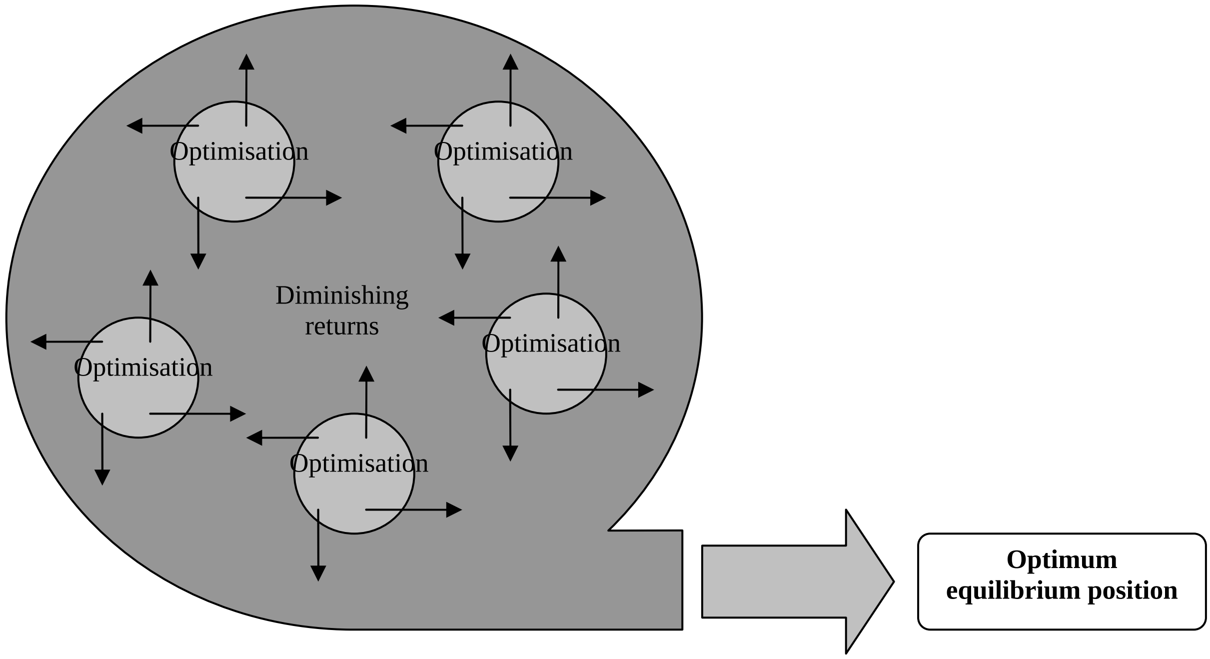

Figure 6. Population level behaviour based on neoclassical economics.

This kind of a model is not compatible with the criteria presented in chapter 1.4. First of all, the assumptions concerning the behaviour of individual organisation are not realistic. The ideas of perfect knowledge, rationality and maximisation can not be realised in real life. Knowledge is never perfect since there is always something to be learned. On the other hand, no actor can be totally rational because all the consequences of each option are not known before the decision is made. Based on this, no organisation can maximise in the actual sense of the word. Thus, no organisation optimises. Each firm strives for profit and is goal-oriented, but because there are limits to the predictability of the environment, no absolute best possible decisions can be reached. Individual organisation does not optimise, but it functions well enough compared to other organisations in its environment.

At the population level, based on this model, each optimising firm faces diminishing returns which leads to optimal equilibrium state. This kind of population level behaviour is not realistic since the assumption of diminishing returns does not hold especially in the case of knowledge based economy and knowledge-intensive service sector. In industries, such as agriculture and mining, which are heavily dependent of limited physical resources diminishing returns is a plausible assumption. In the knowledge based industries, on the other hand, that kind of observation can not be made. Since knowledge and innovations are created in the interaction of existing knowledge and people, it is in its nature that the more knowledge is produced the more can be produced. This leads to the rejection of diminishing returns and to the search of more appropriate theory base. Thus, no optimal equilibrium state can be reached, which makes the benefits of equilibrium analysis questionable.

It has already been stated that the assumption of diminishing returns does not conform to knowledge creation and innovation processes. This means that the model based on neoclassical economics does not acknowledge the importance of knowledge as a factor of production. If perfect knowledge is assumed, then knowledge can not be considered as a valuable asset. This also leads to the unsuitability of the model for analysing knowledge-intensive service industry where knowledge is essential for the success of the firm.

It is concluded here that the model based on neoclassical economics is not suitable for the modelling problem at hand. This is because its assumptions at the organisation and population level are not realistic and especially because it does not give knowledge the role that it has in knowledge-intensive service industry.

3 CORE COMPLEXITY CONCEPTS CONCERNING THE BEHAVIOUR OF AN ORGANISATION POPULATION

"All these terms like emergence, life, adaptation, complexity – these are the things we're still trying to figure out."
(Langton in Waldrop 1992, p. 359)

In this chapter, the organisation population modelling problem is approached with concepts and ideas that are derived from the field of complexity. This is because complexity offers a counterforce to neoclassical economics in the study of socio-economic systems. Many of the problematic assumptions of neoclassical economics, such as perfect knowledge, perfect rationality, optimisation and equilibrium-seeking behaviour, are tackled in complexity science and approached with different kinds of concepts and processes.

First, basic definitions of complexity are reviewed followed by reasoning of how complexity differs from traditional doctrines, such as neoclassical economics. Important complexity concepts, including adaptation, co-evolution, self-organisation and emergence, are defined and analysed in the context of an organisation population. Finally, an organisation population model based on complexity is constructed.

3.1 What is complexity?

Most authors, who discuss complexity, do dot define the concept. They rather write about the characteristics of complex systems, the behaviour of complex systems or the things that complexity science examines. The terms "complexity", "complexity science", "complexity theory", "complex behaviour", "complex systems", "complex adaptive systems", "complex evolving systems" and "complex co-evolving systems" are sometimes used interchangeably. This can be seen as an inconsistency, but it also gives each author the freedom to choose between these terms based on the aspects that he wants to emphasise. These aspects can be system view, the importance of adaptation or co-evolution, the notion of complexity as a science or complexity observed in the behaviour of some entity. Merry's (1995, p. 59) list of the characteristics of complex systems constitutes of

- nonreducibility
- emergent behaviour
- unpredictability and regularity.

A system is nonreducible when it can not be divided into smaller units in order to study the whole. Same kind of ideas can be found in Holland (1995, p. 5). “The task for formulating theory for *cas* is more than usually difficult because the behavior of a whole *cas* is more than a simple sum of the behaviors of its parts.” Thus, to be able to understand the behaviour of a complex adaptive system it must be studied as an entity and not as a group of sub-entities.

Emergent behaviour is the kind of unpredictability that occurs when macro-level behaviour can not be easily foreseen based on micro-level behaviour. Unpredictability can also be induced by nonlinear behaviour of complex systems. On the other hand, there is regularity in the form of patterns in complex systems. These patterns can be detected in the behaviour of the system, repeating in process of time, when sufficient understanding of the system is gained.

According to Foster (2004) the object of study in “complex systems science” is the connective properties between the elements of systems. The objective is to discover forms of order that can be represented analytically in the forms of graph theory, network analysis and agent-based simulation, for example. The emphasis, thus, is on connections instead of the parts of the system. Order here does not mean the kind of static equilibrium of Newtonian physics, but patterns which can be detected when sufficient understanding of the system under examination has been gained. Foster (2004, p. 9) adds that complex adaptive systems are “capable of maintaining themselves”. This means that these self-sustaining systems do not require outside interventions in order to survive.

There are numerous examples of complex systems in recent literature. “Weather is the classic example: many components interacting in complex ways, leading to notorious unpredictability.” (Lewin 1999, p. 11) Other examples mentioned by Lewin are ecosystems, economic entities, developing embryos and the brain. Kauffman (1993, p. 173) states that all living systems, such as organisms, communities and co-evolving ecosystems, are complex systems. Holland’s (1992, p. ix) examples consist of economies, political systems, ecologies, immune systems, developing embryos and brains.

But why are these complex systems under examination? It is often stated that the goal is simply to understand these systems. “The goal of complexity science is to *understand these complex systems* – what “rules” govern their behaviour, how they adapt to change, learn efficiently, and optimize their own behaviour.” (Keskinen et al. 2003, p. 7) Optimisation within complex systems is a controversial subject and we will return to it in chapter 5.3.

There are several lists in recent literature about the principles of complexity. Here, two of these lists are presented in figure 7. On the left hand side, there is a list by Eve Mitleton-Kelly[5] (2003, p. 24). On the right hand side, there is a list by Pierpaolo Andriani (2003, pp. 128-130).

[5] Director of the Complexity Research Programme at London School of Economics.

In figure 7, principles mentioned in both lists are on grey background. These are self-organisation, emergence, connectivity/connectedness, interdependence/interconnections, feedback/feedback loops, and co-evolution. In addition, Mitleton-Kelly states that complex systems function far-from-equilibrium, exploring the space of possibilities, based on their history, as a path dependent process. Andriani, on the other hand, adds that complex systems which are dissipative, consist of agents[6] which operate based on local knowledge, in a non-linear and evolutionary manner, and take part in self-catalytic reactions.

Mitleton-Kelly's list	**Andriani's list**
Self-organisation	Self-organisation
Emergence	Emergence
Connectivity	Connectedness
Interdependence	Interconnections
Feedback	Feedback loops
Co-evolution	Co-evolution
Far-from-equilibrium	Evolutionarity
Space of possibilities	Locality
Historicity and time	Agents
Path dependence	Dissipativeness
	Non-linearity
	Self-catalytic reactions

Figure 7. Principles of complexity by Mitleton-Kelly (2003, p. 24) and by Andriani (2003, pp. 128-130).

Some of these characteristics, including emergence, connectivity, interdependence, and feedback, are familiar from systems theory. The relationship between systems theory and complexity is somewhat ambiguous. Mitleton-Kelly (2003, p. 25) states that "complexity builds on, and enriches systems theory by articulating additional characteristics of complex systems and by emphasizing their inter-relationship and interdependence." It is quite clear that one cannot study complexity without accepting some basis from systems theory.

[6] Definition of an agent can be found in Vuori (2004, p. 37).

Although there are decades of experience with complexity research, there is no uniform well-established theory. Since complexity research has developed as a counterforce to formalised mainstream science, it may well be, in a sense, rejecting traditional scientific conventions. This means that research is maybe not aiming towards forming a doctrine of the field. Since complex systems are various and different, it is perhaps impossible to form a theory which would be suitable for all kinds of complex systems. Complexity scientists are willing to let each develop their own theory and hoping that this kind of liberty will benefit the research most.

Complexity is based on systems theory but enriches the analysis with new concepts. The key is the interconnectedness of the actors, or agents, and phenomena that arise from their interaction. Complexity aims at understanding different kinds of systems, but it remains a question mark whether uniform theory encompassing all kinds of complex systems can ever be constructed.

3.2 Why has complexity emerged?

Complexity science and the study of complex adaptive systems (CAS) have gained a lot of attention during the last decade. These new ideas have greatly benefited research in the fields of biology, chemistry, and physics. Recently, complexity science has also been applied to the study of socio-economic systems.

But why is complexity worthy of our attention? Why should it be studied in relation to the organisation population modelling problem at hand? What is wrong with traditional ways to understand organisation populations? Basically, complexity is aiming at understanding systems without implausible assumptions about their behaviour. Traditional doctrines, such as Newtonian physics and neoclassical economics, see objects under study predictable, linear and deterministic. In addition, objects are studied by reducing them to smaller entities in order to gain understanding of the parts and then by summing up creating a picture of the whole. These can all be implausible assumptions.

Reductionism means that in order to understand a system by traditional terms, one should divide it into smaller and smaller parts and study the working of the parts. This kind of reductionist approach has been widely criticised. It has also been stated that complexity is the opposite of reductionism (see e.g. Waldrop 1992, p. 329). Behind this kind of criticism is the aim to find order and regularities in whole systems and not just in their parts. When considering modelling of an organisation population it is clear that besides the firms in the system there is enormous significance on the connections between these actors. Because these firms are interconnected their behaviour can not be isolated from each other and the rest of the system.

Besides reductionism there is another problem in the traditional view of the world and this is the assumptions of predictability, linearity and determinism. Stephen Hawking[7] describes this traditional approach with the ideas of Laplace[8]. Laplace thought that there can be universal scientific laws that allow us to predict everything from the working of the solar system to the behaviour of people. The only precondition is complete knowledge of the present state. (in Merry 1995, p. 21) The existence of such universal laws is highly questionable when it comes to the behaviour of people. Complete knowledge of the present state, on the other hand, means the same thing as perfect knowledge in relation to neoclassical economics. In chapter 2.4 this idea has been rejected. Also, universal laws concerning the organisation modelling problem, such as maximisation, diminishing returns and equilibrium-seeking behaviour, have been rejected in the same chapter.

There are some basic assumptions concerning traditional doctrines, such as Newtonian physics and neoclassical economics. Merry (1995, pp. 100-101) draws a comprehensive list of them, of which the most relevant are reviewed here.

- Science can learn about things and understand them by breaking them into their parts.

This statement describes the reductionist approach, which is one of the main subjects of criticism in mainstream science. The problem with separating a system into its parts is that when the connections are lost, a great deal of the behaviour of the system is lost. The slogan of systems theory "system is more than the sum of its parts" emphasises the fact that you cannot understand the functioning of a system by studying its parts detached from the entity.

- Science can measure things exactly, and on that basis make predictions about their behaviour in the future.

- It is always possible to make predictions regarding a single case from the general laws pertaining to it.

One can question whether there really are any exact sciences. Surely one can measure things but whether these measurements can describe the system under study in any relevant way is another question. Predictability is still another matter. Can we assume that the world will work the same way in the future as it has in the past? Unfortunately, we have knowledge only about the past and the present state of affairs. And even this knowledge is far from perfect. Exact and relevant predictions of any untrivial behaviour are very hard to make. An organisation population is not predictable in a sense that peoples behaviour does not conform to any linear general laws. The problem with measurements is that it can not be defined which exact measurements would be

[7] Stephen Hawking (1942-). A British physicist whose areas of research in modern physics are general relativity and quantum theory, for example.
[8] Pierre-Simon Laplace (1749-1827). A French mathematician and scientist who contributed to many areas such as integral calculus, differential equations, applications to mathematical astronomy and theory of probability.

relevant in determining the future behaviour of an organisation population. Also, the measurement process itself can have an effect on the behaviour of the system.

- The world is generally linear, with clear direct lines of cause and effect and regular proportion between the dimensions of the cause and the effect.

The clarity of cause and effect is one of the pillars of modern science. Usually scientific models have been linear because the view of the world has seen things happening in a linear way. But does the world really work in a linear and proportional way? This linear thinking has been imposed on the world because this way one can manage the world fairly easily. Unlinear and unproportional model of the world would not be so elegant. In the modelling problem at hand it is clear that the development of an organisation population is not a linear process. A fairly simple innovation can trigger unproportionally large growth and this effect can spread out in the rest of the population through outsourcing and partnering, and perhaps even in the form of competing and complementing innovations.

- Science studies discrete objects whose boundaries can be clearly defined.

Can you separate the system under study from its environment? Can you define where the system ends and the environment starts? These questions do not have simple answers. It is a common assumption in the study of natural sciences that the system is in a vacuum or that the system is closed. Thus, in order to create linear models and exact results quite many of the characteristics of the real world are discarded. One must realise that this kind of an approach has its limits. In order to enhance our understanding of the world the objects under study should be seen in a wider context and without implausible assumptions. In an organisation population there are several factors within the wider environment that limit and enable its development. Each must operate within a legal framework that clearly has an effect on the firm. On the other hand, a large firm or a population of firms can also have an effect on legislation. The question of what to include in the study is troublesome since it is difficult to decide in advance which factors are relevant. Also, the relevance of a factor can change in process of time which requires certain flexibility from the model.

Complexity can be defined as the opposite of reductionism, but it also entails much more. It is about unpredictability, and nonlinear and nondeterministic behaviour. Complexity emphasises interconnectedness of the parts of the system and dynamics that this interconnectedness induces. The aim is to understand, which can be defined as understanding behaviour, relationships or patterns.

3.3 Core complexity concepts in modelling an organisation population

Complexity concepts presented here include adaptation, co-evolution, self-organisation and emergence. These are chosen because they illustrate phenomena that can be observed in the context of an organisation population and that are vital to its development. Some other complexity concepts, such as feedback, locality and interconnectedness are discussed in relation to the four chosen concepts.

3.3.1 Adaptation

Adaptation is a familiar concept already from Darwin's "Origin of Species". Adaptation can be defined "as climbing peaks of higher fitness" (Merry 1999, p. 258). Thus, adaptation means gaining better suitability to the environment. According to Holland (1992, p. 159), adaptation generates "structures of progressively higher performance". This means that adaptation improves the organism's ability to function in its current environment. Organism can be defined loosely to cover all kinds of organisms from biological ones to economic actors.

In the book "The Computational Beauty of Nature" Flake (1998) discusses adaptation from the computational point of view with simulated evolution and genetic algorithms. He defines adaptation with the following equation (Flake 1998, p. 340).

Adaptation = variation + heredity + selection

This approach is purely neo-Darwinist. It differs from Darwinism[9] by taking explicitly into account the role of heredity. Heredity does not necessarily mean biological reproduction, but it can be interpreted as a form of temporal persistence. Variation, on the other hand, emphasises the fact that adaptation does not work on single individuals but on a population consisting of many individuals with varying characteristics. Selection is induced by limited resources which make it possible only for some to reproduce. Flake discusses the phrase "survival of the fittest" and claims that it is often misunderstood tautologically as "survival of the survivors", although it actually means "survival of the reproducers". (Flake 1998, p. 340)

Fuller and Moran (2001, p. 52) claim that in the context of small enterprises adaptation implies learning. "Behaviour is learnt, often through trial and error, and passed on in time through various forms (e.g. culture, rules, social process, knowledge, etc.)." In this approach heredity, or temporal persistence, means culture, rules, social processes and knowledge. This approach clearly is restricted to the level of individual people who carry on these affairs and from whose behaviour the company level behaviour is accumulated.

As a distinction to biological evolution, however, there is conscious choice present in socio-economic systems. "Adaptation implies a more conscious or sentient response to the environment, and memory." (Fuller & Moran 2001, p. 52) This means that people's behaviour is not predetermined but they can make decisions and strive for better achievements. Although it is

[9] Darwin's theory is discussed in chapter 4.1.

possible for a person to encounter selection in the form of getting fired, this is not the sole arena of adaptation in this context. Firms do not purely take in a multitude of people with different characteristics in order to create variation and then let selection induced by limited resources take care of adapting to new situations. People can develop new characteristics and strive to reach goals, and not just passively submit to selection based on static characteristics.

Holland uses mathematics and simulations to describe adaptation. Holland (1992, p. 4) suggests that there are three components associated to adaptation: an environment, an adaptive plan, and a measure of performance. Adaptive plan has here the meaning of a testing plan. It is a tool for defining the measure of performance. The measure of performance, on the other hand, is usually called fitness. There are always different performance measures associated with different environments (Holland 1992, p. 5).

Holland (1992, p. 18) also states that the adaptive plan must be robust. Robustness is a concept related to the systems ability to survive sudden changes in its environment. Robustness thus requires variation inside the system as well as flexibility as a whole. The ability of the system to adapt is a prerequisite for robustness. When considering an organisation population its robustness origins from variation, redundancy and adaptation capabilities. Sufficient variation is essential when some actor is wiped out. It makes it possible for some other actor to compensate for the missing actor. Its competences or compensatory ones can be found in some other actor when there is redundancy in the system. When an organisation population has high adaptive skills it can change quite rapidly and missing competences can be developed fast. According to Holland (1992, p. 18) there are two requirements for robustness.

1. The adaptive plan must retain advances already made, along with portions of the history of previous plan-environment interactions.

2. The plan must use the retained history to increase the proportion of fit structures generated as the overall history lengthens.

The first point emphasises the importance of not losing the progress that has already been achieved. Thus, the adaptation procedure must be able to recognise what counts as advance and also to retain it. The second point means that the adaptation procedure must know what has already been tried and what has worked in the past. Holland states that “the basic concern is discovery of an adaptive plan which, over a broad variety of environments, generates programs which work “near-optimally.”” (Holland 1992, p. 38) Near-optimality is an important observation since it is hard to define an optimal adaptation. Although adaptation can “increase the proportion of fit structures” it can hardly design absolute best variants.

In the case of organisation population the adaptive plan’s requirements for robustness can be associated with the market where the population operates. The market should be able to recognise advancements and support them. The market should also have the ability to enable the development of fitter structures, such as innovative firms and advanced technologies. The market's ability to do these tasks is limited. Near-optimality plays a part also in this context. The limitations of evolutionary processes are further discussed in chapter 4.3.

Mitleton-Kelly (2003, p. 29) emphasises the difference between "adaptation to" and "co-evolution with" the changing environment. The first expression carries the meaning of a passive, stable environment that the adapting organism has no influence on. The second one highlights the organism's power to change its environment, and the interconnected nature of the system. According to Mitleton-Kelly (2004), adaptation can also be interpreted as the sum of co-evolution, self-organisation and emergence. Because these three phenomena are present, the whole system is able to adapt.

This kind of adaptation concerns the population level of an organisation population. Because there is co-evolution between the organisations, the system self-organises without inside controller or outside interventions, and the system produces emergent properties, the organisation population is able to adapt to changes in its environment.

3.3.2 Co-evolution

Bateson defines co-evolution "as a process in which interdependent species evolve in an endless reciprocal cycle – in which changes in species A set the stage for the natural selection of changes in species B – and vice versa." (in Moore 1993, p. 75) Pagie and Mitchell (2004) suggest that co-evolution can happen with one or two populations. In the first case co-evolution shapes the individual fitness of the members of the population. In the second case the fitness of individuals is shaped by their behaviour in the context of the individuals of the second population. The latter can be described as "host-parasite" or "predator-prey" co-evolution.

Merry's (1999, p. 272) definition of co-evolution is not restricted to biology: "When the change in fitness of one system changes the fitness of another system, and vice versa, the interdependency is called coevolution. Coevolution is the evolutionary mutual changes of species (or organizations) that interact with each other." According to Agiza et al. (1997, p. 985) co-evolution is associated with negative and positive interactions. Negative interactions mean, for example, predation and competition while positive interactions include mutualism and sharing. Roos and Oliver (1999, p. 287) give a descriptive example of co-evolution. The ongoing battle between police and organised criminals in developing new technologies for preventing or committing crimes is a co-evolutinary struggle.

Pagie (1999) discusses co-evolution from the point of view of biology. These ideas can, however, be applied to the modelling of an organisation population. According to Pagie (1999, p. 2) the term "co-evolution" was first used by Ehrlich and Raven in 1964 to describe the mutual evolutionary influence between insects feeding on plants and the respective plants. On the other hand, Pagie

(1999, p. 2) states that Darwin recognised mutual evolutionary adaptations between insects and the plants that they pollinate. Pagie (1999, p. 2) claims that “co-evolution” is a term used in situations where a small number of species impose direct selection pressure on each other. In the context of organisation population co-evolution happens between organisations which are interconnected and thus have an effect on each other. The decisions that one firm makes can force or enable other organisations to make some other decisions. The development of a new technology by a firm or a group of firms can trigger many kinds of technology development projects, which can be competitive or complementary, within other firms.

Pagie discusses three types co-evolution: competitive, mutualistic and exploitative. Competitive co-evolution occurs between species that are limited by the same resource. Plant-pollinator systems are an example of mutualistic co-evolution. Exploitative co-evolution includes predator-prey systems, host-parasite systems, and plant-herbivore systems. (Pagie 1999, pp. 2-3) In an organisation population context competitive co-evolution is a very basic case. Firms competing in the same market with a same kind of product are a clear case of competitive co-evolution. Mutualistic co-evolution happens when firms and their products complement each other. Exploitative co-evolution can be observed when a firm has a powerful position in which forces its subcontractors to submit to its terms.

Co-evolution can be divided into two classes: “diffuse” and “pairwise” co-evolution. Co-evolution is pairwise when there are only two species evolving simultaneously and affecting each other. In the case of more than two species co-evolution is diffuse. In nature it is hard to find a case that would be purely pairwise. (Pagie 1999, p. 3) Pairwise co-evolution in an organisation population basically means a duopolistic situation. Thus, diffuse co-evolution is more common also in the context of organisation populations.

Pagie’s view is not, however, a systemic view, since he only discusses species affecting other species, but not of species affecting physical environment or the physical environment affecting species. Species do have an effect on the oxygen content of air, for example, which then again has an effect on species. In Pagie’s text the physical environment is left untouched restricting, thus, a large part of the system outside the study. Organisation population also has an environment that has legal, social, political, environmental and human aspects, which can have an essential effect on the system and its development.

The idea of environment having an effect on a system is taken into account in Merry’s text. “You cannot separate between species, or organisms and their environments. They are not isolated from each other. They are connected and change together. They survive together in coevolution.” (Merry 1995, p. 173) This idea also contests the traditional reductionist approach to research.

In the field of evolutionary economics co-evolution has not been under industrious study. “Although Nelson has done some work on such wider co-evolution processes, the topic is under-exposed in evolutionary economics.” (Geels 2002, p. 1259) The work of Nelson which is referred to, examines the co-evolution between institutions and technologies. Nelson (2001) argues that institutions and technologies co-evolve so that the development of a given technology may be a prerequisite for or a consequence of a certain institutional development, and vice versa.

Choi et al. (1999) claim that the most important feature of a CAS is co-evolution which happens in the context of a system and its environment. “With roots in many disciplines such as evolutionary biology, non-linear dynamical systems, and artificial intelligence, modern theories and models of CAS focus on the interplay between a system and its environment and the co-evolution of both the system and the environment.” (Choi et al. 1999, p. 353) Thus, there are internal mechanisms inside a complex adaptive system and this system has environment. The interaction between a complex adaptive system and its environment is called co-evolution. This is described in figure 8.

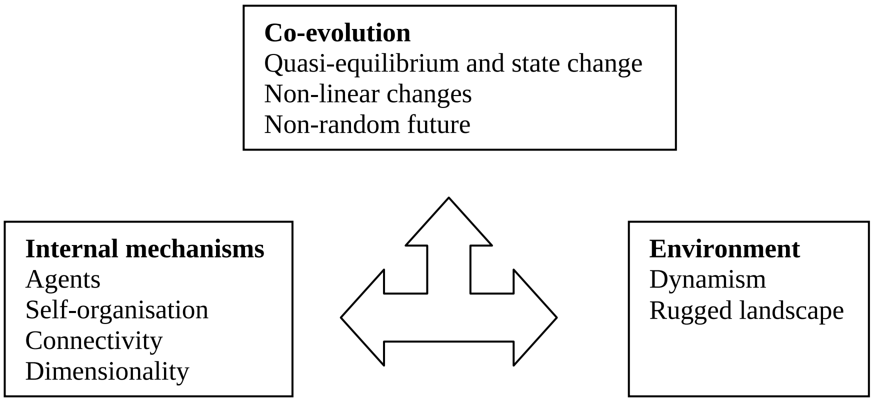

Figure 8. Underlying dynamics involving complex adaptive systems. (in Choi et al. 1999, p. 353)

Choi et al. (1999, p. 353) discuss supply networks as complex adaptive systems. They consider the supply network as the system. Consumer markets, potential supply bases not presently a part of the network, and the larger institutional and cultural systems, constitute the environment. This is a straightforward definition of the system and its environment. These kinds of definitions are essential if a model of a system is to be built.

Bechtold (1997, p. 198) discusses the roles of information generation and exchange as means of co-evolution in a business context. He claims that both exchanging and generating information are equally important. Through connections with simultaneously evolving other organisations and the larger environment the firm is able to receive and transmit information that enables co-evolution. Processing and generating information are methods with which the firm can develop itself and continuously respond to triggers from the environment. Information flows, as well as monetary flows for example, form the interconnectedness of the business world, which are a characteristic of complex systems and also the enabler of co-evolution.

In an organisation population context co-evolution arises from the interconnectedness of these organisations. Connections can be monetary and product flows, but the role of knowledge in the formation of connections is the most important. Because of interconnectedness the organisations *have an effect on each other. The decisions that an organisation makes can enable or force other organisations to make some other decisions, and vice versa. Co-evolution can be interpreted as competitive, mutualistic or exploitative based on the nature of the relationship that the co-evolving organisations have. However, the trigger of co-evolution is always knowledge.*

3.3.3 Self-organisation

Self-organisation has not been defined unambiguously in literature. Thus, the definition must be drawn from the features and functions that are reported relating to self-organization. Anderson (1999, p. 221) claims that self-organisation is a process where "pattern and regularity emerge without the intervention of a central controller." Goldstein's thoughts are practically the same since he defines self-organisation as "a process…, whereby new emergent structures, patterns, and properties arise without being externally imposed on the system" (in Choi et al. 2001, p. 354).

Kauffman sees self-organisation in relation to attractors. "Dynamical attractors "box" the behaviour of a system into small parts of its state space, or space of possibilities. Hence attractors literally are most of what the system does. It is in the boxing of behaviour into small parts of state space which constitutes much of the self-organization we shall encounter." (Kauffman 1993, p. 174) Thus, the system can be attracted to certain states.

According to Merry's definition, self-organisation leads to increased complexity and unpredictability. "In self-organization, systems spontaneously change into more elaborate forms. The new forms they take are more complex, they entail cooperative behaviour and global coherence and their final forms are unpredictable." (Merry 1995, p. 172)

Here self-organisation is defined as a process in which novel structures or features arise in a system without the intervention of an outside actor or an internal controller. Self-organisation is an ongoing process since it will never have completed its final outcome. Novelty is the contribution of self-organisation and it can be specified in various ways in different systems. The lacking of an outside interventions or an inside controller is the key to self-organisation. It is the "self" that organises.

A commonly used example of a self-organising system is language (Dyson 1999, p. xv). The forever ongoing process of inventing, adding new terms, and new meanings brings novelty to the system. But there is no central or outside control. Nobody imposes the change, with the exception of language standard reforms, it just happens in a decentralised manner.

Another common example of a self-organising system is informal networks in organisations. People form them among themselves spontaneously. The long-term outcome of such a system can not be controlled or influenced. (Smith & Stacey 1997, p. 85) These systems also provide important connections and interactions as the means for sharing and creating information. Informal networks are often paramount to organisational success. (Bechtold 1997, p. 198)

Goulielmos (2002) describes the management of shipping companies as a process of self-organisation. Traditionally the captain of a ship has had quite an extensive power of decision over the ship. Since the means of communication have been limited the captain has had to make decisions without the validation of the shipping company manager. Unexpected weather conditions, accidents and breakages oblige the captain to take action. Since a shipping company owns several ships, each of them managed by a captain, the whole system is controlled in a decentralised manner which leads to self-organisation.

Choi et al. (2001, pp. 358-359) suggest that a supply network behaves in a self-organised way. Decisions are “distributed in nature, not linear or sequential but parallel”. The complex web has an adaptive capability to respond to frequently occurring changes. Since each actor has only limited knowledge and control over the supply network, decision making is decentralised. The network itself is an emergent structure – a consequence of a self-organising process.

Other examples of self-organisation include open source movement, internet, and markets (Clippinger 1999, p.4). Open source movement has self-organised in a productive way. Thousands of volunteers all over the world are contributing to the development of Linux, for example. Internet has also developed without strict central control. The joining of new computers to the net has not been monitored. Although the crashing of the system has been predicted many times, it is still running. Markets as the basis of western economy have demonstrated their power to create and allocate resources efficiently. Again, this is a system with decentralised decision making, limited knowledge, and freedom of choice in the framework of legislation.

Self-organisation has been applied in various technological developments. Evolutionary robotics (see e.g. Nolfi 1998) is based on the system’s ability to evaluate the performance of its parts and to target the development to the direction that performs the best. The decentralised and self-organising system of robots is commercially interesting because it requires far less planning and coding compared to robots with predetermined functions. Peer-to-peer applications, on the other hand, are distributed computing systems “based on the concept of resource sharing by direct exchange between peer nodes” (Babaoglu et al. 2002, p. 15). Adaptation, resilience, and self-organisation are seen as the building blocks of the new paradigm of application development of such systems.

It is problematic to define the principles of self-organisation. It is possible to “make self-organisation happen” in man-made systems, but that does not mean that we have found the hidden logic behind self-organisation. For example, we can conduct a simulation of a swarm of birds with three simple rules: stay close to others, do not bump into others, and avoid hitting obstacles. The result is a self-organising swarm of birds flying on a computer screen. This still does not prove that swarms of real birds function according to these rules.

Kauffman (1995, p. 75) has studied self-organisation in Boolean network models where order emerges from simple rules. The basic idea is that the nodes in the network have two states: true and false. The state of each node is defined by the states of some other nodes and Boolean operators.

For example, if node 1 and node 2 are true, then node 3 is true. This can lead to an ever repeating state cycle within the system. As Kauffman (1995, p. 71) puts it: “Self-organization is order for free – it arises naturally.”

In the field of evolutionary economics self-organisation is seen as a form of evolutionary behaviour. According to Radzicki (2003, p. 160) the other forms include path dependence, and chaotic behaviour. Path dependence is often defined with the slogan “history matters”. Path dependent systems “get locked into a particular dynamical path they “choose” early in their evolution (usually by chance) because their future trajectories are critically influenced by the cumulative effects of their past decisions”. Chaotic behaviour means unpredictability, and oscillation with never repeating periods and amplitudes.

Self-organisation of markets has been studied quite extensively in the field of agent-based computational economics (see e.g. Vriend 1995, Tesfatsion 2002). According to Tesfatsion (2002, s. 2) agent-based computational economics (ACE) covers the computational study of economies modelled as evolving systems of autonomous interacting agents. There are two basic targets driving this study: to describe and explain emergent global behaviour, and to give normative instructions for policymakers.

Vriend (1995) studies the self-organisation of markets with a computational approach. The question goes: “How is it possible that a group of agents, each pursuing his self-interest, leads to order rather than chaos?” Vriend finds that competition is the main coordinator of economic activities, and that macroeconomic inefficiency originates mainly from the high communication expenditures.

Tesfatsion (2002, p. 7) highlights that self-organising capabilities of different types of market processes is one of the most active areas in ACE research. One of the points Vriend (1995, p. 224) makes, is the difference between self-organised and organised markets. One specific focus in ACE research is the formation of economic networks (Tesfatsion 2002, p. 11). Important areas in this line of research are dynamics of learning, adaptation, and innovation, as well as the development of trust. Tabata et al. (2001), on the other hand, have studied self-organisation in an agent-based model of firms.

Self-organisation is not, however, something that complexity scientists and economists have come up with during the last decade. Already Schumpeter described this kind of behaviour in The Theory of Economic Development. “By “development” therefore, we shall understand only such changes in economic life as are not forced upon it from without but arise by its own initiative, from within.” (Schumpeter 1951, p. 63) Clearly, this is a description of self-organisation. On the other hand, the problem of the mechanics of self-organisation has been acknowledged by respected economists, such as Smith and Hayek, and is discussed with the term “invisible hand” (in Witt 1997, p. 490).

In an organisation population context, self-organisation implies the absence of central or outside controller. The system has been given the freedom to organise according to its own needs and *capabilities. Basically, a self-organising organisation population develops through decentralised decision making. This is enabled by market economy system. In any real life organisation population, however, there are different kinds of interventions by the public sector. These can be seen as inhibiting self-organisation or as creating enabling structures for self-organisation.*

3.3.4 Emergence

According to Smith & Stacey (1997, p. 83) emergence “means that the links between individual agent actions and the long-term systemic outcome are unpredictable”. According to Phan (2004), Santa Fe Institute sees emergence as “a property of a complex adaptive system that is not contained in the property of its parts”. Holland claims that although emergence has received a lot of attention it is not under serious research efforts. ”Despite its ubiquity and importance, emergence is an enigmatic, recondite topic, more wondered at than analyzed.” (Holland 1998, p. 3)

Merry’s definition of emergence goes as follows. “New properties and novel characteristics emerge that were non-existent in the previous form of the system. This means that at each different scale and level of organization, new types of behaviour develop. These could have never been predicted from an analysis of the lower-level components.” (Merry 1995, p. 173) This is again an objection to reductionism. Harkema (2003, p. 343) states that self-organisation and emergence are closely connected. He claims that emergence is about the interaction of the wholes and the parts.

The key to emergence is the link between micro and macro behaviour. Smith and Stacey claim that the behaviour observed at the macro level is not obvious while examining the behaviour at the micro level. “Emergence means that the links between individual agent actions and the long-term systemic outcome are unpredictable.” (Smith & Stacey 1997, p. 83) They also state that emergence confuses the links between cause and effect, which makes it impossible for one actor to control the whole system. When the connection between action and long-term outcome are lost in the interaction between agents and the system, it is not possible for an actor outside the system or a powerful agent inside the system to control or design the exact behaviour of the system. Instead the behaviour emerges. (Smith & Stacey 1997, p. 83)

Also Radzicki (2003, p. 141) highlights the obscure relation between micro and macro level. Emergence occurs when patterns, such as organised groups and hierarchies arise at the level of the system as a whole. These patterns can not be derived from an analysis of the capabilities of the individual agents. (Radzicki 2003, p. 141) Organisation population is an organised group that hence is an emergent structure. It has been developed through the actions of individual organisations that function according to their own goals and capabilities. At the population level the results may be far-reaching and surprising, such as formation of large scale cooperation networks in the development of some new technology.

Research on emergence is not without its own controversies. Holland (1998, pp. 12-13) states that there are philosophers as well as scientists who think that emergence just can not be explained in scientific terms, such as mechanisms and their interactions. This is because it is hard to believe that more can come out than was put in. (Holland 1998, pp. 12-13) This controversy is summarised in the idea of simple rules, which has its own supporters[10] as well as opponents[11].

Although emergence has not been very popular area in scientific research, there are studies made in a variety of disparate fields (Smith et al. 1999, p. 158). One of the first ones is the classic description of agent-based emergence by Douglas Hofstader from 1979, which describes the ant colony. It is noted that despite the agents have limited capabilities the colony exhibits remarkable flexibility. The simple laws of the ants generate emergent behaviour that is far beyond their individual capabilities. This kind of behaviour happens although there is no central controller in the ant colony. (Holland 1998, pp. 5-6)

Schelling describes agent-based human emergence in his 1978 book “Micromotives and macrobehaviour”. He states that people in general respond to an environment that consists of other people’s responses to their environment. This environment, on the other hand, consists of people’s responses to their environment. (Schelling 1978, p. 14) This kind of interconnected system is rich with positive feedback loops that can cause surprising and perhaps even unwanted results, although people’s behaviour at the micro level is totally understandable. Schelling makes a difference between sequential and reciprocal dynamics. An example of sequential dynamics is people driving a car and turning lights on when triggered by someone else driving with his lights on. Thus, I can trigger you to turn on your lights and you can trigger someone else but not me. An example of reciprocal dynamics is people’s willingness to honk their car horn if they hear someone else do it. Thus, me honking my horn triggers you to honk yours which encourages me honk even more eagerly. (Schelling 1978, p. 14)

Schelling (1978, p. 14) states that in situations where people’s behaviour or choices are dependent on the on the behaviour or choices of other people it is not possible to simply sum or extrapolate the aggregate behaviour. In order to get a picture of the macro level behaviour the system of interaction between individuals and their environment must be studied. This can lead to surprising results. This is also the case in an organisation population. Interconnectedness and co-evolution between the organisations means that their behaviour and decisions are dependent on the behaviour and decisions of other organisations, which in turn are dependent on the behaviour and decisions of other organisations. As a result, the population level behaviour is not a linear sum of individual organisations’ motives, but is the product of complex dynamics because of the feedback loops.

Emergence can be observed also in a game of chess. This is noted by Harkema (2003, p. 343) who states that although the rules underlying the game are fairly simple the outcome can be very complex. People playing have different kinds of strategies and mental models that change according

[10] Supporters include for example Atay & Jost (2003, p. 1).
[11] Opponents include for example Mitleton-Kelly (2004).

to the opponent's strategies and mental models. A game of chess is rich with interaction and feedback loops that make the game unpredictable and interesting. Thus, the result emerges bottom-up. The same is true within the context of organisation population. The strategies that the organisations are applying are changed continuously as response to other organisations' strategies.

In an organisation population emergence can be observed in surprising population level behaviour that can not be linearly extrapolated from organisation level motives. Interconnectedness of the organisation population enables co-evolution which in turn induces both sequential and reciprocal dynamics. These function as feedback loops that have an effect on the behaviour of individual organisations. Thus, the population level behaviour is emergent. It emerges bottom-up.

3.4 Solution to the modelling problem based on complexity

When applying complexity to the problem of modelling a population of organisations the relevant concepts are adaptation, co-evolution, self-organisation and emergence. Organisation population is not seen behaving linearly, deterministically and predictably, but nonlinearly, exploring the space of possibilities and constructing its own future, which leads to unpredictable outcomes.

At the organisation level the most important principle is co-evolution between an organisation and its environment that consists of other organisations and the wider context. This is presented it figure 9. An individual organisation has two sources for triggers of change. Change can be triggered from within the organisation based on its motives and inner logic. However, drastic changes are often triggered by the environment. Any organisation is also a part of the environment of some other organisation. This leads to co-evolution.

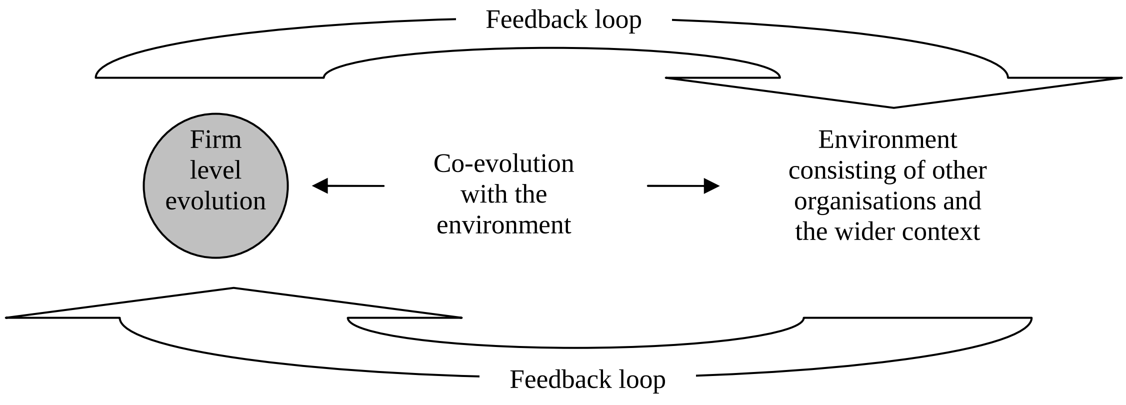

Figure 9. Organisation level model based on complexity.

An important precondition of co-evolution is interconnectedness of the organisations. Connections can be formed of monetary and product flows, but the role of knowledge in creating these connections is essential. Change in the research and development department of a firm can be triggered by a competitor’s new product, but the actual trigger is the knowledge of that product. Just as well, knowledge of the development of a new technology by another firm can trigger both the development of competitive and complementary technology as well as an attempt to join the development process in order to share resources and risks involved.

One aspect of co-evolution is feedback that often takes the form of positive, or regenerative, feedback. Thus, the changes of an organisation trigger changes in other organisations which then echo back to the original organisation triggering it to augment its original changes. For example, a price war started by a firm induces other firms to lower their prices which in turn induces the original firm to lower its prices further which induces the other firms to lower their lowered prices and so forth.

As mentioned earlier, co-evolution can be competitive, mutualistic or exploitative. Competitive co-evolution consists of competitors making moves in order to gain competitive advantage. Price war is an example of competitive co-evolution, as well as the development of competing technologies. Mutualistic co-evolution can be observed when firms develop capabilities for cooperation and complementation. For example, hardware and software are developed to complement each other and the firms involved develop those technologies in mutualistic co-evolution. Exploitative co-evolution may be detected in a situation where some organisation is significantly more powerful than the others. This could happen in the context of a large corporation and its suppliers. The suppliers aim at developing capabilities that would make it less dependent on the large corporation. The large corporation’s goal is, however, to maintain its bargaining power to ensure low prises and timely deliveries.

The population as a whole develops in co-evolution in a sense that the organisation level co-evolution spreads through the population causing the entity as a whole to evolve at the macro level through both sequential and reciprocal dynamics. Other population level phenomena include self-organisation, emergence and adaptation which are presented in figure 10.

Self-organisation is essentially about decentralised decision making. Organisations make their own decisions based on imperfect, maybe locally restricted, knowledge that they have. There is no central or outside controller that would dictate the behaviour of each organisation. In the market economy system the market is a central enabler of self-organisation. It ensures each organisation’s ability to make decisions.

Self-organisation is, however, not perfect since there are numerous public sector interventions, such as business subsidies, import duties and publicly funded development projects, in any market economy and thus concerning any organisation population. These can be interpreted as inhibiting self-organisation or as creating enabling structures for self-organisation.

Emergence, on the other hand, is a phenomenon that arises from organisation level motives and actions that lead to unpredictable and even surprising population level behaviour. It is induced by each organisation’s restricted knowledge of its environment, of its options and of the outcomes of those options. Choice of an option can lead to unanticipated outcomes that induce other organisations to respond with some other choice. Thus, the phenomenon may be amplified in the population and result in an unanticipated situation.

Supply network is an example of an emergent structure. Each member has its customers and suppliers through which an elaborate network can form. This kind of a structure is induced by each organisations motives and actions. This kind of an entity does not optimise well since an organisation usually chooses its suppliers and customers based on local knowledge aiming at local optimum, not reaching it though, which inhibits it to see the bigger picture and the global optimum. Thus, the supply network is induced by organisation level motives that result in unpredictable population level behaviour.

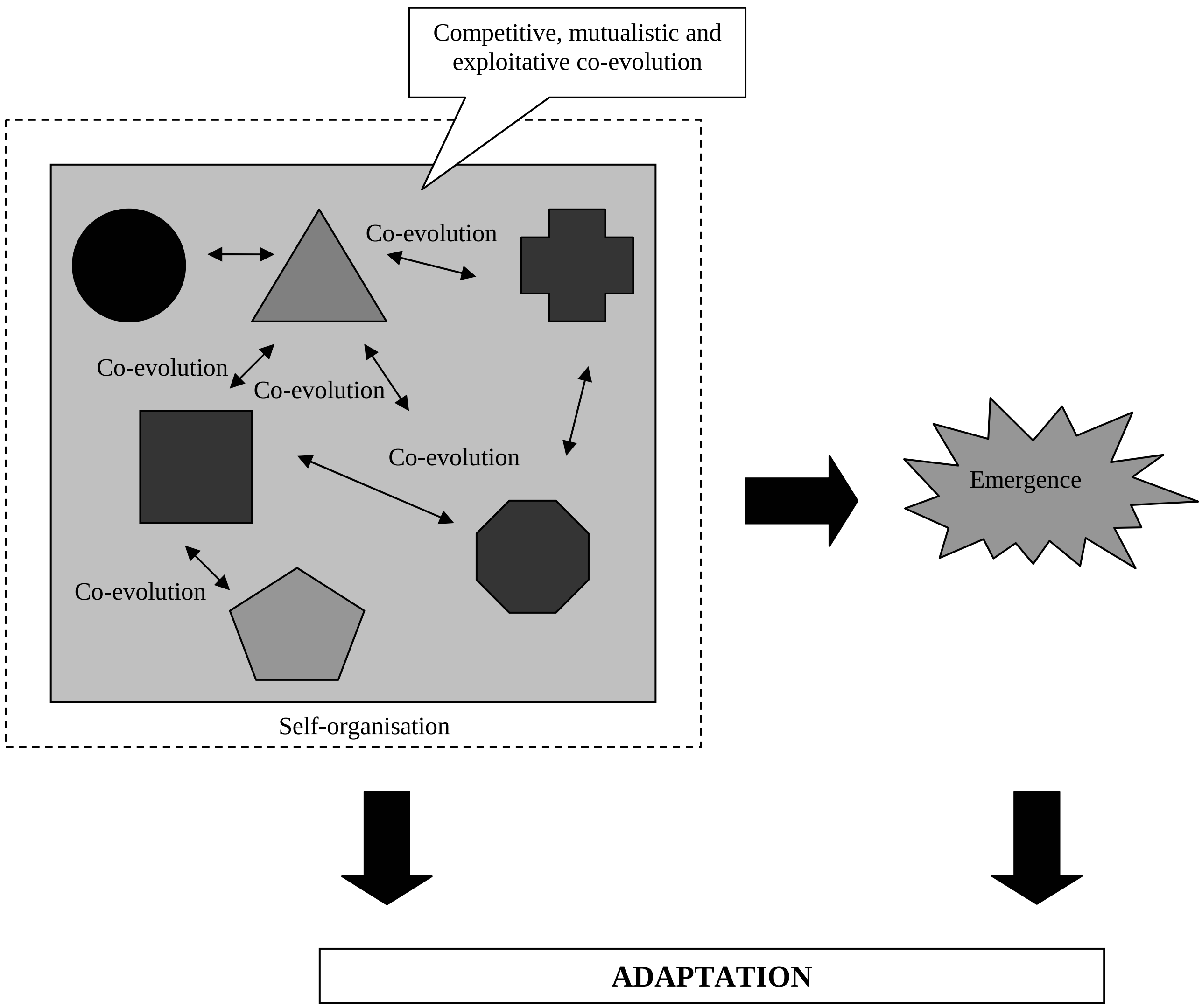

Figure 10. Population level model based on complexity.

As a result of co-evolution, self-organisation and emergence the organisation population is able to adapt. Here, adaptation is interpreted as a population level phenomenon that relates to the organisation population as a whole. Because co-evolution, self-organisation and emergence are present, the entity has adapting capabilities. Without this kind of flexibility and robustness the organisation population would be too rigid and deterministic to respond to changes and affect changes in the wider context.

The criteria for acceptable model of an organisation population were presented in chapter 1.4. Firstly, the assumptions concerning the behaviour of an individual organisation should be realistic. In the model based on complexity an organisation is assumed to have limited and locally restricted knowledge which makes it impossible to reach any optimum decisions or actions. This is realistic in a sense that there is no perfect knowledge and perfectly rational actors reaching optimum outcomes.

The assumptions concerning the population level behaviour should also be plausible. The organisation population model based on complexity takes into account reciprocal dynamics and rich interaction among the organisations and the elaborate structures and developments that follow. The system is not seen as optimising in order to reach an equilibrium but as developing nonlinearly, nondeterministically and leading to unpredictable outcomes. This is realistic since it is not assumed that the population would be predetermined to reach some optimum equilibrium, but the population is seen as actively creating its own future.

It is also essential that knowledge is seen as a valuable factor of production. In the model based on complexity, knowledge is not perfect or global. On the contrary, it is limited and perhaps even restricted to local knowledge. Thus, knowledge has value since it is not already possessed by everyone and it can be bought and sold. Knowledge and its gathering are also essential in order to get an edge, or simply to survive, in co-evolution. This is important also because it gives a role to knowledge-intensive service firms that can enhance an organisation's chances to survive and grow.

At the conceptual level complexity seems to offer a viable option to neoclassical economics. The assumptions that the organisation model is based on seem plausible. The downside of the organisation population model based on complexity is that the theories are not well established and tested. Conceptual models and empirical research conducted based on complexity is very limited in the context of socio-economic systems, not to mention organisation populations. This presents a challenge since the interpretations and applications of complexity concepts are heavily based on the author's own understanding of the field. However, it is the only way to construct new models when no empirical data is available.

4 EVOLUTIONARITY AND COMPLEXITY IN ECONOMICS

"The economy is a complex adaptive system. This was grasped intuitively by, among others, Alfred Marshall, John Maynard Keynes and, of course, Joseph Schumpeter."

(Foster 2004, p. 24)

During the 20th century a lively field of evolutionary economics has developed. It draws analogies and inspiration from evolutionary biology in order to understand economic development. Many of the ideas developed under evolutionary economics are basically the same as ideas developed under the study of economic systems as complex adaptive systems. These two fields are getting closer to each other and already share some of the basic assumptions and propositions as well as some of the same academics.

In this chapter the roots of evolutionary economics in the works of Charles Darwin and Jean-Babtiste Lamarck are briefly reviewed followed by an analysis of variation and selection in economic context. It is discussed where economic evolution is leading to and how this relates to the concept of increasing returns. Finally, organisation population model based on evolutionary economics is constructed.

4.1 From Darwin to evolutionary economics

Variation and selection is the key to the theory of evolution introduced by Charles Darwin in 1859 under the title The Origin of Species (Wallace 1998, p. viii). Darwin's arguments start from examination variation and selection within the breeding of domestic animals. From this he goes to "variation under nature" and to the role of natural selection. Many of the observations reported in the book were made during the voyage of the HMS Beagle in South America between 1831 and 1836. (Darwin 1998)

But Darwin was not the first one to develop theories about evolution. Before Darwin the dominant theory of evolution was that of Jean-Baptiste Lamarck. His view was not, however, widely accepted since the mainstream belief held that the world, and all the species in it, had been the way they are since the Creation. Lamarck's revolutionary claim was that species do change in process of time. This change is induced by each creature's efforts to make minor adjustments to its body to improve its function. Then, these acquired characteristics would be passed on to descendants. Lamarck's main ideas can be summed up to the theories of "acquired characteristics" and of "descent with modification". The most famous example of this kind of evolution was the long neck and legs of giraffes. Lamarck claimed that continuous stretching upwards to reach foliage up on trees had made the giraffes body the way it is. (Rothschild 1990, pp. 28-29)

Darwin's "Origin of Species" was published in 1859 and it was received with controversy in both religious and scientific circles. But by the death of Darwin in 1882 his theory had been widely accepted. One of the basic assumptions was that organisms must compete over scarce resources, and in order to survive in that competition an individual needs "an edge" over other individuals. (Rothschild 1990, p. 41) Darwin claimed that the giraffes have their long legs and necks because those giraffes with slightly longer legs and necks, compared to the others, have better chance to survive and reproduce, and their descendants inheriting the parents' characteristics more often have longer legs and necks than the descendants of the giraffes with shorter ones. Thus, no organism inherits any "acquired characteristics" but some of the characteristics that the parents have since birth.

The idea of "survival of the fittest" has been applied also in the social sciences under the name "social Darwinism". During the 19th century, Industrial Revolution had triggered massive social problems in overcrowded cities with most of the population living in extreme poverty. Some claimed that this was due to their genetic inferiority. Some even believed that these poor and inferior people should be allowed to starve to death in order to improve the genetic status of the human race in general. These ideas also lead to the most horrific application of social Darwinism - the Nazi Holocaust. Perhaps the bad echo of social Darwinism is still keeping economists from applying the theories of modern biology to explain the complexities of the economy. (Rothschild 1990, pp. 343-345)

There is, however, a lively field of evolutionary economics searching inspiration from evolutionary biology. The most important authors are often said to be Joseph Schumpeter, Richard Nelson and Sidney Winter. Schumpeter, though, did not approve the use of biological metaphors to explain economic phenomena. According to Foster (2000, p. 312), he "did not believe that biological analogies were of much use in understanding economic evolution."

Schumpeter's view is clear in his book "The Theory of Economic Development". He claims that "the evolutionary idea is now discredited in our field… To the reproach of unscientific and extra-scientific mysticism that now surrounds the "evolutionary" ideas, is added that of dilettantism. With all the hasty generalisations in which the world "evolution" plays a part, many of us have lost patience. We must get away from such things." (Schumpeter 1951, pp. 57-58)

Although Schumpeter thought that biological metaphors were something that one must get away from, many post-Schumpeterian evolutionary economists have used the biological analogy of natural selection, either Darwinian or Lamarckian type. Nelson and Winter, whose 1982 book "An Evolutionary Theory of Economic Change" was a seminal step in the development of evolutionary economics, define their own text as "unabashedly Lamarckian" (Nelson & Winter 1982, p. 11). This is because they use the theory of acquired characteristics as well as "the timely appearance of variation under the stimulus of adversity."

The usage of Darwinian or post-Darwinian ideas to explain economic evolution is, at least, problematic. This is well described in Hodgson's (1994, p. 214) text. "If economic development is determined by some process of natural selection, with something analogous to genetic replication and to random variation or mutation, then what role remains for the notions of intentionality, purposefulness or choice, which economists of many schools of thought have held so dear?"

Lamarckian idea of evolution has clear advantages in the field of economics compared to Darwin's theory of evolution. It can take into account conscious choice and people's ability to improve heir performance and acquire new characteristics. But it does not have to be a dispute between Darwinists, Lamarckianists and those not willing to approve any kind of thought brought from biology to economics. One can study evolution in socio-economic systems in their own right, and not as mere metaphor or analogy from biology.

Brian Arthur, the first leader of the economics programme at Santa Fe Institute, states that "as we study evolution more deeply, we find that biology provides by no means all of the examples of interest" (Arthur 1994a, p. 77). He states that evolutionary phenomena may be observed in any system that has inherited alterable structures and is pressured to improve its performance. According to Arthur (1994a, p. 77) connections between complexity and evolution will be found increasingly from the field of economics. Thus, biology is not the only source for theory formation about evolution, but economics can also serve as a research field. Maybe this approach could have been approved also by Joseph Schumpeter.

Thus, theory of economic evolution can not be simply derived from the theory of biological evolution. In nature the species do not have any other goals besides survival. The genes that organisms inherit will be passed on to their offspring with some random mutation and according to the organism's ability to reproduce. In an economic context, conscious choice makes the evolutionary process different. People that form economic entities can strive to reach goals and are able to develop new capabilities in order to survive in selection. Thus, economic evolution is a product of people's efforts and choices and not a predetermined process of survival of the fittest that the organisations involved have no influence on.

4.2 Variation and selection

Since variation and selection are central to Darwinist and post-Darwinist biological evolution, it is natural that they are important also in evolutionary economics. Tordjman (1998, p. 9) states that "selection mechanisms and variation mechanisms are at the heart of evolutionary theories, as the latter is determining the possible worlds and the former is selecting among them." Tordjman claims that these mechanisms must be defined precisely, since they shape the dynamics of evolutionary processes.

Hull (in Foxon 2004) defines evolution to consist of variation, transmission and selection. He states that a population will undergo evolutionary change if the following three conditions are met.

- There is a variation amongst the entities, so that they are similar but not identical.

- The entities do not last forever, but have the capacity to make copies of themselves to form succeeding generations, whose characteristics are at least partially determined by the corresponding characteristics of their forebears.

- The frequency of copies made varies, depending on interactions between certain characteristics of the entities and features of the environment in which the entities exist, i.e. the entities have differential fitness.

This process is clearly the same as the post-Darwinian equation of adaptation discussed in chapter 3.3.1. It does not, however, pay attention to the processes that produce variety. Variation is just assumed. This problem is acknowledged in Foster and Metcalfe's (2001, p. 6) three-stage model of evolution which will be presented later in this chapter.

In figure 11, there is a very basic model of evolution which has two stages: variation and selection. Firstly, there must be variation in the characteristics of a population of selection units in order to have meaningful selection. The process of selection evaluates the characteristics to create a fitness score for each unit and causes the number of fitter than average units to increase in the population. In this model the characteristics of the selection units are exogenously given, although their relative importance is shaped by the interaction with other units and the environment. (Foster & Metcalfe 2001, p. 6-7)

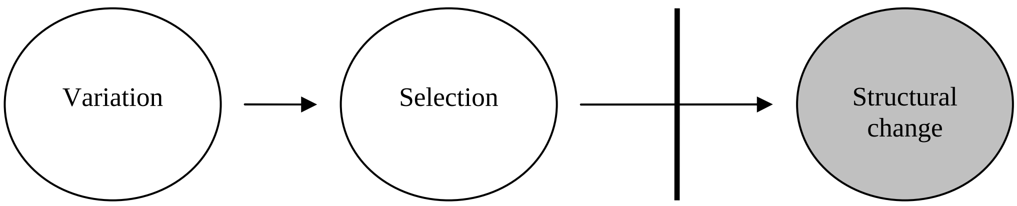

Figure 11. Two-stage model of evolution (Foster & Metcalfe 2001, p. 6).

Foster and Metcalfe (2001, pp. 6-7) state, that in an economic context, variety is generated by innovations in products, organisations and methods of production. This variety is evaluated by market processes causing differential profitability for the firms. The competitive dynamics among firms in the same industry translates this differential profitability into differential growth. This leads to patterns of structural change that are emergent and a vital part of modern capitalism. (Foster & Metcalfe 2001, pp. 6-7)

This model, however, places emphasis only on exogenous factors and does not take into account conscious choice. In the two-stage model of evolution variation is generated by some random process since it does not explicitly comment on the origin of variation. For this reason Foster and Metcalfe (2001, p. 6) introduce another model of evolution which has three stages: variation, selection and development (figure 12). They discuss the model especially in the context of innovation.

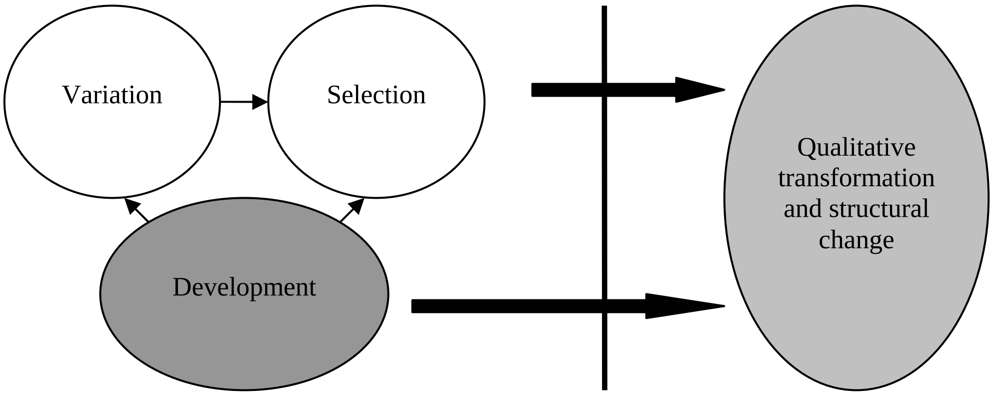

Figure 12. Three-stage model of evolution (Foster & Metcalfe 2001, p. 6).

Foster and Metcalfe (2001, p. 10) state that development and selection are subject to mutual interaction, since innovation process is, to a substantial degree, endogenous to the economic system. In an economic system variation is not generated by random processes because they are too slow to explain the observed rates of economic and social change. The distribution of profitability of the past and the present influence the distribution of future R&D in an industry. Also, firms of different sizes receive different pay-offs from innovations. Most fundamentally, the experience gained in production and in market activity is an important determinant of the differential innovative performance. "Presented in this light, a compelling case can be made for the endogeneity of evolutionary innovation processes such that the development of variety and the selection of variety become inseparable processes." (Foster & Metcalfe 2001, p. 10) Thus, variety generation is not a random process but variety is developed in such a way that selection steers the direction of development at all times.

If we incorporate development into an evolutionary model we can see that it is not just a random process, or a process where some are determined to win and some to loose. Foster and Metcalfe (2001, p. 13) also introduce a model of development and selection (figure 13).

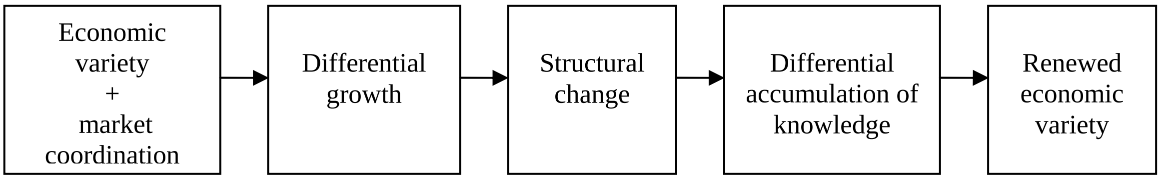

Figure 13. Development and selection (Foster & Metcalfe 2001, p. 13).

In this model, economic variety and market coordination induce differential growth for the firms in question. Differential growth leads to structural change and differential accumulation of knowledge. This difference of accumulated knowledge between companies causes economic variety to renew. This is how variation is present for the next development and selection process. Thus, Foster and Metcalfe's emphasis is on knowledge and its role in variation, selection and development. Nelson and Winter (1982), from whose work evolutionary economics still draws grounds for arguments, however, did not emphasise the role of knowledge but the role of routines.

Nelson and Winter (1982, p. 4) state that their evolutionary theory of economic change emphasises "the tendency of the most profitable firms to drive the less profitable ones out of business". This is the basic assumption of their reasoning. They, however, do not concentrate on analysing equilibrium states of particular industries "in which all the unprofitable firms no longer are in the industry and the profitable ones are at their desired size". (Nelson & Winter 1982, p. 4) They also reject the assumption of maximising behaviour. Instead, the firms "are modelled simply having, at any given time, certain capabilities and decision rules. These capabilities and rules change over time as a result of both deliberate problem-solving efforts and random events. As the market determines which firms are profitable and which are unprofitable, the economic analogue of natural selection operates by deserting the latter.

In Nelson and Winter's evolutionary theory routines play the role that genes play in biological evolutionary theory. Routines are a persistent feature of the organism and determine its *possible* behaviour while also the environment has an affect on the organism's *actual* behaviour. Nelson and Winter (1982, p. 14) explain the heredity of the routines with an example of a plant. When a new plant is built, it has many of the same characteristics as today's plants of which the new plant is generated from. Selection comes to play since plants "with certain routines may do better than others, and, if so, their relative importance in the population (industry) is augmented over time." (Nelson & Winter 1982, p. 14)

Nelson and Winter concentrate in their analysis on the concept of "routine". According to them, routines of a firm equal genes of a biological organism. Therefore, there is selection among both routines and firms. But search and selection are not optimising in a sense that the absolute best would ever be found. On the contrary, exploration is continually finding new regions of better technologies, management methods etc. This leads to continual improvement in a space where the perfect solutions remain unattainable and out of our knowledge.

According to Dosi et al. (2000, pp. 11-12), there are two propositions behind evolutionary economics: continuity and distinctiveness. Continuity means that firms have ways of doing things which do not change over night. Distinctiveness, on the other hand, means that the ways firms do things are different, even within functionally similar tasks. These propositions make it possible for variation, selection and retention to work in the context of market processes.

However, these evolutionary approaches to economic development have their own problems. Two of these are discussed in Nelson and Winter (1982, p. 160) and they are:

- the tendency of the routines of extant firms to determine, to some degree at least, the environment that selects on routines.

- the necessity of, in order to play a role in an actual market situation, a routine to be consistent with survival in a previous market situations.

These problems are faced whenever young companies in a specific industry grow as a result of their preliminary success. The routines, to use Nelson and Winter's term, that are required to succeed as a start-up, are not necessarily the same that are required as a well-established company of a considerably larger size. This means that routines, which would succeed in the later stages of industry development, may be wiped out in the beginning because they are unsuitable for small-scale firms. As a result, selection may favour the kind of routines that will not survive the selection in the future, and, on the other hand, the kind of routines that would be essential in the future may be selected out in the beginning. Thus, for a routine to be present, it must have survived in the past in all selection environments that it has encountered.

The problem with selection environment is that it is defined by existing firms and their routines. Thus, firms and their routines are not competing against the best possible adversaries but against existing competitors and their routines. This may lead the selection process to concentrate on routines that are not advantageous to the development of an industry. For example, existing firms may reassign funding from R&D to marketing which will lead to growth in sales in the short term. In order to survive in the changed selection environment a firm may be forced to change its behaviour in a direction that is not desirable in the long term.

So far, selection environment has been defined as consisting of competing firms. There are, however, also other factors that are included in the environment. Nelson and Winter (1982, p. 161) claim that the environment of the individual species, or population of firms, can not be taken as exogenous. Thus, fitness, or profitability, is not the factor shaping the development. According to Nelson and Winter the interaction between the whole evolving system and its truly exogenous features of the environment plays an important role. They claim that product demand and factor supply curves are such exogenous factors. It is of great importance to define the system under investigation. What constitutes the system and what constitutes the environment? Here Nelson and Winter discuss exogenous factors and their interaction in the evolution of a system. But is it plausible to determine that product demand and factor supply curves are purely exogenous factors? The interaction between exogenous and endogenous aspects, however, brings these ideas extremely close to co-evolution which is discussed in chapter 3.3.2.

Merry (1995, p. 175) points out that surviving in evolution is not only about winning in the selection process. He stresses the importance of interaction which can be both competition and cooperation. This complements the Darwinian view of evolution by competition. He claims that complexity theory is pointing out to the important part that cooperation plays in evolution. “In the evolutionary process, cooperation and competition complement each other.” (Merry 1995, p. 175) Thus, in order to survive in the selection process and improve their fitness scores firms can form alliances to share resources and risks.

In an economic context evolutionary processes consist of variation, selection and development that do not function sequentially but in mutual interaction. Variation is not generated by some random process but there is conscious choice in the form of development. In addition, the creation of variation faces selection throughout in such a way that variation is steered to a desirable direction. An organisation faces a selection environment that consists of other organisations and the wider context. Thus, an organisation must survive in the present selection environment consisting of existing organisations in order to be present in future selection environments. However, surviving in selection is not only about competing but cooperation may play a central role since this way organisations can improve their fitness scores compared to other existing organisations.

4.3 Evolution in complex economic systems

Cooke (2002, p. 40) has divided evolutionary economics into four distinct schools. These are the Schumpeterian tradition, institutional economics, Marxist political economy and the Austrian School. Another classification can be found in Radzicki (2003, p. 135) where there are eight schools of evolutionary thought identified. These are institutional economics, Post Keynesian economics, ecological economics, agent-based computational economics, behavioural economics, Austrian economics, radical political economics, and evolutionary economics. The relationships of these evolutionary schools are presented in appendix 1.

These classifications are not consistent since, for example, in Cooke’s text institutional economics is a part of evolutionary economics where Radzicki defines these two schools to be parallel. It is not, however, important to define this analysis to belong to any one of these evolutionary schools. This is because the borders of different evolutionary schools are not clear and the schools are interlinked. The aim here is to find the relationship between evolutionary economics and complexity science.

According to Cooke (2002, pp. 47-48), evolutionary economics is based on the following assumptions and characteristics.

1. The agents (individuals or organisations) can never be perfectly informed and they have (at best) to optimise locally rather than globally.

2. The decision-making of agents is normally bound to rules, norms and institutions.

3. Agents are to some extent able to imitate the rules of other agents, to learn for themselves and to create novelty.

4. The processes of imitation and innovation are characterized by significant degrees of cumulativeness and path dependency but they may be punctuated by disruptive change.

5. Interactions between agents are typically made in disequilibrium situations and the result is successes and failures of commodity variants and method variants as well as of agents.

6. The process of change occurring in a context described by the above assumptions and characteristics are non-deterministic, open-ended and irreversible.

All of these theses are present also in the study of complex adaptive systems. First of all, locality is present in both complexity and evolutionary economics. The actors, or agents, function based on local knowledge which is always imperfect. Second, not everything is possible in a given situation. The agents must adapt to the restrictions that the environment imposes on them. Third, learning and novelty are essential for evolution. Since knowledge is imperfect learning can happen, and since the agents adapt to their environment they must learn. Novelty is the product of self-organisation and emergence. Fourth, path dependence or historicity is an important feature in all theories of complexity. Disruptive change is described with the terms "space of possibilities" and "bifurcation" in the field of complexity. There can be countless possibilities but when the bifurcation takes place the system or the agent ends up choosing only one. Fifth, "disequilibrium" is often replaced with "far-from-equilibrium" in complexity theory. Sixth, change is always portrayed as non-deterministic, open-ended and irreversible in the context of complex systems.

Potts (2000, p. 161) claims that there are two elemental propositions underpinning the evolutionary microeconomics.

1. The economic system is a complex adaptive system.

2. The essential behaviour of this system is endogenous change and self-transformation (in historical time).

Potts calls his approach "The New Evolutionary Microeconomics". He acknowledges that several evolutionary economists have developed and used the kind of ideas that are now put under "Complexity Science" with the proposition that there is something totally new invented. Evolutionary economics and the study of economic systems as complex adaptive systems share many of the same assumptions and propositions, and both aim at understanding economic development in an undeterministic way and not concentrating on equilibrium states. Potts (2000, p. 186) suggests that complexity should be defined as "the singular general principle of evolutionary framework".

But where is this development or evolution leading to? According to Hodgson (1994, p. 197) “it is widely, but wrongly, assumed that evolutionary processes lead generally in the direction of optimality and efficiency.” He states that the idea of natural selection as some kind of an optimising force dates back to Social Darwinism. This idea has been criticised extensively in biology by, for example, Stephen Jay Gould and Richard Lewontin. Hodgson (1994, p. 198) claims that these wrong assumptions are still alive because “many economists seem unaware of developments in modern biology and general evolutionary theory that undermine the idea that evolution is necessarily a progressive and optimizing force.” Thus, the danger in applying analogies from other fields is that one should follow the developments in the original field and not apply a theory that has been discredited by its inventors.

According to Foster and Metcalfe (2001, p. 1), “selection mechanisms bring to the fore techniques, organizational routines and products that are best adapted to their respective environmental contexts.” The key here is that there is always an environmental context present. There are no all-around best techniques, organisational routines or products. The environment is an important determinator of what technique, organisational routine or product of the ones present is best adapted. This brings us to the second important point. The best is chosen from the available options with the criteria of that exact moment. Thus, the best that is chosen can be far from the optimum, and even farther as time passes.

Hodgson (1994, p. 25) is emphasising the same idea. He states that “according to modern theory, evolutionary processes do not necessarily lead to – by any reasonable definition – optimal consequences.” According to Hodgson (1994, p. 201), natural selection leads only to the tolerably fit, not to the superlative fittest. “Change can be idiosyncratic, error can be reproduced and imitated, and a path to improvement can be missed.” Optimisation is impossible also because for evolution to work there must be variation. If evolution would produce the optimal situation, then all organisms would have the same absolute best characteristics. This would make any future evolution impossible, since the indispensable variation would not be present in the system.

Nelson and Winter (1982, p. 31) have also tackled the problem of where this evolution is aiming at. They claim that the market forces the firm to act in a way that can be described as “profit-seeking” or “profit-motivated striving”. But it is not “profit maximization”. Thus, the firms surviving the selection in the market are not functioning in an optimal way - only well enough.

Potts (2000, p. 183) claims that despite the problems and faulty conclusions made in the past “the evolutionary metaphor, once carefully reconstructed, provides the basis for the study of economic change and process”. There is still debate over “the interior detail” but evolutionarity, however, offers a clear alternative to the equilibrium doctrine. On the other hand, Potts claims that “the mechanistic paradigm hid from view a fundamental question: what is the nature of order and coordination in a complex system?” According to him this question needs to be answered with the concepts complexity and self-organization. This also leads to the recognition of time as an irreversible process.

Foster and Metcalfe (2001, p. 14) also emphasise the role of self-organisation in evolutionary economics. “Thus evolutionary economic principles must embrace both *economic* self-organization and *economic* competitive selection, if a unified and versatile analytical framework is to be constructed.” This also means that the theory cannot be simply borrowed from biology, but evolution and self-organisation must be studied in their own right within the field of economics.

Evolutionary economics and the study of economic systems as complex adaptive systems share some basic propositions, such as self-organisation, limited and local knowledge, nondeterministic view of the future, and the acknowledgement of time as an irreversible process. In evolutionary economics the evolutionary process is not seen as optimising, but only as increasing the number of fitter than average units in the system. Thus, economic evolution does not lead to any optimal outcome but favours those who are well enough suited to the current selection environment.

4.4 Increasing returns and path dependence

Neoclassical economics is based on the assumption of diminishing returns. Schumpeter (1951, p. 28) describes this phenomenon to consist of two complementing functions. First of all, “the more a particular want is satisfied, the less the intensity of the desire for more in the same line, hence the less the increase in satisfaction to be achieved through further production.” This is often illustrated with the example of coffee consumption. A customer is willing to pay more for the first cup of coffee than for the second cup. The willingness to pay decreases as the amount of coffee sold increases.

Second, “the sacrifice connected with production in this direction also increases simultaneously”. The more coffee is produced the more land must be used for the production. This means that coffee trees must be planted to wider areas which can be not as well suited for coffee trees. This makes the price of production per unit to go up as the amount produced increases. Limited capital to buy the land, coffee trees and equipment must be drawn from other investments, which can be more profitable. “The gain in value from the production in one direction becomes therefore continually smaller, and finally it vanishes. Thus we can speak here of a law of decreasing returns in production.” (Schumpeter 1951, p. 28)

Arthur (1994b, p. 3) states that “the parts of the economy that are resource-based (agriculture, bulk-goods production, mining) are still for the most part subject to diminishing returns”. He, however, opposes this view when it comes to knowledge-based high-technology industries. “The parts of the economy that are knowledge-based, on the other hand, are largely subject to increasing returns.” Increasing returns “appears to be the appropriate theory for understanding modern high-technology economies” (Arthur 1994b, p. 2).

Arthur (1996) claims that the fundamental ideas of economics should be changed in order to depict what is really happening. According to him, “the underlying mechanisms that determine economic behaviour have shifted from ones of diminishing returns to ones of increasing returns.” This means that those who are ahead tend to get further ahead, and those who have lost advantage tend to go on losing advantage. This is a mechanism of positive feedback, which can lead to lock-ins. Increasing returns do not cause the economic system to head towards equilibrium but instability. Increasing returns reign especially in the knowledge-based industries. Arthur lists the properties of increasing returns as follows:

- market instability
- multiple potential outcomes
- unpredictability
- the ability to lock in a market
- the possible predominance of an inferior product
- large profits for the winner.

Arthur (1996, p. 102) gives an example of products which have been subject to increasing returns. In the early 1980s there were three major players in the operating systems market: CP/M, DOS and Apple’s Macintosh. Operating systems are a great example of increasing returns. The one that gets ahead encourages software developers to invest in software development for that operating system making it more attractive for potential buyers. DOS won the battle, not because it would have been superior in performance or usability, but because Microsoft’s software was available early on, thus subjecting the DOS system to increasing returns.

Increasing returns can cause the market to lock in to an inferior product. QWERTY-typewriter keyboard is the classic example (Arthur 1989, p. 126). The organisation of the letters is far from optimal but since people are accustomed to it, it would be hard to change the system. Another example is the US nuclear industry (Arthur 1989, p. 126). Because of learning and construction experience gained in 1950’s military projects the US market is locked by light-water reactors. This is the case although is it widely approved that the gas-cooled reactor would have been superior, given equal development.

When the market is locked-in with an inferior product it is impossible for an evolutionary market process to change the direction of the development to the better product. This phenomenon is called path dependence. It is often described with the phrase “you can’t get there from here”. It was acknowledged by Schumpeter (1951, p. 9) although not with today’s terminology. “Thus the economic system will not change capriciously on its own initiative but will be at all times connected with the preceding state of affairs.” (Schumpeter 1951, p. 9)

According to Cooke (2002, p. 33) neoclassical economic growth theory is based on two key assumptions, both of which have proven problematic. The first is that the production function operates under conditions of diminishing returns. Secondly, constant returns to scale are assumed.

In the new knowledge economy diminishing returns can not be assumed. New knowledge, technology and innovations have the feature of building on to preceding knowledge, technology and innovations. Thus, the more of these are developed the more possibilities there are for further development. In addition, many products have the nature that the more users they have the more useful and valuable they are. This can lead to lock-in situations where the benefits from masses using the same technology and the effort required for adopting a new superior technology overpower the potential advantages related to the new technology. Evolutionary market processes can not steer the situation to the right tracks. However, increasing returns are a source of emergent properties since the positive feedback involved may lead to unpredictable outcomes.

4.5 Solution to the modelling problem based on evolutionary economics

Evolutionary economics is based on the assumption that economic development has evolutionary features. This basically means that variation and selection are major factors in the creation of economic future. However, in the field of evolutionary economics the mechanisms that produce variety and effect selection are different from those that are associated with biological evolution. The greatest difference is conscious choice that people and organisations posses. They can acquire new characteristics, improve their performance and strive to reach their goals. Biological organism will pass their genes on to the next generation without the ability to change them. Thus, economic evolution is not an analogy of biological evolution but must be studied in its own right in order to form new theories and models. The organisation level model based on evolutionary economics is presented in figure 14.

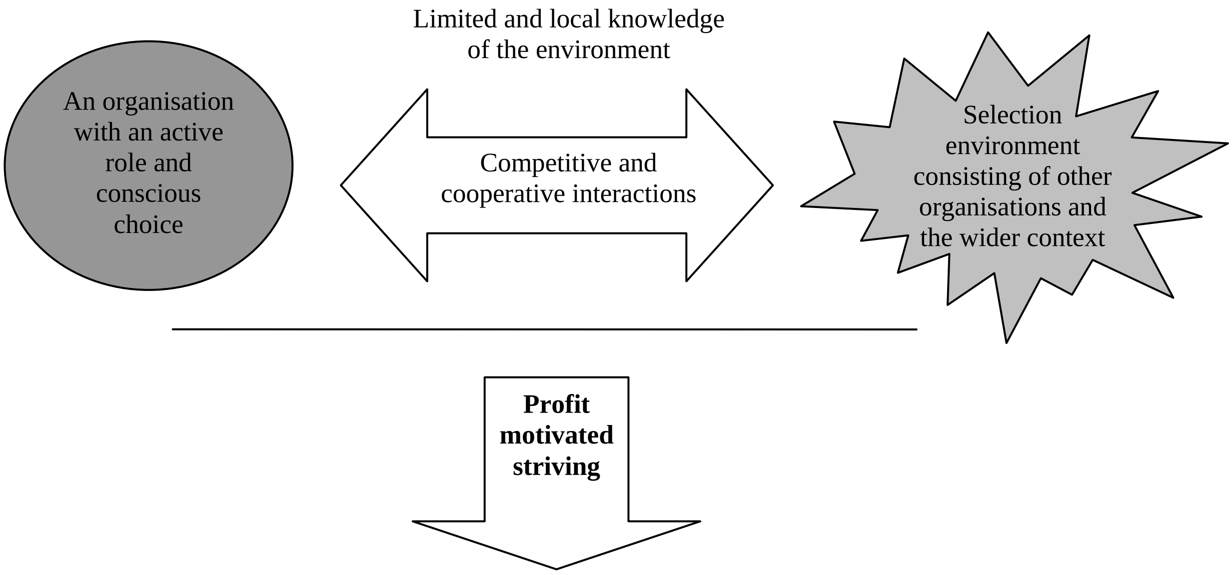

Figure 14. Organisation level model based on evolutionary economics.

An organisation has an active role and is able to make conscious choices. It has limited and local knowledge of its environment. The environment functions as selection environment. In addition to competitive interactions, an organisation may have cooperative interactions with other organisations in its environment. This kind of behaviour leads to profit motivated striving instead of optimisation as the model based on neoclassical economics presented in chapter 2.4 suggests.

When this reasoning is examined at the population level, in addition to variation, selection and development, increasing returns must be mentioned. In the model based on neoclassical economics presented in chapter 2.4 diminishing returns led to equilibrium seeking behaviour. Thus, now that diminishing returns is replaced with increasing returns, no equilibrium state will be achieved. Instead, an organisation population will encounter and construct a nonlinear and unpredictable future.

Variation, selection and development are present in an organisation population and are subject to mutual interaction. Variation, in the form of new organisations, new knowledge and new innovations, is not a product of some random process but results from conscious development efforts. Selection steers variation generation and development processes throughout in such a way that all the three function simultaneously in a reciprocal manner instead of sequential order that is usually presumed in the context of variation and selection. The population level model based on evolutionary economics is presented in figure 15.

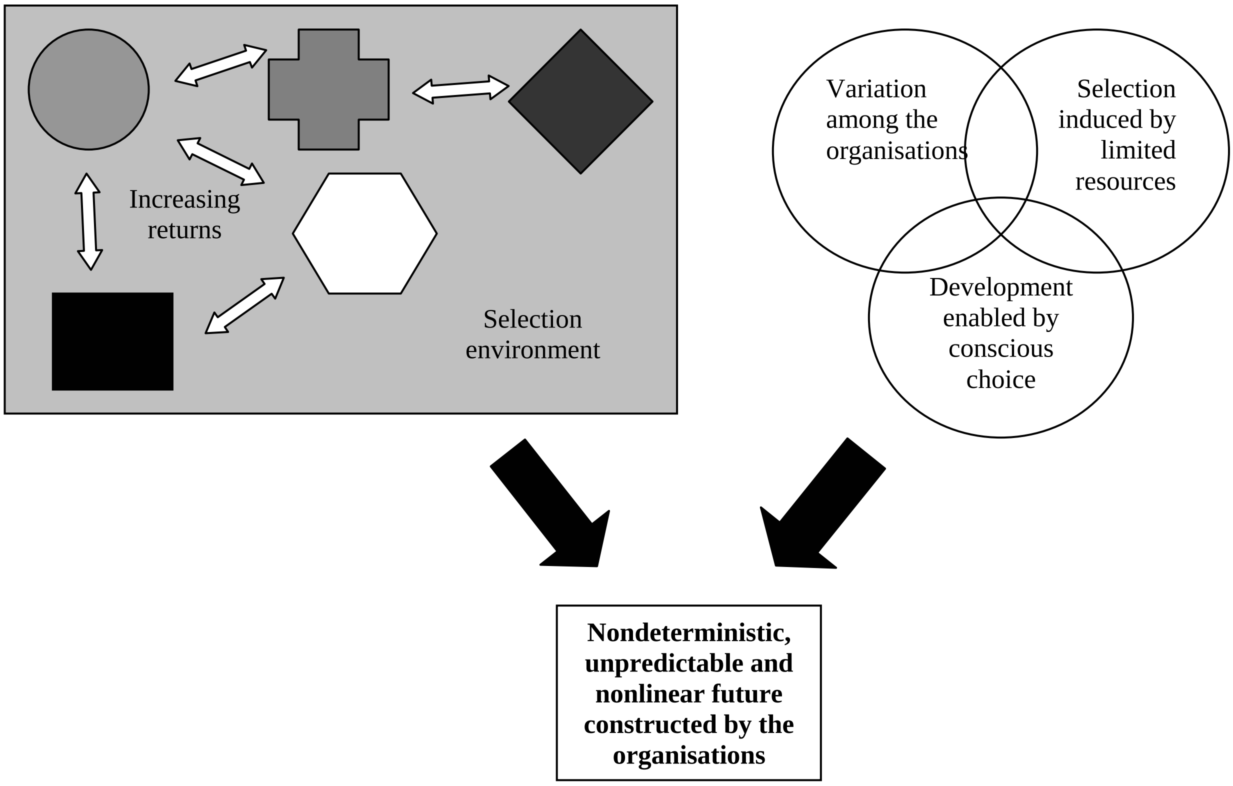

Figure 15. Population level model based on evolutionary economics.

In this model the organisation population constructs its own future through profit motivated striving that is based on limited and local knowledge. Variation, selection and development processes interact which leads to economic evolution. Increasing returns function as positive feedback resulting in surprising population level behaviour. As an outcome the future is nondeterministic, unpredictable and nonlinear.

The criteria for an acceptable organisation population model were presented in chapter 1.4. The organisation level assumptions in this model are conscious choice, limited and local knowledge, competitive and cooperative interactions and profit motivated striving. An organisation has conscious choice, since it can make decisions, affect change in its behaviour and develop new capabilities. An organisation does not simply subject to the selection process but can function based on its own motives. Limited and local knowledge can be assumed since all knowledge can never be possessed by any organisation. Any organisation has both competitors as well as collaborators. As a result an organisation strives as an active actor to make profit based on limited knowledge that it has of its environment.

Population level behaviour consists of variation, selection and development, in addition to increasing returns. Variation is present in any organisation population since there are no two organisations that would be exactly the same. This relates to the fact that organisations consist of people that are all individuals and different from each other. Selection results from scarcity of resources that an organisation faces through market interactions. Development is a sign of conscious choice that the organisations have. Increasing returns are plausible to assume in industries that are not heavily based on physical resources but on knowledge and high technology.

Increasing returns relates also to the role and value that knowledge has in the new knowledge economy. When increasing returns are assumed, growth is limited mainly by the obstacles in the availability of information and not by limitations in physical resources. Knowledge is created in the interaction of existing knowledge and people. Hence the more knowledge exists the more knowledge can be created. The bottleneck is in the communication of this new knowledge to those who can benefit from it. This also means that knowledge can be bought and sold. Thus, this model with increasing returns acknowledges knowledge as an important factor of production and is suitable in the context of knowledge-intensive service organisations.

5 BUSINESS ECOSYSTEM AS AN ORGANISATION POPULATION MODEL

"You don't have to bring complexity to the world of business: It is already there."
(Lewin 1999, p. 200)

Business ecosystem is a new concept that has its roots in biological ecosystem. It draws analogies from nature and studies how these phenomena may be observed in business context. Because of its novelty, the definition of business ecosystem must be formed by drawing ideas from many sources and comparing the concept to cluster and value network. Finally, modelling of an organisation population based on the concept of business ecosystem is discussed. This chapter is partly based on the author's conference paper (Peltoniemi 2004).

5.1 From biological to business ecosystem

Dictionary definition of biological ecosystem goes as follows.

"A system of organisms occupying a habitat, together with those aspects of the physical environment with which they interact"

(The New Shorter Oxford English Dictionary 1993)

"A community of living organisms with air, water and other resources"

(The Merriam-Webster Third New International Dictionary of the English Language 1986)

First of all, a biological ecosystem is a system. It consists of different organisms living on the same area. There is interaction between the organisms and the physical environment, and the environment can address restrictions to the organism. The second definition emphasises the community aspect of biological ecosystem. Physical resources of the environment are an important part of the system.

Hannon (1997, p. 472) claims that economics and ecology have many obviously common features. They both study dynamic, organically-based systems, which have methods of production, exchange, capital stocks and storage. Ecosystems, as well as economic systems, "are not thought to be optimizing anything." According to Hannon (1997, p. 478) an ecosystem net output, called Gross Ecosystem Product or GEP, can be defined and counted as an analogy of GNP of economic systems. GEP can be used as a measure of ecosystem performance since it assesses the mass and energy flows.

According to Lewin (1999, pp. 198-199) there are ecological communities in nature in which species exist as part of a rich network of connections. These communities form local ecosystems which have system level properties. Lewin draws an analogy to business world by explaining that companies, like biological organisms, operate within a rich network of interactions, forming the local economy on a local scale and the global economy on the global scale. He claims that "businesses do not merely *resemble* natural ecosystems; rather, they share some fundamental properties" if one adopts the complexity perspective. Biological ecosystems and economic systems "are complex adaptive systems and thus follow the same deep laws". The biggest distinction between economic and ecological systems is, according to Lewin (1999, pp. 198-199), the ability of people to make conscious decisions, whereas in biological systems there is no conscious intent of that kind. Despite the differences Lewin believes that "an understanding of these laws in nature will lead to a greater understanding of the workings of companies and the economy of which they are a part." (Lewin 1999, pp. 198-199)

Kauffman discusses business ecosystems and defines them as "niches around some kind of activity". When transport was dependent on horse-drawn carriages, there were many complementing businesses such as wheelwrights, blacksmiths, saddleries, wayside inns, and so on. After the automobile came to dominate transport, new kinds of activities formed, such as road paving, gas stations, motels, and so on. In this way the horse-drawn ecosystem was replaced by the automobile ecosystem. In this kind of ecosystem formation co-evolution plays an important role. "The process of co-evolution is producing even more complex economic webs in the world of high technology, with software, hardware, and Internet companies interacting to produce a complex economic web." (Lewin 1999, pp. 206-207)

It should, however, be pointed out that there are differences between natural and business ecosystems. First of all, in business ecosystems the actors are intelligent and are capable of planning and picturing the future with some accuracy. Second, business ecosystems compete over possible members. This kind of behaviour can not be observed in nature. Third, business ecosystems are aiming at delivering innovations, where natural ecosystems are aiming at pure survival. (Iansiti & Levien 2004, 39)

Hannon (1997, p. 480) states that "the ecosystem and the economic system as currently pictured, do differ, but in reconcilable ways." The analogy is not perfect, but it can be useful in understanding economic systems. "When we understand that the economy is an ecosystem – not a machine isolated and insulated from the environment - we grasp fundamental truths about what makes the economy work." (Baden in Lewin 1999, p. 204)

Biological ecosystem and business ecosystem share some fundamental properties such as interaction, interconnectedness and system level behaviour. It is also noted that both kind of systems function organically and not like a machine. In addition, neither biological ecosystem or business ecosystem are optimising anything in their behaviour. In business ecosystem the firms are interpreted to be the equivalents of organisms of biological ecosystem.

5.2 Different ecosystem analogies

Business ecosystem is not the first application of ecosystem thinking outside biology. The term "industrial ecosystem" was introduced by Frosch and Gallopoulos (1989) and has been advanced by Korhonen et al. (2001), for example. The goal of industrial ecosystem analysis is to minimise the input of virgin material and energy in industrial operations. Thus, industrial ecosystem thinking is about environmental protection and sustainable development.

"Economy as an ecosystem" is an analogy built by Rothschild (1990). He states that the key phenomena observed in nature, such as competition, specialisation, co-operation, exploitation, learning and growth, are also central to capitalist economy. The main difference between change in economy and change in nature is speed, which is quite a lot faster within economic change. Rothschild calls his view of economics "bionomics". In Rothschild's analogy firms serve as biological organisms and industries as species. Rothschild's ecosystem, efficiency is rewarded by survival. Inefficiency, on the other hand, is punished by extinction.

"Digital business ecosystem", on the other hand, is a European Union funded project which aims at enhancing the possibilities of European SMEs in software business. Digital business ecosystem consists of "digital species" which occupy a "digital environment". These digital species can be software components, applications, services, knowledge, business models, training modules, conceptual frameworks, and laws. The environment enables species to behave like species in natural world, to interact, evolve and even become extinct. (Nachira 2002)

"Social ecosystem" by Mitleton-Kelly (2003) emphasises the interdependence of organisations in the business world. Organisations co-evolve within a social ecosystem, since co-evolution can not happen in isolation. Social ecosystem, thus, consists of organisations and not of individual people, as the term "social" could imply. Mitleton-Kelly argues that social ecosystem is a complex evolving system.

Thus, the term "ecosystem" has been applied in different fields in social sciences and also in pragmatic business research. Some link it complexity, some only to biology. These ecosystem analogies are further discussed in (Peltoniemi & Vuori 2004).

5.3 Key characteristics of the business ecosystem

The business ecosystem concept has been used by several authors, but it still lacks a precise definition. Some claim it to be just an analogy or metaphor, some do not comment on that. Iansiti and Levien (2004) state that they use business ecosystem as an analogy, which aims at explaining and understanding certain issues of modern business life. "We found that perhaps more than any other type of network, a biological ecosystem provides a powerful analogy for understanding a business network." (Iansiti & Levien 2004, p. 8) This is because biological ecosystems, like business ecosystems, are characterised by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival. According to Iansiti and Levien (2004, p. 9) biological species in ecosystems share their fate with each other the same way that firms in a business ecosystem. "If the ecosystem is healthy, individual species thrive. If the ecosystem is unhealthy, individual species suffer deeply." (Iansiti & Levien 2004, p. 9)

According to Moore (1993, p. 76) members of a business ecosystem "work co-operatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations". Thus, business ecosystems base their success on both competition and cooperation. Lewin (1999, p. 210) states that in a business ecosystem it is challenging to figure out who is a friend and who is an enemy. The difficulty is augmented since this situation changes as the environment changes. Lewin adds that not merely competitive interactions are important in the business ecosystem, but rather the entire complex of interactions. (Lewin 1999, pp. 210-211) According to Iansiti and Levien (2004, p. 35) features of a business ecosystem include both competition and cooperation, but also fragmentation and interconnectedness.

According to Iansiti and Levien (2004, p. 46) there are three critical success factors of a business ecosystem. First, productivity is a very basic factor which, at some point, will define the success of any kind of business. Second, any business ecosystem should be robust. Robustness in natural ecosystems means capabilities of surviving when shocks from inside or outside the ecosystem threaten to destroy it. In business life this means drawing competitive advantage from many sources and having the ability to transform when the environment changes. Third, a business ecosystem should have the ability to create niches and opportunities for new firms. This requires a change in attitudes from protectionist to co-operative.

Business ecosystem rejects both regionality and the concept of industry. Moore (1996) claims that modern communication technology and global competition reduces the importance of geography. Moore (1996, p. 15) also wishes to abandon the concept of industry, since the fast-paced development of technology makes it difficult and fruitless to define such industries.

Lewin points out that although being a part of an interconnected network of companies – the business ecosystem – has benefits, there are also dangers. The benefits include the opportunity to form alliances and thrive in the network, protected from potential invaders. The same interconnectedness, however, also poses the threat of disaster. "When everything is connected directly or indirectly to everything else, changes in one part of the system may be propagated throughout the system, and sometimes organizations may go extinct through no fault of their own." This kind of unpredictability is an unpleasant aspect of complex systems, but it can give a realistic picture of business life. (Lewin 1999, pp. 210-211)

Moore (1996, p. 26) defines business ecosystem as "an economic community supported by a foundation of interacting organizations and individuals --. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders." The idea of business ecosystem is the same as of natural ecosystem. It is a system that can sustain itself without outside interventions.

Business ecosystem can also be defined in terms of landscapes. This kind of thinking originates from Kauffman's (1993) fitness landscape which is a structure picturing fitness of an organism in its environment. Fitness landscape can be thought of as a plane stretched among two axes which depict different factors of fitness, such as speed, agility, endurance or intelligence. This plane can have hills and pits according to different fitness scores associated with different values of fitness factors depicted by the axes. Naturally, there can be more than two axes, but it is easier to think of this structure in only three dimensions. An organism or a population is currently at some point of the fitness landscape, but this can change due to changes of the organism's characteristics or due to changes in the environment. Fitness landscape is, thus, a dynamic structure where the organism favours the peaks.

Although fitness landscape is originally a tool developed in the field of biology for the analysis of biological ecosystems, it has been used also in the context of business ecosystems. Lewin (1999, pp. 207-208) defines business ecosystem as consisting of several companies, each at certain position in its own landscape. These landscapes then are coupled to each other so that changes in one landscape have an affect on other landscapes, those of competitors, collaborators, and complementors.

Iansiti and Levien (2004) introduce four different roles that organisations can take in business ecosystems. Keystones are the kind of companies which serve as the enablers and which have a great impact on the whole system. However, they constitute a small number of the system. Niche players, on the other hand, make up the largest mass of the business ecosystem. Dominators and hub landlords are the kind of organisations which attract resources from the system but do not function reciprocally.

Business ecosystem consists of a large number of participants that can be business firms and other organisations. They are interconnected in a sense that they have an affect on each other. This interconnectedness enables various interactions between the members. These interactions can be both competitive and cooperative. These with interconnectedness lead to shared fate. The members are dependent on each other, and the failures of other actors can result in failures of a certain firm.

The members of a business ecosystem are capable of conscious decisions of their own part. The firms are aiming at innovations and commercial success and hope to take advantage of other members and their capabilities. This is challenging since a business ecosystem is coupled to its environment that may change rapidly and unpredictably. Thus, business ecosystem is fundamentally a dynamic structure that evolves and develops in process of time.

5.5 Comparison of business ecosystem to cluster and value network

Cluster and value network are well-established models in the analysis of an organisation population. They, however, present a limited view to the dynamics and behaviour of such an entity. There are certain assumptions in both of these models that make it questionable to use them in the context of this research. In addition, by defining cluster and value network and by positioning those in relation to business ecosystem will give a deeper view to the concept of business ecosystem.

5.5.1 Cluster

Cluster is a concept introduced by Porter (1990). Clustering is a phenomenon linked to geographic concentrations of national industries which origin from vertical or horisontal relationships between companies. Firms in a cluster are often located in a single town or region within a nation (Porter 1990, p. 154). Other authors have also argued that regionality or locality is a major characteristic of a cluster (see e.g. Arboníes & Moso 2002, Scheel 2002, Andriani 2003, Tallman et al. 2004). According to Porter (1990) the power of a cluster lies in fierce competition within it, which obliges the firms to elevate their standards of performance. Aggressive rivalry is induced by the bargaining power of customers who may be in contact with several firms within the cluster. These connections also encourage the flow of information and diffusion of innovations. (Porter 1990, p. 151) These phenomena can also be termed as spillovers. In addition to rivalry, Arboníes and Moso (2002, p. 347) claim that clusters prosper on the basis of their interaction. Andriani (2003, p. 130) claims that the presence of collective learning and diffused tacit knowledge is descriptive to clusters.

According to Porter (1990, p. 152) developing clusters attract resources away from isolated firms and industries. This is because clusters can exploit these resources more efficiently. Physical proximity of world-class rivals of the same industry acts as the driving force. (Porter 1990, p. 156) The concept of industry is central in the cluster model. It is often taken as a self-evident fact that a cluster is a part or a representative of an industry (see e.g. Dayasindhu 2002, Tallman et al. 2004).

Within a cluster information about “needs, techniques, and technology” flows and is exchanged among buyers, suppliers, and related industries (Porter 1990, p. 152). At the same time, rivalry must be maintained. According to Porter (1990, p. 152), conflicts among buyers, suppliers, and rivals may prevent the flow of information, since each actor may want to keep their information proprietary. Information flow, however, is enhanced by informal ties between employers of different firms. In addition to contacts with other companies, Arboníes and Moso (2002, p. 351) state that universities are important source of knowledge for a cluster. Universities are on the supply side and firms in the demand side. This picture, however, does not take into account the importance of knowledge flow from firms to universities.

Bachtelt et al. (2004, p. 31) discuss spatial clustering of economic activity and its relation to the spatiality of knowledge creation. According to knowledge-based theory of spatial clustering, as they call it, innovation, knowledge creation and learning are results of interactive processes where actors with different types of knowledge come together to solve problems. When knowledge is codified, these processes are less space-sensitive. On the other hand, when the knowledge is tacit the interaction and exchange are dependent on the spatial proximity of the actors. Bachtelt et al. (2004, p. 31), however, criticise this reasoning since it does not take into account that interactions and transactions among firms within a cluster are often fairly limited. They (Bachtelt et al. 2004, p. 36) argue that members of a cluster benefit from their co-location because it allows them to be well informed about the characteristics of their competitors' products and about the quality and costs of their production mechanisms. According to this view, the advantages of proximity do not rise from interaction but from continuous monitoring and comparing.

5.5.2 Value network

According to Mariotti (2002), a value network is "an interactive combination of information machines, and people." Value networks are concentrated in creating value in each node. Fjeldstad and Haanæs (2001, p. 4) claim that value creation in a value network does not lie in transforming objects per se, but in their mediation. The strength of a value network originates from cooperation and interaction among participating companies. According to Haglind & Helander (1998) cooperation is motivated by increased revenue and reduced cost. The customer is the one in charge and other companies organise their activities around it. A company is chosen to be a member of the network because of its unique competencies. (Haglind & Helander 1998, pp. 350-351) There is an active function of choice. Value network is not seen as bound to certain region - it can even be global. The concept of industry is included in the discussion of value networks, but companies inside a value network can be parts of different industries.

Before value network we had value chain. As Turati and Ruta (2002) point out, chain refers to sequential flow while a network implies multidimensional connectedness. The connections stand for movement of products and services, but what is the role of knowledge within these connections? Does it run both ways? Where is knowledge created and does it transform within the network? Haglind and Helander (1998, p. 351) mention what kind of information they think is moving in a value network: economical figures, order quantities, transportation arrival times, quality measurements, and design specifications. In other words, it is operational information which does not have a lot to do with innovation. All information must be available to all its members (Haglind & Helander 1998, p. 351). If that happened, all resources would be tied up to communicating and receiving information. What good would such a huge amount of information do, when there are not enough resources to analyse and exploit it?

5.5.3 Comparison of key features of cluster, value network and business ecosystem

These three models have a lot in common and also quite a lot of differing characteristics. Here five features have been chosen for comparison. First, the importance of geography is discussed. Then, the role of competition and co-operation is analysed. Third, the significance of the concept of industry in each model is assessed. After that, knowledge creation and knowledge transfer issues within each model are discussed. Finally, it is considered who has control or power in each model.

Depending on the author, the basic idea of cluster is either geographic concentration, locality, or regionality. This is seldom questioned although Arboníes and Moso (2002, p. 350) state that nowadays cluster benefits should arise more from cluster thinking than physical realities. In addition, Cooke (2002, p. 127) argues that "it is clearly no use to define clusters in terms of co-location alone as many studies do". Value network and business ecosystem are not based on geographic aspects. Texts about value networks place hardly any emphasis on the issue of locality versus globality. Value network can be global, but it can also be restricted to quite a limited area. Business ecosystem is deliberately rejecting the importance of geography. Because of deregulation and the development of information and communication technology, place has become a far less important determinant of success. Place has not lost its meaning, but its importance has been reduced. What a couple of decades ago would have been considered as 'international' can now be stated as 'local'. Steinbock (2003, p. 207) states that advantage should not be based on geographic but on strategic realities. Tallman et al. (2004, p. 259) are wondering whether geography even matters anymore.

The emphasis placed on competition and co-operation differs in these three models. Cluster's success is based on fierce rivalry within the cluster. Some authors, however, acknowledge the role of cooperation in a cluster setting. According to Cooke (2002) "clusters are characterized by cooperative and competitive, trustful and rivalrous, exchange and favour-based business interactions". Value network, on the other hand, is quite strictly a co-operative structure. Each member has its tasks which are strictly defined and members are usually not competing with each other. However, there is competition when the members of a value network are chosen. Business ecosystem induces both competition and co-operation. In a capitalistic economy competition is always present, and possible methods of co-operation are strictly dictated by the law. Competition has its benefits in accelerating research and development, but it can also cause wasteful usage of resources. This can be prevented with co-operation.

The concept of industry has a significant role in texts about clusters. Porter (1990, p. 149) mentions clustering of industries as well as clustering of firms. Industry is a self-evident tool in analysing clusters. Members of a value network can be seen as parts of different industries. The whole idea of value network arises from the notion that a single firm cannot produce the whole product by itself and needs other firms with different capabilities to complement the product. Business ecosystem rejects the concept of industry. Moore (1996, p. 13) argues that industry is no longer a useful concept in contemplating business. Moore even suggests that the term ‘industry’ should be replaced with the term ‘business ecosystem’. Iansiti and Levien (2004), on the other hand, use the term ‘industry’ in their text about business ecosystem, but do not undertake a thorough analysis about it.

Knowledge creation and knowledge transfer issues are treated quite differently in these three models. Fierce rivalry within a cluster limits the willingness to share knowledge and create it co-operatively. However, ‘local buzz’ is quite often seen as a major benefit of co-location. Local buzz does not necessarily mean efficient knowledge transfer, but monitoring changes in the environment and answering to those aggressively. Bachtelt et al. (2004, p. 40) think that undirected, spontaneous local broadcasting may have its own benefits, but the role of intentional knowledge transfer through ‘network pipelines’ should not be underestimated. In value network shared knowledge can be limited to operative information, such as order quantities. Development of new products, however, requires co-operation and joint effort. Iansiti and Levien (2004, p. 18) stress that interconnectedness and shared fate are key elements of a business ecosystem. Interconnectedness can be seen as enabler and shared fate as motivator of knowledge sharing and co-operative knowledge creation.

The question ‘Who has control?’ can be answered in many ways. It depends on the power of negotiation that each member has. In a cluster there need not be any control at all, since the members are fairly independent of each other. In a case of joint technology development, for example, the control can be divided unevenly according to the market power that each member has. In a value network it is common that one actor is quite a lot larger than the others. Then, small suppliers that can be completely dependent on the dominant actor and must submit to its terms. In a business ecosystem control is decentralised. Although Moore (1996) claims that in each ecosystem there is a large dominant actor, so-called keystone species, it cannot dictate the terms to the extent that the leader of a value network can.

Table 2. Comparison of the key features of cluster, value network and business ecosystem.

	Cluster	**Value network**	**Business ecosystem**
Geography	Geographic concentration	Anything from local to global	Rejects the role of geography
Competition and cooperation	Fierce rivalry	Cooperation	Both simultaneously
Industry	Firms represent the same industry	Different industries complement each other	Finds the term “industry” obsolete
Knowledge	Rivalry limits the willingness to share	Limited to operative information	Interconnectedness as the enabler and shared fate as the motivator of cooperation
Control	Members fairly independent	One powerful actor	Decentralised decision making

Also other features could have been analysed. For example, whether a model is static or dynamic, modelled with agent-based simulations or differential equations are important issues. However, these features can not be included in the definitions of the models, since they are dependent on the analyser's methodology and point of view.

5.4 Business ecosystem as an organisation population model

Business ecosystem is a concept that depicts an organisation population as an interconnected and interdependent entity. In figure 16, the shape of a business ecosystem is presented. The circles, squares and triangles represent different actors of the business ecosystem. The arrows describe interactions between the actors, one-ended signifying competitive interactions and double-ended cooperative interactions. The explosion shape represents the business ecosystem, and the difficulty to define its borders. The grey area depicts the environment of the business ecosystem.

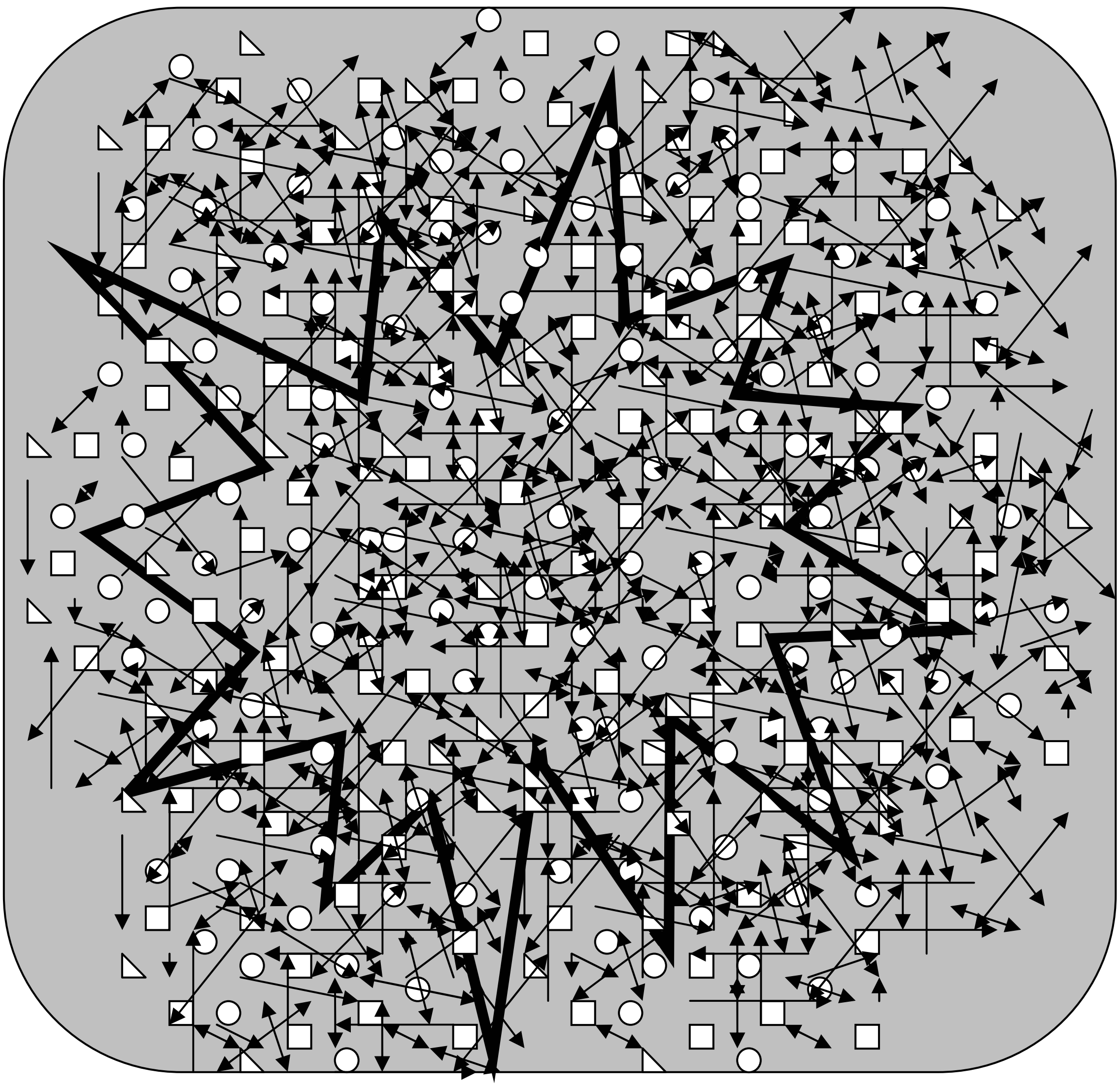

Figure 16. A presentation of the shape of a business ecosystem.

In a business ecosystem the members are different from each other and thus exactly similar logic in their functioning can not be assumed. Among the organisations there is both competition and cooperation present. These can be present between the same organisations at different times or simultaneously. For example, two companies can cooperate by developing a technology together but compete by selling products that perform the same tasks.

A business ecosystem is hard to outline since the interactions between organisations do not suddenly stop at some border. The solution is to examine thoroughly which actors are important and clearly interconnected in a way that they can be interpreted as a part of a certain entity. An important aspect of that entity is the environment that the business ecosystem is coupled with. Since the environment is subject to change, as well as the business ecosystem is, the whole presents dynamics that may be unpredictable. Characteristics of business ecosystem are presented in figure 17.

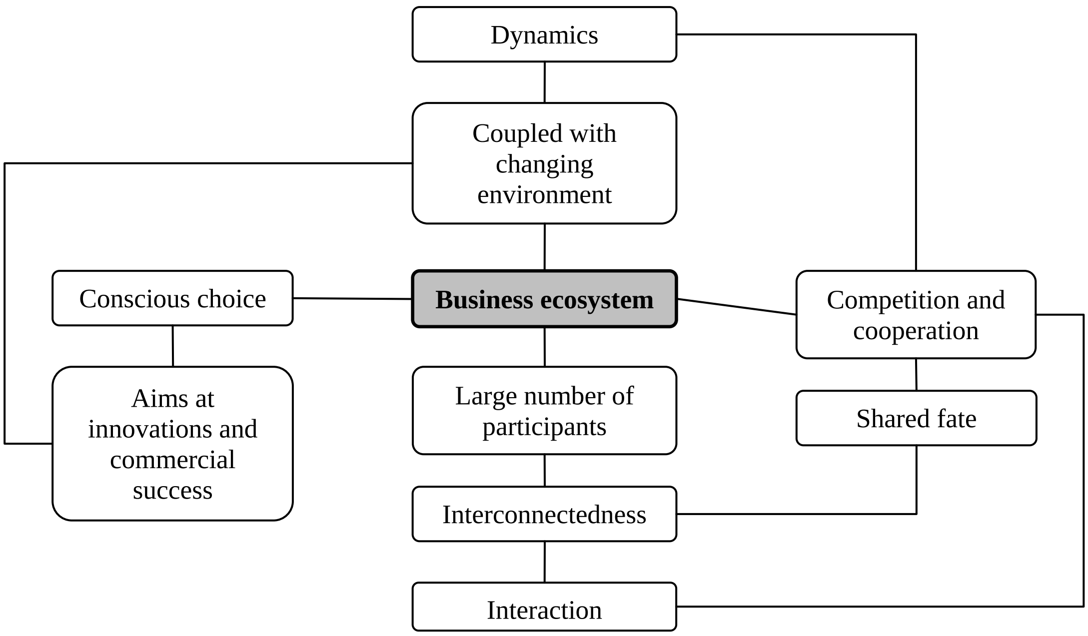

Figure 17. Characteristics of business ecosystem.

At the organisation level business ecosystem assumes conscious choice in such a way that the members aim at delivering innovations and reaching commercial success. Interconnectedness with other organisations and the environment is also an important assumption. This basically means that an organisation can aim at certain directions, but since it has an affect on other organisations and other organisations have an affect on it, not everything is possible for the organisation. This is plausible in a sense that every organisation has goals and strives to reach them but other organisations may prevent or enable their operation. This is also related to the competitive and cooperative interactions that organisations in a business ecosystem may have.

At the population level interconnectedness leads to shared fate in a sense that failure or success of one organisation may echo through the whole system. Competition and cooperation, in addition to changing environment, lead to unpredictable dynamics. Here, business ecosystem is defined to consist of organisations that can be both business firms and public sector organisations. The environment consists of things like inflation, interest levels, weather conditions, pollution and other business ecosystems, with which the members of the business ecosystem may interact with but are not active members of that entity. The interaction between a business ecosystem and its environment is a source of unpredictable dynamics. This kind of a picture about population level behaviour can be stated as realistic since it is quite a flexible framework and can incorporate many types of behaviour by the organisations.

The role of knowledge in business ecosystem is not explicit. However, something may be reasoned based on the dynamics that it incorporates. Since business ecosystem assumes constant change there must be triggers to and realisers of that change. At the level of an individual organisation conscious choice implies that an organisation may effect change based on triggers that it receives. These triggers fundamentally constitute of knowledge. In addition, the realisation of cooperation as a meaningful function relates to the role of knowledge. In cooperation knowledge and capabilities may be combined in order to reach commercial success with some idea. These thoughts would indicate that business ecosystem acknowledges knowledge as an important factor of production and is thus appropriate in the context of knowledge-intensive service firms.

6 CONCLUSIONS

In this chapter the integrated organisation population model is constructed based on concepts from complexity, evolutionary economics and business ecosystem framework. It is evaluated based on the criteria presented in chapter 1.4. The whole research process is evaluated and some recommendations for future research are presented.

6.1 Integrated organisation population model

In this report the organisation population modelling problem has been approached with the ideas from complexity, evolutionary economics and business ecosystem. These have been chosen since they share some fundamental propositions and also constitute an opposing force to neoclassical economics that would have been the mainstream solution for analysing the behaviour and development of an organisation population. Neoclassical economics is rejected here because the assumptions of perfect knowledge, rationality, optimisation, equilibrium-seeking behaviour and diminishing returns are found implausible in the new knowledge-based economy. Especially the assumption of perfect knowledge does not fit with the notion of the great importance that knowledge has as a factor of production and as a determinator of commercial success. This is important in this study because the role of knowledge-intensive services, whose products essentially consist of knowledge, is assumed to be decisive in an organisation population that develops and produces high technology products.

At the organisation level complexity suggests that an individual organisation evolves, in addition to change triggered by the organisation's motives and inner logic, through co-evolution with other organisations. Thus, changes and decisions of an organisation can trigger changes and decisions in other organisations. This way the organisations are constantly monitoring their environment and reacting to knowledge that they receive. Co-evolution is enabled by feedback loops that carry the triggers in a way that a move made by an organisation induces others to make their moves which induces the original organisation to make a second move and so on in an endless reciprocal cycle. An important enabler of co-evolution is interconnectedness of the organisations. Thus, they can receive information and knowledge of each other and can have an effect on each other through market interactions.

In evolutionary economics it is emphasised that an organisation has conscious choice and is capable of making decisions based on available knowledge. This basically differentiates economic evolution from biological evolution since biological organisms aim at pure survival where business organisations aim at developing innovations and reaching commercial success. The proposition of conscious choice in evolutionary economics differentiates from the proposition of rationality in neoclassical economics in the definition of available knowledge. Neoclassical economics assumes perfect knowledge which together with rationality leads to optimisation. Evolutionary economics assumes limited and local knowledge which with conscious choice leads to profit motivated striving.

In evolutionary economics variation and selection are at a central position. However, they are not understood in pure Darwinist sense since conscious choice steers the process at all times. Firms are not simply wiped out from the market because their capabilities do not happen to give them an edge in current selection environment. Firms can develop their own capabilities and aim their contribution to what they believe will pay off. Firms do not passively stand still as the environment changes. This, of course, applies to all organisations in a population. This is how the environment, consisting of other organisations and the wider context, enforces selective pressure on an organisation and an organisation also constitutes a part of the selective pressure that is enforced on other organisations.

The business ecosystem concept emphasises the interconnectedness of a large number of organisations that all are different from each other. There are both competitive and cooperative interactions between the organisations. It can also be the case that two organisations are at the same time both competing and cooperating. Thus, the whole variety of interactions is an essential part of the behaviour and development of a business ecosystem. The integrated organisation population model at the organisation level is presented in figure18.

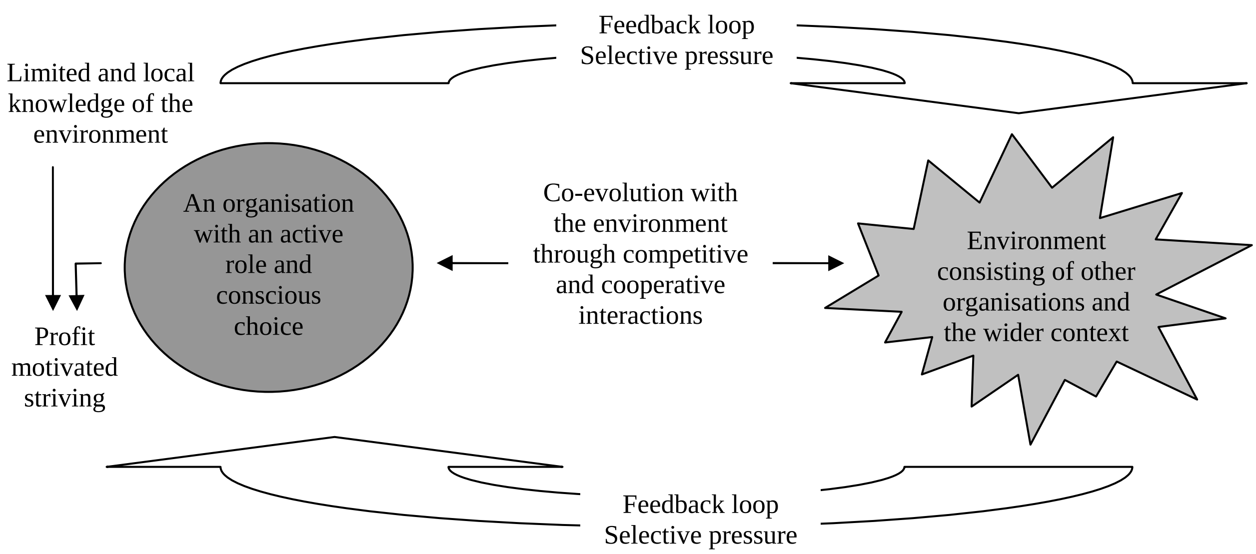

Figure 18. Integrated organisation population model at the organisation level.

At the population level complexity suggests that an organisation population develops through co-evolution, self-organisation, emergence and adaptation. Organisation level co-evolution spreads through the population and the entity develops through both sequential and reciprocal dynamics. Co-evolution can be competitive, mutualistic or exploitative. Competitive co-evolution happens among competing organisations whereas mutualistic co-evolution takes place among cooperating companies. Exploitative co-evolution, on the other hand, happens when one organisation has a considerably stronger position than the others and can dictate the terms that other organisations must submit to.

On the other hand, an organisation population is a self-organising system. Self-organisation relates to decentralised decision making. In an organisation population each organisation can make its own decisions, although those decisions may be constrained by other organisations, in such a way that there is no inside or outside controller. In market system economies the market functions as enabler of self-organisation. In any market economy, however, there are countless of government interventions such as business subsidies, import duties and publicly funded development projects. These can be seen as inhibiting or enabling self-organisation.

Emergence is a phenomenon that origins from organisation level motives that lead to surprising population level behaviour. An organisation's motives cause it to behave in a certain way. The objective may be to increase market share and a firm might decide to lower its prices in order to reach that goal. This will trigger the competitors to lower their prices which will in turn induce the original company to lower its prices even further. At the population level this leads to lower prices and lower profits in the industry although the aim of an individual organisation was to increase its market share. Adaptation is here interpreted as the sum of co-evolution, self-organisation and emergence. Because these three phenomena are present the organisation population is able to adapt.

Evolutionary economics finds that population level phenomena can be observed as the interplay of variation, selection and development. In order to have meaningful selection variation must be present in the population. However, the creation of variation through the formation of new organisations and delivering new innovations is subject to conscious choice in the form of development. Nor are the selection mechanisms resulting from pure random events. These three, variation, selection and development, function in reciprocal interaction and not in a sequential manner as variation and selection are often thought to operate.

An important factor in the evolutionary framework is the notion of increasing returns. Neoclassical economics assumes that in every industry production operates under diminishing returns. Thus, the more you produce the less profit you will make per unit. Increasing returns, however, acknowledges that there are products that get more useful the more users they have. This is clearly a case of increasing returns since the more you are able to sell the more people will want to buy your product. In the context of knowledge-intensive services increasing returns is a plausible assumption since current knowledge is an essential ingredient of new knowledge. Knowledge is created in the interaction of existing knowledge and creative people. Thus, the more knowledge is available the more knowledge can be created.

Within the business ecosystem framework interconnectedness leads to interdependence that exists in the form of shared fate. The success of an organisation can echo through the whole business ecosystem, but it can also happen that the failure of an organisation drags down others. Hence, the environment can effect restrictions and difficulties on an organisation in a sense that not everything is possible for the organisation through profit motivated striving.

This kind of picture about the behaviour and development of an organisation population leads to the notion that the organisations construct their own future that is nonlinear, nondeterministic and unpredictable. Random events also have a role in this picture but the organisations and the people that they consist of have an active role, not an optimising one though, in the development of the organisation population. The integrated organisation population model at the population level is presented in figure 19.

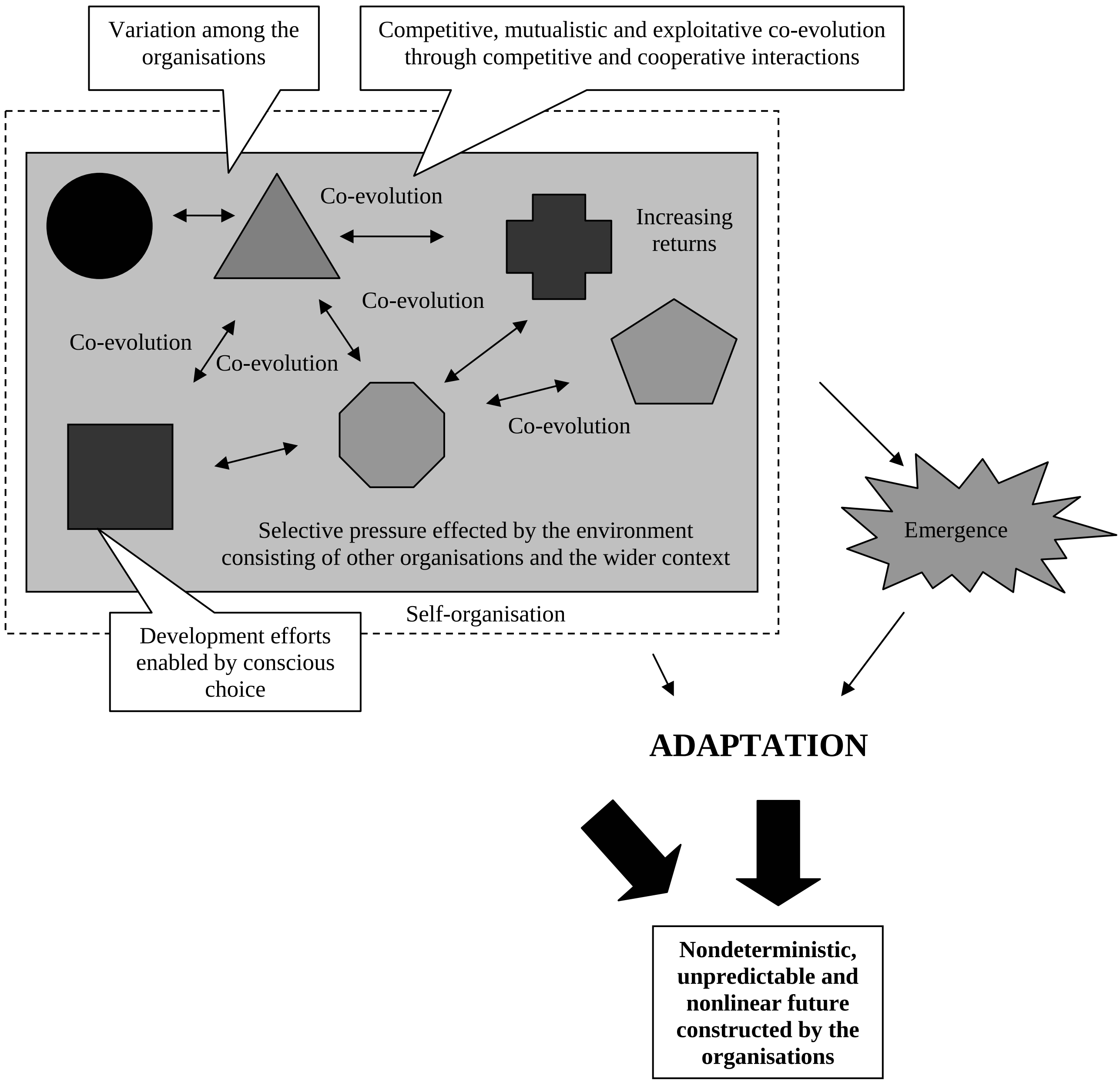

Figure 19. Integrated organisation population model at the population level.

There are several overlapping concepts in these conceptual models. For example, emergence and self-organisation can not be separated and treated as independent phenomena. They work in a reciprocal cycle where it can not be determined which one causes which. Emergent properties can be a product of self-organisation, but self-organisation can also emerge bottom-up.

Feedback and co-evolution describe different aspects of the same phenomena. One can say that feedback enables co-evolution. Co-evolution is essentially about triggers that travel through the population and cause new triggers to be sent. This is how each organisation's actions at some point will be echoed by the other organisations back to it.

Also, positive feedback and increasing returns propose the same kind of behaviour, increasing returns being positive feedback related to production and profits. Increasing returns proposes that the more you produce the more profit per unit you will make. Buying a product that is subject to increasing returns will accelerate the buying pattern since the more products are sold he more people are interested in buying one. Thus, the buying pattern feeds back in a positive way causing success for some, and in a negative way, failure to others who do not manage to reach some critical level of sales that would accelerate the system into increasing returns.

Selective pressure can also be interpreted as a form of feedback since an organisation faces selective pressure on behalf of the other organisations but also constitute a part of the selective pressure that other organisations encounter. Thus selective pressure that an organisation encounters will shape its future efforts which in turn will shape a part of the selective pressure encountered by other organisations. This clearly forms a reciprocal cycle that has a feedback aspect.

Feedback seems to be tangled up with most of the phenomena discussed in this report. Feedback is caused by interconnectedness of the organisations. Thus, because of the interconnectedness the organisations can have an effect on each other and interconnectedness can also make them dependent on each other. In figure 20 the links between the concepts of the integrated organisation population model are presented.

In addition to interconnectedness and feedback related to it, conscious choice plays a major role in the behaviour and development of an organisation population. Conscious choice enables development efforts associated with the creation of variation and selection environment. Without it, variation and selection would be subject to mere random events. Conscious choice also enables meaningful co-evolution, since without it organisations would be purely reacting to triggers from the outside. However, the power of co-evolution lies in each organisations power to decide how to react to the triggers. Conscious choice enables the organisation to think with a longer perspective, to integrate new knowledge with the old knowledge, to try to guess a competitor's next move, to create tactics and even to try to cheat.

Emergence and self-organisation are products of decentralised decision making in a sense that the system is more than the sum of its parts. If the system would be directed from the outside there would be no need for conscious choice since the decisions would be made for the organisations. Then the emergent properties would also be lesser since there would be no reciprocal and sequential mechanisms creating them. This would seriously hinder the organisation population's abilities to adapt.

Increasing returns is related to conscious choice from the point of view of both the seller and the buyer. The seller strives to make his product the kind that will be subjected to increasing returns. The buyer makes a conscious choice buying it when it has become clear that the benefits of the product surpass its cost. The amount of actors making this decision determines on its part the amount of actors that will make this decision in the future. Thus, actors react to other actors' decisions. However, conscious choice has an important role in this process, since the actors make their decisions to buy at different times. Hence they have different preferences and different decision criteria in the decision making process. If there would be no conscious choice this kind of recursive process would not be possible since the first buyer, who could imagine the benefit of the product with future masses of users but could not base the decision on anything else but the current situation, would never make the buying decision.

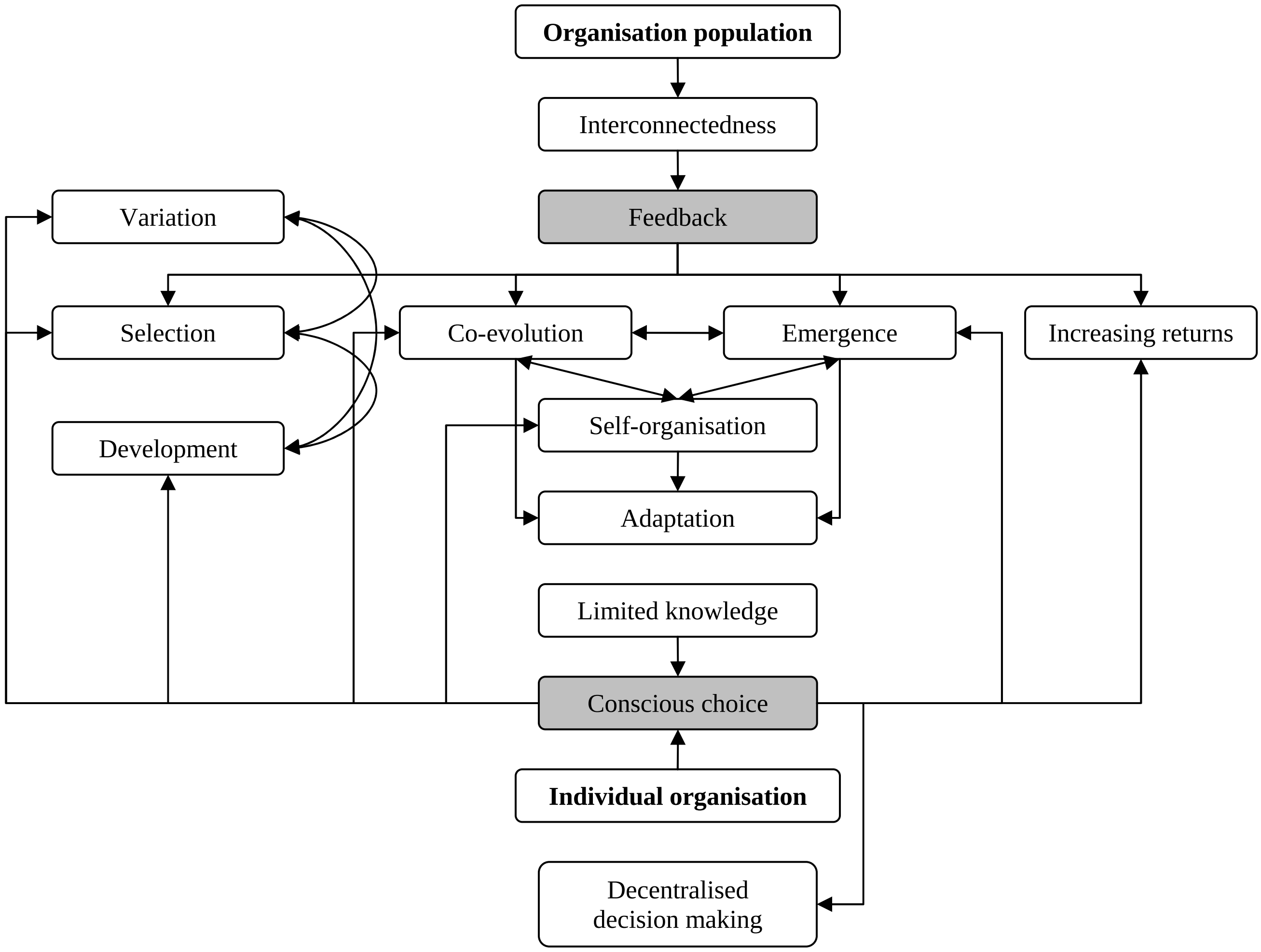

Figure 20. Links between the concepts of the integrated organisation population model.

In chapter 1.4 it was stated that the conceptual model to be built should be based on realistic assumptions at the level of individual organisation as well as at the level of an organisation population. In addition it was required that the model would see knowledge as an important factor of production and thus be suitable for analysing populations that knowledge-intensive service firms are an important part of.

The model is built on the assumptions that there is no perfect knowledge and no perfect rationality. It is, however, assumed that the organisations have conscious choice. In addition, it is assumed that the organisations are interconnected and thus form an entity that is a meaningful research object. The model proposes that the behaviour and development of an organisation population is a result of each organisation’s decisions and actions, and can be surprising and even irrational at times.

Knowledge is seen as limited and local in such a way that no organisation can have perfect knowledge. This reasoning acknowledges that knowledge can be an important factor of production. This is highlighted in knowledge-intensive services whose product knowledge essentially is. Aspects of feedback discussed earlier in this chapter also have knowledge as an important ingredient. Knowledge is also a factor in the interplay of variation, selection and development. Development efforts are guided by knowledge to a great extent.

In the author’s opinion these assumptions are realistic in the context of an organisation population that knowledge-intensive service firms are an important part of. The role of knowledge is also clearly acknowledged. It must be remembered that a model is always a simplified representation of some aspects of reality. Thus, a model can never be perfect in a sense that it would include all possible factors and phenomena. Since this model is based on ideas from complexity, evolutionary economics and business ecosystem, it includes factors and phenomena that are defined to be important in these fields.

6.2 Evaluation of the study

The aim of this study was to find a suitable theoretical framework for the author’s empirical research to be conducted later within the TIP research programme. Theories from the fields of complexity, evolutionary economics and business ecosystem have been reviewed extensively and thus the theory base for future empirical research has been constructed. Thus, this research has reached its objective well.

The research problem was stated in the beginning as follows.

How can the behaviour and development of an organisation population, of which knowledge-intensive service firms form a part, be modelled at the conceptual level?

The solution – the conceptual model constructed in this research report - was subjected to criteria that constitutes of

1. realistic assumptions concerning the behaviour of individual organisation
2. realistic assumptions concerning the behaviour of an organisation population which is induced by organisation level behaviour
3. acknowledgement of knowledge as an important factor of production
4. suitability of the framework for analysing knowledge-intensive service industry.

The research problem has been solved with an interdisciplinary approach. This poses challenges but it also enables opportunities that a strictly constricted approach could not have offered. Among the borders of different fields new kind of thinking can emerge. However, this kind of combination can also lead to misguided interpretations.

This study has been explorative in nature and limited to findings in literature, journal articles and conference papers. Exploration is a problematic research method since it can not be guaranteed that all relevant material has been found and used. All relevant areas are most probably not covered, since this exploration has been conducted in a heuristic manner. Some findings have triggered search in some other sources. For example, organisation ecology, which has not been covered in this study, could have given useful insights for understanding populations and their behaviour.

However, the conceptual model constructed in this research is plausible according to the criteria set for it. The conceptual model includes a multitude of concepts. Some of them overlap and can not be strictly defined as individual phenomena. Probably in future empirical research these concepts will be eliminated and some will be more important than others. Future research will show whether analysis based on this model will contribute to both academic and managerial fields.

In this research a number of concepts from natural sciences have been brought to economic or business context. This is something which must be done with great care. The suitability of these concepts can not be assessed until they have been used in empirical research in real life. Some authors have, however, assessed the suitability of analogies from different fields in general.

The usage of analogies or metaphors and bringing concepts from different fields can be beneficial when new kind of thinking is required. Hodgson (1994, p. 24) states that "the appropriation of ideas from biology portends considerable improvement for economic science". This is because he believes that real world economic phenomena "have much more in common with biological organisms and processes than with the mechanistic world of billiard balls and planets". Thus, economic principles should not be drawn from Newtonian physics concentrating on equilibrium and predictability, but from evolutionary biology.

Despite all the problems and dangers, Hodgson (1994, p. 32) suggests that "modern biology provides a rich source of ideas and approaches from which the new economics can draw". He also claims that complexity, tangled structures and causalities, continuous change and huge variety are present in both economic and biological systems. These issues have been faced up to by biologists but not by economists. “The adoption of biological metaphors may help to redress the balance.” (Hodgson 1994, p. 32)

There are, however, also those who think that the usage of analogies from biology has gotten out of hand. Foster (2000, p. 317, 324) claims that in the field of evolutionary economics old-fashioned biological analogies are still widely used. He states that Darwinian or Lamarckian natural selection analogies should not be used in evolutionary economics. This is because self-organisation is an important aspect of modern theory of biological evolution, and also because evolution does not function the same way in biological and economic systems.

Foster (1997, p. 430) argues that “the unique character of economic evolution lies in its *distinctiveness* from biological evolution”. This distinctiveness is not in competition but “in the creative and co-operative dimensions of human behaviour in the economic domain”. Foster (1997, p. 430) emphasises that “an economic process may sometimes appear to operate 'like' a biological one but it is inappropriate to then model such a process 'as if' it is essentially biological”. On the other hand, analogies can be beneficial in the preliminary stages of research and also as illustrative devices in argumentation. (Foster 1997, p. 448) Hannon (1997, p. 471) states that “analogy is mother to creativity”.

According to Foster and Metcalfe (2001, p. 3) the new complexity science offers a possibility to find analytical principles in social science contexts. They, however, emphasise that this is not a matter of analogy, “since both self-organization and selection operate differently in different kinds of systems”. Mitleton-Kelly (2003, p. 25) states that it is possible “to examine the generic characteristics of natural complex systems and to consider whether they are *relevant or appropriate to social systems*”. But this approach is limiting and can only serve as a starting point. Mitleton-Kelly argues that “social systems need to be studied in their own right” and not as an analogy of natural systems.

Mitleton-Kelly (2003, p. 26), however, states that analogies and metaphors may be used as ‘transitional objects’ in order help the transition in thinking when faced with new concepts and ideas. “The point being emphasised, is that using metaphor and analogy is not the *only* avenue available to us in understanding complexity in an organizational or broader social context”. That means that there is an extensive amount of research to be done in order to fully understand social and economic complex systems.

Thus, analogy can benefit research as a tool for changing thinking form well established traditional ways to new and creative. But academic research can not be based on pure analogy. The new features and phenomena must be found in the research object and they must be researched in their own right and not as mere analogies from other fields. Also, differences in those features and phenomena must be explicitly mentioned. Hence the difference between a system functioning like a system from another field and a system being somewhat similar to a system from another field must be maintained. Analogies can induce new kind of thinking but that thinking must be in line with the behaviour of the actual system under study.

6.3 Suggestions for future research

The study of socio-economic systems as complex adaptive systems is still in the beginning. The mainstream of such research is purely conceptual concentrating on defining concepts and their relationships. Some have moved on to descriptive empirical research where they identify phenomena associated with complexity in real life socio-economic systems. But what is required is the kind of research that can give normative suggestions of what should be done in order to enable the development of a complex socio-economic system. There is a clear gap in research in this direction. It is possible that the novelty of complexity concepts in economic or business context inhibits their empirical application and it is only a matter of time that this kind of research will emerge. It is also possible that the empirical application of complexity concepts within economic or business contexts is so difficult that research efforts have so far mostly failed. However, this kind of empirical application of complexity concepts in normative research would be an object of enormous interest.

REFERENCES

Agiza, H.N., Elettreby, M.F. & Ahmed, E. 1997. On a generalized model of biological evolution. Journal of Statistical Physics. Vol. 88(3/4), pp. 985-989.

Anderson, P. 1999. Complexity theory and organization science. Organization Science. Vol. 10(3), pp. 216-232.

Andriani, P. 2003. Evolutionary dynamics of industrial clusters. In Mitleton-Kelly, E. (eds.) Complex Systems and Evolutionary Perspectives on Organizations: The Application of Complexity Theory to Organizations. Pergamon. pp. 127-145.

Arboníes, A.L. & Moso, M. 2002. Basque country: the knowledge cluster. Journal of Knowledge Management. Vol. 6(4), pp. 347-355.

Arthur, W.B. 1989. Competing technologies, increasing returns, and lock-in by historical events. The Economic Journal. Vol. 99(394), pp. 116-131.

Arthur, W.B. 1994a. On the evolution of complexity. In Cowan, G.A., Pines, D. & Meltzer, D. (eds.) Complexity: Metaphors, Models, and Reality. Westview, pp. 65-81.

Arthur, W.B. 1994b. Increasing Returns and path Dependency in the Economy. The University of Michigan Press.

Arthur, W.B. 1996. Increasing returns and the new world of business. Harvard Business Review. Vol. 74(4), pp.100-109.

Atay, F.A. & Jost, J. 2003. On the emergence of complex systems on the basis of the coordination of complex behaviors of their elements. SFI working paper. http://www.santafe.edu/research/publications/wpabstract/200402005

Babaoglu, O., Meling, H. & Montresor, A. 2002. Anthill: a framework for the development of agent-based peer-to-peer systems. Distributed Computing Systems, 2002. Proceedings. 22nd International Conference on 2-5 July 2002. pp. 15 – 22.

Bachtelt, H., Malmberg, A. & Maskell, P. 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Progress of Human Geography. Vol. 28(1), pp. 31-56.

Bechtold, B.L. 1997. Chaos theory as a model for strategy development. Empowerment in Organizations. Vol. 5(4), pp. 193-201.

Choi, T.Y., Dooley, K.J. & Rungtusanatham, M. 2001. Supply networks and complex adaptive systems: control versus emergence. Journal of Operations Management. Vol. 19(3), pp. 351-366.

Clippinger, J.H.III. 1999. Order from the bottom up: complex adaptive systems and their management. In Clippinger, J.H.III (eds.) The Biology of Business: Decoding the Natural Laws of Enterprise. Jossey-Bass Publishers. pp. 1-30.

Cooke, P. 2002. Knowledge Economies: Clusters, Learning and Cooperative Advantage. Routledge, London.

Darwin, C. 1998 (originally published in 1856). The Origin of Species. Wordsworth editions limited.

Dayasindhu, N. 2002. Embeddedness, knowledge transfer, industry clusters and global competitivness: a case study of the Indian software industry. Technovation. Vol. 22, pp. 551-560.

Dosi, G., Nelson, R.R. & Winter, S.G. 2000 Introduction: The nature and dynamics of organizational capabilities. In Dosi, G., Nelson, R.R. & Winter, S.G. (eds.) The Nature and Dynamics of Organizational Capabilities. Oxford University Press. pp.1-22.

Dyson, E. 1999. Foreword. In Clippinger, J.H.III (eds.) The Biology of Business: Decoding the Natural Laws of Enterprise. Jossey-Bass Publishers. pp. xi-xvi.

Fjeldstad, Ø. & Haanæs, K. 2001. Strategy tradeoffs in the knowledge and network economy. Business Strategy Review. Vol. 12(1), pp. 1-10.

Flake, G.W. 1998. The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation. Cambridge, Bradford Book.

Foster, J. 1997. The analytical foundations of evolutionary economics: From biological analogy to economic self-organization. Structural Change and Economic Dynamics. Vol. 8(4), pp. 427-451.

Foster, J. 2000. Competitive selection, self-organisation and Joseph A. Schumpeter. Journal of Evolutionary Economics. Vol. 10(3), pp. 311-328.

Foster, J. 2004. Why is economics not a complex systems science? A paper presented at the Conference "Organisations, Innovation and Complexity: New Perspectives on the Knowledge Economy", University of Manchester, 9-10th September 2004. NEXSUS, The Complexity Society and CRIC Centre for Research on Innovation and Competition.

Foster, J. & Metcalfe, J.S. 2001. Modern evolutionary economic perspectives: an overview. In Foster, J. & Metcalfe, J.S. (eds.) Frontiers of Evolutionary Economics: Competition, Self-Organization and Innovation Policy. Edvard Elgar, pp.1-16.

Foxon, T.J. 2004. Innovation systems as the setting for the co-evolution of technologies and institutions. A paper presented at the Conference "Organisations, Innovation and Complexity: New Perspectives on the Knowledge Economy", University of Manchester, 9-10th September 2004. NEXSUS, The Complexity Society and CRIC Centre for Research on Innovation and Competition.

Frosch, R.A. & Gallopoulos, N.E. 1989. Strategies for Manufacturing. Scientific American. Vol. 261(3), pp. 144-152.

Fuller, T. & Moran, P. 2001. Small enterprises as complex adaptive systems: A methodological question? Entrepreneurship & Regional Development. Vol. 13(1), pp. 47-63.

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy. Vol. 31, pp. 1257–1274.

Goulielmos, A.M. 2002. Complexity theory applied to management of shipping companies. Maritime Policy Management. Vol. 29(4), pp. 375-391.

Gummesson, E. 2004. Many-to-many marketing: marketing in the new economy. A presentation given at eBusiness Research Forum, Tampere, Finland, September 20-22, 2004.

Haglind, M. & Helander, J. 1998. Development of value networks – an empirical study of networking in Swedish manufacturing industries. IEEE International Engineering Management Conference. pp. 350-358.

Hannon, B. 1997. The use of analogy in biology and economics – From biology to economics, and back. Structural Change and Economic Development. Vol. 8(4), pp. 471-488.

Hardagon, A. & Sutton, R.I. 1997. Technology brokering and innovation in a product development firm. Administrative Science Quarterly. Vol. 42(4). pp. 716-749.

Harkema, S. 2003. A complex adaptive perspective on learning within innovation projects. The Learning Organization. Vol. 10(6), pp. 340-346.

Hodgson, G.M. 1994. Economics and Evolution: Bringing Life back to Economics. Polity Press, Cambridge.

Holland, J.H. 1992. Adaptation in Natural and Artificial Systems. The University of Michigan.

Holland, J.H. 1995. Hidden Order: How Adaptation Builds Complexity. Cambridge, Perseus Books.

Holland, J.H. 1998. Emergence: From Chaos to Order. Cambridge, Perseus Books.

Iansiti, M. & Levien, R. 2004. The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability. Harward Business School Press.

Kauffman, S. 1993. The Origins of Order: Self-Organization and Selection in Evolution. New York, Oxford University Press.

Kauffman, S. 1995. At Home in the Universe: The Search for the Laws of Self-Organization and Complexity. New York, Oxford University Press.

Kemppilä, S. & Mettänen, S. 2004. Innovations in knowledge-intensive services. Proceedings of the 5th International CINet Conference, 22-25 September 2004, Sydney, Australia, pp. 326-335.

Keskinen, A., Aaltonen, M. & Mitleton-Kelly, E. 2003. Organisational Complexity. FFCR Publications 6/2003. Finland Futures Research Centre, Turku School of Economics and Business Administration.

Kirman, A.P. 1997. The economy as an interactive system. In Arthur, W.B., Durlauf, S.N. & Lane, D.A. The Economy as an Evolving Complex System II. Westview, pp. 491-531.

Korhonen, J., Wihersaari, M. & Savolainen, I. 2001. Industrial ecosystem in the Finnish forest industry: Using the material and energy flow model of a forest ecosystem in a forest industry system. Ecological Economics. Vol. 39(1), pp. 145-161.

Kuusisto, J. & Meyer, M. 2003. Insights into services and innovation in the knowledge intensive economy. Technology Review 134/2003. Tekes.

Lewin, R. Complexity: Life at the Edge of Chaos. The University of Chicago Press.

Liedtka, J. 2002. Ethics and the new economy. Business and Society Review.Vol. 107(1). pp. 1-19.

Maula, M. 2000. The senses and memory of a firm – implications of autopoiesis theory for knowledge management. Journal of Knowledge Management. Vol. 4(2). pp. 157-161.

Mariotti, J.L. 2002. The Value Network. Executive Excellence. Vol. 19(7), p. 18.

Merry, U. 1995. Coping with Uncertainty: Insights from the New Sciences of Chaos, Self-Organization, and Complexity. Praeger, Westport.

Merry, U. 1999. Organizational strategy on different landscapes: A new science approach. Systemic Practice and Action Research. Vol. 12(3), pp. 257-278.

Mitleton-Kelly, E. 2003. Ten principles of complexity and enabling infrastructures. In Mitleton-Kelly, E. (eds.) Complex Systems and Evolutionary Perspectives on Organizations: The Application of Complexity Theory to Organizations. Pergamon. pp. 23-50.

Mitleton-Kelly, E. 2004. Tutorial with the TIP research group. 11th November 2004 in Helsinki.

Moore, J.F. 1993. Predators and prey: the new ecology of competition. Harvard Business Review. Vol. 71(3), pp. 75-83.

Moore, J.F. 1996. The Death of Competition: Leadership & Strategy in the Age of Business Ecosystems. New York, Harper Business.

Nachira, F. 2002. Towards a network of digital business ecosystems fostering the local development. European Commission Discussion Paper. Bruxelles. 23 p. http://www.digital-ecosystem.org/html/repository/dbe_discussionpaper.pdf

Nelson, R.R. 2001. The coevolution of technology and institutions as the driver of economic growth. In Foster, J. & Metcalfe, J.S. (eds.) Frontiers of Evolutionary Economics: Competition, Self-Organization and Innovation Policy. Edvard Elgar, pp.19-30.

Nelson, R.R. & Winter, S.G. 1982. An Evolutionary Theory of Economic Change. The Belknap Press of Harvard University Press.

Nolfi, S. 1998. Evolutionary robotics: Exploiting the full power of self-organization. Connection Science. Vol. 10(3&4), pp. 167-184.

Olkkonen, T. 1994. Johdatus teollisuustalouden tutkimustyöhön. Teknillinen korkeakoulu, Tuotantotalouden laitos, Teollisuustalous.

Pagie, L.W.P. 1999. Information Integration in Evolutionary Processes. Dissertation thesis. Faculteit Biologie, Universiteit Utrecht.

Pagie, L. & Mitchell, M. 2004. A comparison of evolutionary and coevolutionary search. To appear in International Journal of Computational Intelligence and Applications.

Peltoniemi, M. 2004. Cluster, value network and business ecosystem: Knowledge and innovation approaches. A paper presented at the Conference "Organisations, Innovation and Complexity: New Perspectives on the Knowledge Economy", University of Manchester, 9-10th September 2004. NEXSUS, The Complexity Society and CRIC Centre for Research on Innovation and Competition.

Peltoniemi, M. & Vuori, E. 2004. Business ecosystem as the new approach to complex adaptive business environments. To appear in the Frontiers of e-Business Research 2004. Proceedings of eBusiness Research Forum, Tampere 20.-22.9.2004.

Phan, D. 2004. From agent-based computational economics towards cognitive economics. Bourgine P. & Nadal J.P. (eds.) Cognitive Economics: An Interdisciplinary Approach. Springer Verlag.

Phan, P.H., Siegel, D.S. & Wright, M. 2005. Science parks and incubators: observations, synthesis and future research. Journal of Business Venturing. Vol. 20(2). pp.165-183.

Porter, M.E. 1990. Competitive Advantage of Nations. London, Macmillan.

Potts, J. 2000. The New Evolutionary Economics: Complexity, Competence and Adaptive Behaviour. New horizons in institutional and evolutionary economics. Edward Elgar.

Radzicki, M.J. 2003. Mr. Hamilton, Mr. Forrester, and a foundation for evolutionary economics. Journal of Economic Issues. Vol. 37(1), pp. 133-173.

Rothschild, M. 1990. Bionomics: Economy as Ecosystem. New York, Henry Holt and Company.

Roos, J. & Oliver, D. 1999. From fitness landscapes to knowledge landscapes. Systemic Practice and Action Research. Vol. 12(3), pp. 279-293.

Sargent, T.J. 1993. Bounded Rationality in Macroeconomics. The Arne Ryde Memorial Lectures. Oxford University Press.

Scheel, C. 2002. Knowledge clusters of technological innovation systems. Journal of Knowledge Management. Vol. 6(4), pp. 356-367.

Schelling, T.C. 1978. Micromotives and Macrobehaviour. W.W. Norton Company.

Schumpeter, J.A. 1951. The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. (Fourth printing) Harvard University Press.

Smith, M.Y. & Stacey, R. 1997. Governance and cooperative networks: An adaptive systems perspective. Technological Forecasting and Social Change. Vol. 54(1), pp. 79-94.

Smith, R.E., Kearney, P.J. & Merlat, W. 1999. Evolutionary adaptation in autonomous agent systems — a paradigm for the emerging enterprise. BT Technol J. Vol 17(4), pp. 157-167.

Steinbock, D. 2003. Globalization of wireless value system: from geographic to strategic advantages. Telecommunications Policy. Vol. 27(3-4), pp. 207-235.

Tabata, M., Ide, A., Eshima, N., Takagi, I. & Takei, Y. 2001. Self-organization exhibited by a stochastic agent-based model of firms seeking higher desirability in business expressed by the market potential. Proceedings of the Fourth International Conference on Computational Intelligence and Multimedia Applications, 30 Oct.-1 Nov. 2001, pp. 4-8.

Tallman, S., Jenkins, M., Henry, N. & Pinch, S. 2004. Knowledge, clusters, and competitive advantage. Academy of Management Review. Vol. 29(2), pp. 258-271.

Tesfatsion, L. 2002. Agent-based computational economics: Growing economies from the bottom up. ISU Economics Working Paper No. 1, 15 March 2002.

Tordjman, H. 1998. Evolution: history, change and progress. In Lesourne, J. & Orléan, A. (eds.) Advances in Self-Organization & Evolutionary Economics. Economica. pp.9-36.

Turati, C. & Ruta, C.D. 2002. Technology in knowledge based value chain. PICMET.

Vainio, V-V. 2005. Forthcoming.

Veblen, T. 1898. Why is economics not an evolutionary science? The Quarterly Journal of Economics. Vol. 12(4), pp. 373-397.

Vriend, N. J. 1995. Self-organization of markets: An example of a computational approach. Computational Economics. Vol. 8(3), pp. 205-231.

Vuori, E. 2005. Tietointensiiviset palvelut liiketoimintaekosysteemeissä: Agenttipohjaisen mallintamisen mahdollisuudet – käsiteanalyyttinen tutkimus. e-Business Research Center, Research reports 16/2005.

Waldrop, M.M.1992. Complexity: The emerging science t the edge of order and chaos. Touchstone, New York.

Wallace, J. 1998. Introduction. In Darwin, C. The Origin of Species. Wordsworth editions limited, pp. vii-xxiii.

Witt, U. 1997. Self-organization and economics - what is new? Structural Change and Economic Development. Vol. 8(4), pp. 489-507.

Appendix.

The relationships of different schools of evolutionary economic thought (Radzicki 2003, p. 135).