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Outlining the distinguishing characteristics of an evolutionary theory of innovation[1]

By

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Abstract: This paper discusses notions of theory in relation to evolutionary understandings of innovation. It starts by empirically demonstrating the relevance of evolutionary perspectives – broadly defined – for understanding the "basics of what's going on" in the economic sphere when it comes to innovation. It continues to argue and show that appreciative evolutionary understandings of innovation are connected to the Darwinian processes of variation, selection and retention in the theoretical "high range". Multilevel theorizing, where researchers move between different levels and degrees of abstraction is therefore a key feature of an evolutionary theory of innovation. The paper ends by identifying puzzles and research challenges that evolutionary reasoning with respect to innovation need to address.

Keywords: Innovation; evolutionary theory

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1. Introduction

Innovation is a concept with an old history and has been defined in different ways [1]. Currently however, innovation and the related concept technological change[i] are mainly used with reference to the commercialization of new ideas, knowledge and inventions in the economic sphere [1]. Because innovation is a key driver behind the performance of national economies and firms [2,3,4,5], it constitutes an important social and economic force that scholars need to understand. The theoretical lens used to understand innovation is vital in this regard [6, 7, 8]. Both evolutionary economics and neoclassical economic theory provide a theoretical framework that shed light over the emergence, nature and diffusion of innovation [9, 10, 11].

Evolutionary economics and neoclassical economics differ strongly in their account of technological change, however. Outlining the main differences between these two theoretical accounts of innovation has been the objective of many academic papers [12, 13, 9, 10]. A usual starting point in this literature has been the argument that evolutionary economic theory can and should explain the "same tings" as neo-classical economics, such as macro-economic growth, although with more realistic assumptions [14].

New and emerging paradigms also need to explain "peculiarities" that previous theories can not account for [15]. At the risk of oversimplification, innovation is not explicitly dealt with in mainstream neoclassical economics. This has caused Nelson [16] to argue that neoclassical economic theory can not "deal adequately with an economic context in which innovation is important" (p.6). Neo-classical economic theory has therefore little to offer scholars interested in understanding innovation [12]. This paper will therefore focus on evolutionary perspectives on innovation.

Biological metaphors and analogies have often been used to describe, understand and predict technological change and socio-economic evolution [17, 8, 18]. As an indication of the relevance of evolutionary theory, consider the following viewpoint from a Nobel price winner in economics about what the future might hold for economics and economic theory:

"….the very notion of what constitutes an economic theory may well change. For a century, some economists have maintained that biological evolution is a more appropriate paradigm for economics than equilibrium models analogous to mechanics. Evolutionary theory is a point of view rather than a complete theory such as has been the desideratum of economists, and economic theory may well take an analogous course" [19. p1618].

It is interesting to note that Arrow argues that biological evolution may provide an interesting paradigm for understanding economic change, but that the evolutionary perspective is far from being a

"complete theory". In the following pages I will therefore elaborate what the "evolutionary point of view" has to say about innovation. Because the evolutionary point of view is considered by some not to be a "complete theory", it is useful to discuss what we mean with theory and whether different notions of theory exist. Such discussions are not only relevant for scholars but also for policymakers. Technology and innovation policies, foresight analysis and planning studies, should be grounded in a robust theoretical and empirical framework [9,10]. As a point of departure I use theory in a rather broad and rough way to mean a reasonably coherent intellectual framework that integrates existing knowledge for purposes of explanation and understanding [20, 21].

In many social science disciplines, for instance neoclassical economics, the ambition is to develop and test formal theories in the "high range", e.g. theories formalized by means of mathematics and logic and where the ambition is to develop general "law-like" relationships or regularities between entities [21]. Although such theories in the "high-range" are by many regarded as the "ideal", it is useful to acknowledge that different notions of theory exist, at both the lower and higher range.

According to Nelson & Winter [14, 20] theory can be found at different levels of abstraction, where they distinguish between appreciative and formal theory. The former is expressed mostly verbally and is close to the empirical subject matter, while the latter is articulated more abstractly, often in the form of a mathematical model, and is more suitable for logical exploration and manipulation [16]. In the first part of this outline the objective is to capture the "basic's of what's actually going on" in relation to innovation. For such purposes appreciative theory is well suited [16]. Towards the end of the paper I will however discuss the relationship between "evolutionary theories of innovation" based on appreciative reasoning and more formal Darwinian theory in the theoretical high range.

If we are to understand innovation we need to draw on both formal and appreciative theory. Nelson [14] argues in a recent paper that if we are to understand economic phenomena, such as innovation, then this insight needs to be guided by both formal and appreciative theory. He further adds that appreciative theory needs to draw on formal theory, which in turn requires "formal theory to be in tune with appreciative theory regarding the basic economic processes and contexts involved" (p.15). Throughout the paper I will therefore provide some descriptive statistics that demonstrate the relevance of "evolutionary perspectives on innovation", in the sense these captures the "basics of what's actually going on" in the business sector and the economy in relation to innovation.

It is, on the other hand, impossible to develop a complete outline of an evolutionary theory of innovation in a single paper. I have chosen to outline what to me appears to be (some of) the *distinguishing* characteristics of an evolutionary theory of innovation. The argument in the paper is that such a theory is centered on the firm, but recognizes at the same time that innovation is a

multilevel phenomenon [22]. Although such an outline treats the firm as the most important actor, it is acknowledged that sources of innovation reside at different levels, such as the industry, technology, regional and national levels. Multilevel reasoning, explanations and theorizing, where researchers move between different levels and degrees of abstraction is therefore a key feature of evolutionary reasoning with respect to innovation.

In order to outline *evolutionary reasoning* around the concept of innovation I will discuss the arguably three most influential academic research traditions that have developed the evolutionary understanding of innovation. There are (1) Joseph Schumpeter's understanding of innovation and economic development, (2) Nelson & Winter's evolutionary economic theorizing and (3) the systemic approach to innovation.

Schumpeter, Nelson & Winter, and the "systemic approach" have all developed evolutionary perspectives on innovation – and even defined the concept innovation. Together these three traditions have developed evolutionary theories of innovation mostly based on appreciative reasoning. Towards the end of the paper I will organize concepts and insights from these contributions into an evolutionary outline centered on innovation where the links between appreciative reasoning and more formal Darwinian theory in the "high range" are made more explicit. This outline will include key insights, as well as puzzles and research challenges. In order to do so it is necessary to start with Joseph Schumpeter's theorizing about innovation and economic development.

2. Schumpeter on innovation

From the late 1800's to his death in 1950, one of Joseph Schumpeter's main aims was to develop a theory of economic development, where economic development was a direct result of innovation and technological change [23, 24]. In doing so, he was one of the first to provide an analysis of the importance of innovation for economic change [25].

What Schumpeter did was to devise a framework where technological change and economic development is an outcome of technological competition between firms. He devised a "model" where endogenous technological change is an outcome of investments made by business firms to compete and beat their rivals [18]. According to this view, economic growth occurs through a process of creative destruction where the old industrial structure is continually challenged and changed by innovation [26].

Schumpeter developed a comprehensive understanding of innovation in this regard. Innovation, he argued, can be understood as "new combinations" of existing resources, equipment and knowledge – and needs to be separated from invention [23]. While invention is the first occurrence of an idea for a

new product or process, innovation is the commercialization of invention [25]. This understanding of innovation is clearly linked to the notion of creative destruction: Only through economic commercialization and market introduction of new products and processes can new ideas and inventions destroy the competence of incumbent firms and change the industrial structure and the economy from "within".

It may in this context be illuminating to distinguish between different types of innovations, as these may have different economic impacts on the rate and nature of technological change [4, 27, 28]. One of the first classifications was actually offered by Schumpeter when he distinguished between "new products", "new methods of production", "new sources of supply", "the exploitation of new markets", and "new ways to organize business" [23, 29]. Although Schumpeter's classification is old, in the sense that it was developed in his early work [23], it still continues to shed interesting light over economic dynamics in our contemporary business world [29] as exemplified below.

According to recent data from Eurostat, over 40 % of the industrial enterprises in the EU 27 area were active in innovation in the time period 2002-20004, in the sense that these companies either had developed a product and / or a process innovation [30]. Among the companies that were active in innovation, about 57 % developed an organizational and / or market innovation [30]. Hence, Schumpeter's classification seem to capture a basic element of "what's actually going on" in the business sector. It is further interesting to see that Schumpeter's understanding of innovation is broad enough to also cover non-technological innovation, such as organizational change and market innovation.

Schumpeter also emphasized radical innovation over incremental innovation. He argued that historical and economic change is more or less a result of a series of explosions caused by radical innovation, rather then gradual and incremental transformation [25, 9, 10]. Although this classification of radical versus incremental has been criticized [31], it is nevertheless a useful approximation to some of the dynamics that goes on in the business world. According to the third version of the Community Innovation Survey (CIS), about 54 % of product innovating industrial enterprises in the EU 27 area developed a product innovation "new to the market" (radical innovation) and not only "new to the firm" (incremental innovation) in the time period 1998-2000 [32]. These statistics show that Schumpeter's distinction between incremental and radical innovation captures an important source of economic dynamics in the enterprise sector.

Early in his career Schumpeter focused especially on the importance of radical innovations introduced by entrepreneurial young and small firms. What is the contemporary relevance of such an argument? According to recent statistics from the Global Entrepreneurship Monitor (GEM) project, that covers

more than 40 countries (both developed and developing), 4,2 % of the adult population is in the process of starting a new firm each year. 3,8 % of the adult population in these countries actually own and manage a recently established business[ii] [33]. These statistics demonstrate that many individuals seriously attempt to create a new firm. If we look at the importance of recently established firms, then statistics from 10 OECD countries show that about 20 % of the firm population enter and exit the business sector every year [34]. Entrepreneurial initiatives are thus an important source of new business renewal as Schumpeter [23].

The statistics discussed above demonstrate something of the economic dynamics that Schumpeter wanted to understand, e.g., the process of creative destruction where individual entrepreneurs and new firms challenge established firms through innovation. But it turns out that far from all start-up firms pursue innovation, and at least not radical innovation [35]. According to recent statistics from the GEM project, "only" 16 % of early stage entrepreneurs claimed that they have developed a product that is new to the market and "only" 11 % of early stage entrepreneurs claimed that they used the very latest technology, not available a year ago, in order to produce goods and services in 2007 [33]. Although these statistics demonstrate that the early Schumpeter [23] was right to insist upon the importance of entrepreneurship and new business creation as sources of innovation and economic development, it also shows that most entrepreneurs simply copy the competence of existing firms [35]. Hence, only a relatively minor fraction of entrepreneurial activity feed into the process of (radical) creative destruction as described by Schumpeter [23].

Later in his life Schumpeter suggested that innovation had become the domain of the large firm where the process of innovation had become institutionalized and routinized. The later Schumpeter's insistence upon the large firm as a modern powerhouse of innovation has led to a large literature where the objective has been to discover whether large firms are dis-proportionally more innovative compared to smaller firms [36, 37, 38]. Let us take an empirical look at this argument or "hypothesis".

According to the latest CIS survey done in Norway, 62 % of all firms with more than 500 employees introduced either a new process or a product innovation in the time period 2002-2004. In comparison, 20 % of the firms with between 10-20 employees had done the same [39]. Based on these statistics alone it is tempting to conclude that the large firm is a modern powerhouse of innovation. It is, however, important to have in mind that only a "handful" of large firms exist in the enterprise sector, at least when compared to the prevalence of small firms. As an example, there were only 262 enterprises in Norway with more than 500 employees in 2006[iii]. In comparison, 305 957 enterprises with less than 500 employees existed, of these 13 662 enterprises had between 10-19 employees. So although large firms are more innovative compared to small firms, smaller firms still contribute a lot to the total amount of innovation in the economy due to their sheer number [40].

It is also debatable whether Schumpeter really argued that innovation is in the domain of the large firm. An alternative interpretation of his writing is that firm size is not a determinant of innovation – but rather is a consequence of innovation [25]. This inherently more dynamic view argues that (at least some) innovating firms are rewarded by the market with increased profitability and market shares and hence grow into being a large firm. Such an interpretation of Schumpeter's work argues that innovation processes are organized differently in large and small firms [36, 37, 20]. Such an interpretation of Schumpeter's work opens up for policy and economic analysis where firm heterogeneity is important.

Under the assumption that small and young firms pursue distinct and heterogeneous approaches to innovation, then the number of innovating small firms will increase the "innovation variance" of the economy. An increase in the heterogeneity of approaches to innovation will increase the economy's robustness and ability to withstand negative lock-ins and other forms of negative past-dependency effects. On the other hand, a few large firms can be crucial for the economic performance of entire national economies. As an example, the 262 firms with more than 500 employees in Norway employed 23 percent of the workforce in the private sector although they only accounted for 0,07 % of the number of firms in the enterprise sector in 2006. What emerges as important then is firm heterogeneity and the role of firm heterogeneity in explaining innovation and economic development. This may arguably be what Schumpeter actually had in mind – and is a pointer to the evolutionary economics tradition associated with Nelson & Winter [14].

A last central message from Schumpeter is that innovation is not an easy activity to pursue. Schumpeter argued that firms pursuing innovation face considerable resistance to new ways of doing things from the social environment and from society [23]. Entrepreneurs and firms with new ideas need to overcome this resistance if they are going to be successful.

Recent statistics from 10 OECD countries show that between 20-40 % of entering firms fail and hence exit the business sector within the first 2 years of life [34]. This demonstrates, first of all, that it is not easy to pursue innovation, and secondly, that many start-up firms fail in the attempt to set-up a viable business [35]. However, firms that survive tend to grow relatively fast. After seven years of life, entering firms in USA had a 60 % growth in employment relative to start-up size. Same statistics for European countries showed a growth rate between 5 – 35 % (France lowest – UK highest). So although innovation is hard firms that get it right are rewarded, just as Schumpeter would predict.

The statistics presented and discussed above demonstrate that there is something to the Schumpeterian understanding of innovation. So clearly, innovation is important, and many firms pursue it, but far

from all firms, as the presented statistics suggest. The reason why all firms do not pursue innovation is not well developed in Schumpeter's account of innovation however. He focused instead on the heroic character of entrepreneurship that he deemed was necessary to carry of new innovations [41]. Arguably, Schumpeter can be criticized for not developing an elaborated theoretical account of the firm in his understanding of innovation processes [25]. Schumpeter's attention was thus shifted away from understanding how the new knowledge on which innovation are based is created and how firms search and experiment in order to innovate [41]. This is actually a pointer to more recent evolutionary theorizing about firm behavior, starting mainly with Nelson & Winter [14] that we will discuss in section 3.

Although Schumpeter did not provide an elaborate perspective on why and how firms innovate [25], it is nevertheless clear that the firm is the main actor in Schumpeter's account of innovation. Subsequent theorizing, from Schumpeter's death and onwards, came to embrace and develop a micro-level view of innovation where the firm is the most important actor operating almost in isolation from the rest of society. This has traditionally been a central part of an evolutionary-economic perspective on innovation [9, 10]. One might ask whether this view is in line with Schumpeter's own theorizing however. Implicit in his work is a notion about an "entrepreneurial function" that points to the recent "system approach to innovation" [23]. As a result of the systemic approach to innovation, the sole focus upon the firm level in innovation studies is slowly changing towards a multilevel understanding of innovation where the firm and it's context are both important for innovation [22]. I will return to this issue in section 4.

What emerges from the Schumpeterian view is that innovation is the key driving force behind economic development and industrial dynamics. And although there might be some conflicting views about whether small or large firms are the main source of innovation – the firm is the main actor when it comes to innovation. Schumpeter did not outline an economic perspective on innovation grounded in biological theory however [42]. Although he is regarded as perhaps the most important evolutionary economist in the broad sense, he actively refrained from using biological metaphors and analogies in his academic work [42, 41].

3. Nelson & Winter on innovation

The development of evolutionary theorizing in economics is more recent. A vital event in this regard was the publication of the book "An Evolutionary Theory of Economic Change" by Nelson and Winter in 1982 [14]. Building upon academic work that directly challenged the neoclassical understanding of firm behavior and the sources of economic change [43, 44, 45] this book has made a major and lasting contribution to evolutionary theory in economics, sociology and management [25, 31, 46]. The evolutionary economics tradition associated with Nelson & Winter [14] distinguishes

itself from neoclassical economics by explicitly using biological metaphors and analogies in academic work.

In their book, Nelson & Winter extended Schumpeter's view that technological competition between firms is the main driving force behind economic development and change in capitalist economies. In their theory biological concepts and metaphors, especially the evolutionary concepts "*variety*" and "*selection,*" are important. In Nelson & Winters evolutionary world firms generate new variety through search and innovation. The market is the main selection mechanism that picks winners and losers, which either grow or decline. So in Nelson & Winter's evolutionary economic theory firms compete with each other in much the same way as animal species compete for survival in the natural environment [9, 10]. Another major difference when compared to Schumpeter in this regard is that Nelson & Winter developed an elaborated theoretical perspective of firm behaviour as well as why and how firms innovate using the concepts *bounded rationality*, *routine*, and *localized search*.

Bounded rationality is a key concept in Nelson & Winter's evolutionary theory. Coming from psychology and the behavioural theory of the firm [44, 45], the basic theoretical reasoning behind bounded rationality is the argument that because the world is so complex, the wealth of information is so large, it is not reasonable to expect that firms have access to perfect information. Humans and firms have instead limited and flawed cognitive-information-processing capabilities. These information-processing capabilities are highly firm specific, which constitutes an important source of firm heterogeneity.

In table 1 below we have provided the share of industrial enterprises in the EU 27 area that perceive the displayed factors to represent an obstacle to innovation of high importance[iv]. The data is taken from the CIS 3 survey [32]. It is important to underline that the obstacles are *perceived* by the responding firm manager. Although there might exist a correlation between perceived obstacles and real obstacles, the strength of this correlation is believed to vary across firms, constituting a source of variety in the business sector. As can be seen in the table, there is a considerable degree of heterogeneity in the business sector when it comes to what kinds of obstacles firms and their managers perceive too be important obstacles to innovation.

[Table 1 about here]

When it comes to the most important perceived barriers to innovation, "perception of economic risk", "innovation costs to high" and "lack of qualified personnel" are among the most important – for both innovative and non-innovative firms. Among the least important are "lack of information on

technology" and "lack of information on markets". As we can see (table 1), many firms and their managers claim that innovation is a "risky" activity that is "costly" to pursue.

Closely related to the risky and uncertain nature of innovative activity, is the idea that firms are rather unable to predict the outcomes of their actions and strategies with much precision. Firms aim instead for satisfactory results and outcomes [44, 45]. In order to achieve "satisfying performance" firms follow simple decision rules and standard-operating procedures. These decision rules are called routines. In Nelson & Winter's evolutionary theory organizational routines are the counterpart to genes in biology. These routines determine firm behavior in roughly the same way that genes determine animal and human behavior [9, 10].

Nelson & Winter distinguished between three classes of routines in this regard: (1) operating characteristics governing the firm's short-term behavior, (2) investment rules, and (3) higher-order procedures that modify procedures at lower levels [47]. With the introduction of this nested structure of routines, Nelson and Winter [14] ensured that firms can change their routines or genes in a deliberate manner, unlike organisms and animals in biological theory [9, 10]. Firms can change their routines through deliberate search [14, 20].

Somewhat simplified, firms in Nelson & Winter's view start to search for new or better production techniques and routines when their profits falls below a certain level and firm survival is a risk [25, 48]. Search is initiated when firm performance is below a satisfactory profit level. A firm can search for new routines in basically two different ways: The firm can either develop a completely new routine from scratch (e.g. innovation) or it can copy and adopt an already existing superior routine possessed by competing firms (e.g. imitation). In both cases there are search costs, the standard case being research and development (R&D) [25]. An empirical example may illustrate the potential relevance of this theoretical perspective on firm behavior.

If we look to the European enterprise sector then about 40 % of innovating firms spent funds on R&D in the time period 20002 – 2004 [49]. Hence, there appears to be a positive "correlation" between R&D and the probability to innovate. This has been confirmed by empirical research [50, 51, 52]. This correlation is not perfect however. As the statistic suggests, 60 % of innovating firms did not spend fund on R&D. "Non-R&D based" innovation is something which evolutionary-economic theory does not capture very well. But as I will discuss in a little while, R&D is far from being the only source of innovation.

Firms' ability to undertake change through search activity is according to the evolutionary theory put forth by Nelson & Winter is rather limited. As an example, only 16,5 % of firms in Norway spent money on R&D in 2006, while 21 % were innovative in the time period 2002-2004 [39, 53].

Although there is always the possibility that a firm can discover a radically new routine or innovation in Nelson & Winter's theory, the likelihood that this is going to happen is rather small. There is instead a built-in tendency for firms to look for new production techniques and technology in the proximity of what the firm already knows. This is the notion of localized search [14, 54].

The notion of localized search implies persistence over time in the type of innovative activity pursued and conducted at the firm level. In table 2 below we have produced a correlation matrix that sheds some empirical light over the evolutionary- theoretical idea that firms persist in innovation. The correlation matrix has been developed on the basis of the CIS 3 micro-data for Norway. In the table we can see that there exist rather strong positive correlations between the nature of technology developed in the past and current R&D efforts at the firm level. For instance, there is a 0, 65 correlation coefficient between product innovation and product R&D, and a 0, 44 correlation coefficient between process innovation and process R&D. Although these correlation coefficients are rather strong, the correlation between current and planned R&D efforts is very strong. There is actually a 0, 92 correlation coefficient between internal R&D in 2001 and planned internal R&D efforts in 2002.

[Table 2 about here]

The data presented in table 2 shed some empirical light over the evolutionary-theoretical idea that firms are somewhat persistent when they search for new innovations. It also suggests that the same firms tend to innovate over time. These statistics also echo Schumpeter's argument that the propensity to innovate is unevenly distributed in the firm population. Nelson & Winter elaborated this perspective by adding that firms persistently differ in the innovation process.

A fundamental point about the evolutionary economic world developed by Nelson & Winter is the ongoing introduction of novelty, heterogeneity and variety, into the economic system. The sources of new economic variety are search activity, innovation, and heterogeneous cognitions and information processing capabilities at the firm level. The market is the main selection environment where firms with superior production technologies are rewarded with higher profitability and market shares, while firms with inferior routines face the risk of extinction unless they are able to discover better production technology through search activity. That at least some innovating firms are rewarded by the market and thus experience positive external selection, is a distinguishing feature of the evolutionary theory developed by Nelson & Winter [14]. Let us take a closer look at the empirical relevance of this argument.

In table 3 we have provided the share of innovating enterprises in the European business sector that have reaped a positive outcome or effect from innovation on a selected list of factors [55]. As can be seen in the table 3, almost 38 % of innovating industrial enterprises in the time period 2002-2004 in the EU27 area claimed that "improved quality in goods and services" was a highly important effect of the conducted innovation activity. Other "effects", such as "increased range of goods and services", "entered new market or increased market shares", and "improved flexibility of production or service production" were also highly important to many innovating industrial enterprises.

[Table 3 about here]

The statistics in table 3 also shed some empirical light over the evolutionary-theoretical argument that innovation is not a homogenous entity. Outcomes from innovation processes are heterogeneous, like innovation itself [56, 14]. In such a framework, only a subset of all developed innovations have beneficial effects at the firm level. But firms that "get it right" are rewarded. According to CIS 3 data for the EU27 area, product innovating firms derived 27 % (in average) of their turnover in 2000 from an innovation introduced in the 1998-2000 time period [32].

It is necessary to emphasize in this context that firms in the evolutionary world can learn from "failure" in the innovation process [57, 58, 59]. Firms can follow a "parallel-path" approach to innovation where knowledge and learning gained from following one distinct search path to innovation may enable innovation in another but related search path to innovation [57]. Failure in one search domain may thus spur innovation in a related technological domain. In table 4 below we have provided a correlation matrix on the basis of the Norwegian CIS 3 survey that shed some empirical light over this phenomenon.

[Table 4 about here]

The correlations in table 4 support the evolutionary argument that "failure" does not have to be "bad" and can in fact enable innovation. As can be seen in the table, there is a 0,3-0,4 correlation coefficient between abandoned innovation activity and developed innovations (product and process) on the one hand and a 0,4 correlation coefficient between abandoned innovation activity and ongoing innovation activity on the other hand. These correlation coefficients suggest that "failure" can in fact enable innovation. There are also strong correlation coefficients (about 0,5-0,7) between developed innovations (product and process) and ongoing innovation activity. This is another illustration of the evolutionary argument that firms tend to "persist" over time in relation to innovation [14].

Given the beneficial outcomes associated with innovation – illustrated in table 3 above - new knowledge and superior routines will at some point diffuse among firms in the same environment in the evolutionary theory developed by Nelson & Winter [14]. Firms will more or less successfully copy and adopt superior production technology and routines possessed by competing firms through learning, diffusion and retention processes. At some point in time superior production technology will become common practice so that new variety, routines and innovations need to created and produced in order to challenge old ways of doing things [35, 14, 35]. In this perspective, economic development is a never ending and ever changing process of economic dynamics. The business sector – nor the economy – is never in rest and stable. Innovation will always break tendencies to economic stability and well-anticipated economic change [19, 10, 16]. Statistics I have presented and discussed suggests that this theoretical perspective is in line with "what's actually going on" in the business sector.

What emerges from Nelson & Winter' [14] evolutionary theorizing is that bounded rationality, search activity, and innovation are three important sources of economic variety. The ongoing and continuous introduction of new variety in the economy ensures that economic change and development is a never ending and ever changing process that is endogenous to the economic system itself. The firm with its innovative activity is a key actor in this regard.

4. The systemic approach to innovation

The most recent development in the field of innovation is the systemic approach to innovation. The systemic approach to innovation builds on novel research efforts conducted in the 1980's and 1990's. At that time many researchers came to embrace the Schumpeterian idea that the innovation process has a systemic and interactive character [25]. Partly as a response to the failure to integrate institutions in economic analysis, scholars in the field of science, technology and innovation studies invented the (national) innovation system concept [60]. Although authors seem to disagree slightly on how to define a (national) innovation system, variants of the innovation systems approach places institutions and have these promote and disseminate knowledge in the forefront. To illustrate, an innovation system in Nelson's [61] sense "is a set of institutions whose interactions determine the innovative performance of national firms" (p. 4) while an innovation systems in Lundvall's [62] sense is "constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (p.2).

What empirical research in the systemic approach to innovation has shown is that innovation is an outcome of complex interactions between individuals within the same firm, between different firms, and between firms and other actors in the environment such as suppliers, customers, and universities [58, 63, 61, 62, 64, 65].

The systemic approaches to innovation have developed into different directions. What most of these approaches do is that they, either at the country level, regional level, industrial sector level or technology level, identify and describe the most important actors, organizations and institutions that take part in or influence R&D and innovation at the firm level [66, 67, 70,64, 69, 70, 65]. But to what extent is the knowledge relevant for industrial innovation sourced externally? Let us take a closer empirical look at this argument.

In table 5 we have provided the extent to which innovating industrial enterprises in Europe used any of the displayed information sources in the innovation process. The statistics have been produced on the basis of the CIS 4 survey for the European business sector [71]. In the table we can see that knowledge sources within the enterprise are deemed by most firms to be a highly important source of information for innovation. However, many firms also claim that information and knowledge from suppliers, as well as clients & customers are important for the organizational ability to innovate. The statistics in table 5 thus shed some empirical light over the argument that important sources of information for innovation are distributed in the interface between the firm and its environment [63, 72, 70, 66].

[Table 5 about here]

So it turns out that the argument that knowledge relevant for industrial innovation is distributed among a range of different types of actors has some relevance. What emerges is that most firms do not innovate in isolation [31]. Firms are a part of a broader knowledge environment where external sources of knowledge influence learning and search activities at the firm level [66, 46, 61, 63, 72]. Recent strategic management theory has started to adopt this insight from innovation studies in general – and from the systemic approach to innovation in particular. Drawing upon Schumpeter's understanding of innovation as "new combinations" it has subsequently been shown that organizations using external knowledge in the search process have a higher propensity to innovate and to develop innovations with a higher commercial success [73, 74, 75, 76, 63, 77, 78, 79]. The ability to learn – and draw upon – external knowledge thus emerges as important.

Incremental learning is particularly important in the IS approach developed by Lundvall [62, 46]. Lundvall argues that an innovation is a new (re)combination of knowledge drawn from different sources. The sources of industrial innovation are in this approach believed to be distributed in the interface between the firm and its external environment, particularly in the interaction with customers and suppliers. Is there any empirical relevance to such an argument? According to results from the European CIS 4 survey, 26 % of innovating enterprises in the European Business sector had cooperative arrangements with other economic actors (firms, universities, suppliers etc) in the time period 2002-2004 [30]. Further, about 30 % of all innovating industrial enterprises in Norway had

according to the CIS 3 survey developed a product innovation in cooperation with other firms or actors. These statistics demonstrate that while some firms actually develop innovations together with other actors in their knowledge environment, many firms innovate alone.

What emerges is that the ability to use and draw upon external knowledge sources in the environment is an important source of firm heterogeneity that we need to better understand. Schumpeter argued that the organizational ability to innovate was unevenly distributed in the firm population [23]. This insight seems to be valid also when it comes to the organizational ability to draw on – and use – external knowledge in the innovation process.

The systemic approach to innovation has reminded researchers that economic activity, such as innovation, takes place within a social-institutional context [66, 67, 68, 64, 69, 70, 65]. The systemic approach to innovation has developed the evolutionary economic theory introduced by Nelson & Winter [14] by adding the importance of "structural-institutional" macro variables and the importance of "context" [16]. Empirical survey data reinforce the theoretical idea that institutional variables at a macro level is important for the organizational ability to innovate. According to the CIS 4 survey, countries differ a lot when it comes to innovation. For example, Germany is the most innovative county in Europe were almost 73 % of the firms in the manufacturing sector and 58 % of the firms in the service sector were active in innovation in the time period 2002-2004. The least innovative country in the survey was Bulgaria were 18 % of the firms in the manufacturing sector – and 12,7 % of the firms in the service sector – were innovative [30]. Hence, "macro" variables and institutional context obviously matter to innovation at the firm level [80, 81, 82, 66, 61, 62]. It is thus rather clear that institutions (at the country level) "determine the innovative performance of national firms" [61. p4].

The statistics presented in the section above suggest that evolutionary perspectives on innovation are highly relevant and capture essential elements of "what actually goes on in the economy" when it comes to innovation. So far the paper has been based mainly on appreciative reasoning and loose references to evolutionary theory and biological analogies. It is time to discuss whether and how the appreciative theorizing outlined above fit within more formal evolutionary theory in the theoretical "high range".

5. An outline and some research challenges

Theories of evolutionary change deal with processes of "variation", "selection", "retention & diffusion" and "competition" [83, 35, 14]. Recent research on the variation-selection-retention model argue that these generic evolutionary processes can be used to explain both social (including economic) and biological evolution at a high abstract level [84, 85]. The model is more akin to a meta-theoretical framework in the theoretical high range, and does not specify the detailed sources of

variety nor explain important domain-specific concepts such as innovation [84, 85]. Additional and auxiliary explanations and insights are hence needed in order to make the variation-selection-retention model concrete at a more detailed and "hands-on" level. The ambition in the following pages is therefore to establish "key facts" and research challenges at a more detailed level of analysis in order to contribute to the development of an evolutionary theory of innovation. This "detailed" analysis will however be nested within the generic evolutionary processes described above.

5.1 Variety

At the general level, variation can be defined as any departure from routine or tradition [35]. As we have seen, "variety" is the main source of growth in evolutionary economic theorizing [25]. How is variety related to innovation? What we have learnt from Schumpeter and Nelson & Winter is that innovation is arguably the most important source of new variety and novelty in the business sector. This variety can however come in different "disguises". We have seen that one classification distinguishes between product, process, organizational and market innovation. Another classification distinguishes between radical and incremental innovation. Statistics we have presented and discussed demonstrate that such classifications capture some of the dynamics that goes on in the business world.

When it comes to the emergence or creation of variety through innovation, Schumpeter and Nelson & Winter have taught us that the firm is the main actor. Innovation is, by and large, the commercialization of inventions and new ideas. This goes on within an organized setting, in the firm. Creation of new variety and innovation occurs when firms actively attempt to discover routines that deviate from and challenge established practice. This is the notion of search that is vital to Nelson & Winter's evolutionary theory of economic change. Although deliberate search is a main determinant of variation and innovation in Nelson & Winters evolutionary-economic theory, failure and mistakes are also important sources of innovation and new (economic) variety in other evolutionary perspectives [35]. As we have seen in table 4, there are positive correlations between "failure" and "success" in the innovation process.

According to Nelson & Winter, firms mainly search internal and local knowledge when they attempt to innovate. What applied innovation research has discovered is that innovation is a complicated process with interaction and feedback effects between different stages and knowledge sources [58]. A critique of Nelson & Winter's evolutionary theorizing is that they did not pay enough attention to the fact that firms do not innovate in isolation [16]. The systemic approach to innovation has reinforced this critique with the argument that knowledge relevant for industrial innovation is distributed among a diverse set of actors such as suppliers, universities and customers [63, 72, 62]. This perspective seems to be valid – but only to some extent: Statistics we have presented suggest that although many firms draw upon external knowledge sources in the innovation process, far from all firms do that. We have

seen that many firms seem to "innovate alone", without interacting much with other firms or actors. Firm internal knowledge seems to dominate as a source of industrial innovation, although costumers and suppliers also emerge as important.

5.1.1 Research challenges in relation to "variety creation" and firm heterogeneity

There are a number of research challenges that needs to be solved in order to advance evolutionary theory with respect to innovation. When it comes to "variety creation" we need to better understand how search efforts at the firm level are related to innovation, especially radical innovation. Although the notion of localized search is well-established in innovation studies, real-world examples suggest that incumbent firms can develop radical innovations and alter their organization in novel ways. An emerging research challenge is then to study why and how firms are able to implement and develop such path-breaking innovations [86]. A related research challenge is to study "innovation variety" within firms. Sources of variation in relation to innovation have mainly been explored across firms within evolutionary economics [87]. Evolutionary economics has therefore downplayed the possibility that heterogeneity in relation to innovation also can be observed within the firm.

A related research challenge is to address the rather unexplored relationship between "failure" and "success" in the innovation process. Although studies and reviews tend to argue that the determinants of "failure" are different from the determinants of "success" in the innovation process [88], this argument might be at odds with theories and models of innovation based on evolutionary reasoning. Evolutionary theories recognize that innovation processes are uncertain and that it is impossible to predict "success" with much accuracy. The knowledge gained from failure can in this framework enable innovation and learning in the longer run [59, 89]. Unexpected feedback effects are thus to be expected.

Whether "failure" is "all bad" or can enable innovation at a later stage is thus an important issue to resolve in order to further develop evolutionary perspectives on innovation processes. This is because the policy and economic implications of a theory of technological change that recognizes that both failure and success are important and inter-related aspects of the innovation process is very different from a theory of innovation arguing that the determinants of failure and success are different from one another. Although qualitative research findings suggest that failure can be good, in the sense that it can enable innovation in the longer run [58], we know less about whether this relationship holds when tested against large-scale databases. More research on this issue is needed.

It is further not clear how firms actually use external knowledge in the innovation search process. There is still more to learn about how firms draw on and use their external knowledge environment in the "variety creation" process. According to Schumpeter and Nelson & Winter, innovation is an

outcome of a search process where firms "recombine" knowledge sources in new ways. External knowledge sources are vital to this "recombination" process [86]. Although there exist a nice theoretical link between Schumpeter's view of innovation as "new combinations", Nelson & Winter's notion of "search", and the importance of "external knowledge" in the systemic approach to innovation, we need to know more about how external knowledge enters the firm and the process of recombination. We need to ask ourselves how access to external knowledge can guide firms in their search for new innovations. This question was first asked by Nelson [90] but has remained poorly analyzed. How firms learn in a systemic knowledge environment is thus still a key research issue [91].

At the evolutionary-theoretical level there is more work to be done when it comes to the relationship between organizational routines (as the DNA of the firm) and firm behaviour. Recent evolutionary theorizing stresses that firm behaviour is far more than the "sum of routines". It is argued that what current evolutionary understandings of firm behaviour misses is knowledge about organization, understood as the specific ways in which genes, skills and individuals are connected with one another within the firm [48]. In absence of knowledge about organization, we will not be able to predict firm behaviour with much success, even with complete knowledge about firms' routines or genes [48]. This is an area where interactions between evolutionary economics on the one hand, and the fields of organizational studies / strategic management on the other hand, appears to be especially useful and promising.

Further, although management researchers have studied how firms search for new routines and innovations [86], few have actually looked at the relationship between search routines and other organizational routines at lower levels in the routine hierarchy in an empirical manner. Does the search for new innovations change organizational routines at lower levels in the routine hierarchy within the organization? If so, how does this happen?

What emerges from this section is that innovation is a key source of variety, and that firms generate such variety through search. The main research challenge is arguably to explore under what circumstances firms create new variety and innovation, and what role external knowledge and bounded rationally have in this context.

5.2 Selection

Forces that eliminate certain types of variations constitute the second key evolutionary process, which is selection [35]. How is this related to innovation? What we have learnt from Nelson & Winter [14] is that selection forces either enable or inhibit the creation and diffusion of new variety. In the evolutionary economic theory developed by Nelson & Winter [14] the main selection environment is the market. Commercial success is in this evolutionary perspective the key determinant of whether

newly developed variations and innovations (and the companies developing them) survive and grow. If new variations enjoy commercial success then these variations are preserved through institutionalized learning and localized search and copied by competing firms [57, 14, 35, 92].

Due to the focus upon the market as the main selection environment, Nelson & Winter's evolutionary economic theory stresses external selection. External selection theory argues that forces external to the firm constitute the main selection environment [59, 35]. Statistics we have presented suggest that this is indeed a relevant perspective as many firms exit and disband the market each year. Survival is not easy.

The market is not the only relevant external selection environment however [93]. What the systemic approach to innovation has have taught us is that the "innovation system" – at either the regional, sectoral, national or technology levels - also constitute important external selection environments. Statistics I have presented and discussed have demonstrated that far from all firms get access to and use external knowledge in the innovation process. Many firms thus appear to "innovate alone". Many firms are thus either not able – or are denied access – to important external knowledge sources relevant for industrial innovation.

Access to external knowledge is thus an important source of firm heterogeneity. What Schumpeter and more recent strategic management theory have shown is that the ability to recombine existing knowledge sources in new ways – and integrate such knowledge with internal "know-how" - is a key aspect of innovative performance [89, 90, 75, 77, 78, 79]. Hence, access to external knowledge enables the creation of new variety and radical innovation. Although this point is rather absent in Nelson & Winters [14] evolutionary theorizing, it is clearly relevant for the further development of evolutionary reasoning with respect to innovation.

Another shortcoming in Nelson & Winter's [14] evolutionary theorizing about the firm is the idea that firms are rather inert and unable to change in the face of rapid environmental change. Firms are in Nelson & Winter's classical framework almost unable to change because they tend to search for new technology and routines in the neighborhood of current practice. This is the notion of localized search. In the evolutionary perspective developed by Nelson & Winter [4] firms conduct localized search even though current practice is obsolete due to large scale changes in the external environment (such as the introduction of a radical innovation by a start-up firm). Many "real-world" examples demonstrate however that incumbent firms are able to overcome inertia and localized search. Although Nelson & Winter [14] made a great job in showing and explaining that economic change is endogenous to the economic system itself, they can be criticized for treating the firm as a rather inert actor that mainly tend to search along well established technological trajectories, even in the presence of environmental

turbulence. Such theorizing appears to be at odds with "the basics of what's actually going on" in the business sector.

Although firms in Nelson & Winter's evolutionary perspective can, at rare occasions, develop radical innovations that break with established technological practice, the sources or determinants of search are mainly external: Firms start to search for new innovations when their profit level declines and firm survival is at risk. The main problem with this particular aspect of Nelson & Winter's evolutionary theorizing is that it is assumed that sources of change and search are mainly external to firms. Several studies have shown that firm internal dynamics are important for innovation and change within firms [94, 95, 96, 97].

Nelson & Winter [14] can thus be criticized for offering a theoretical context in which "managerial action" and "strategy making" becomes rather insignificant as sources of endogenous organizational search and change. This may be a point in which Nelson and Winter's [14] theorizing and more recent strategic management theory might be at odds with each other: Where Nelson & Winter argue that firms – at best – can adapt to their environment, recent strategic management theory argue that successful firms proactively seek to alter and change their environment. Internal selection theory may offer a way to remedy this shortcoming in Nelson & Winter's evolutionary perspective however.

5.1.1 Research challenges in relation to "selection" and innovation

External selection theory dominates the evolutionary economics tradition developed by Nelson & Winter [14] due to the importance of the market as the main selection force. In this perspective, economic change is mainly a result of selective replacement of inert incumbent firms by new firms [98, 99, 100, 101, 102, 35]. Internal selection theory takes a rather different perspective [59].

According to internal selection theory a firm is a loosely integrated organizational creature with several "cores". New ideas are launched by frontline managers and workers within the firm. Different ideas have to fight over funding within the firm where the top management selects which ideas to fund. Top management can choose to fund ideas that are in line with existing practice, or fund more radical departures from existing practice. Due to the latter, firms can potentially undertake radical organizational transformations [103, 94, 95, 96, 59].

Hence, internal selection theory argues for an evolutionary perspective where incumbent firms are capable of implementing both incremental and radical change and to influence external selection criteria to their advantage. The main selection environment studied in this regard is "within the firm" and in this environment the (top) management is an important selection force. Important sources of search and organizational change are thus found within the firm. Internal selection theory thus opens

up for the idea that firms not only react inertly and passively to environmental turbulence – but that firms also can implement proactive strategies that aim to influence their environment and industry [59]. The role of managerial action and strategy making at the firm level is clearer in this latter perspective.

Internal selection theories contrast rather strongly with Nelson and Winter's emphasis upon the market as the main selection environment. Both "external" and "internal" selection theory are however firmly grounded in evolutionary theory – although they emphasize different types of selection environments. Both external and internal selection theory have as such interesting perspectives on the emergence and creation of new variety and innovation – and how forces internal and external to the firm influence the creation of new variety. An important research challenge in the future is to unite both internal and external selection theory and analyze how they are inter-related and influence innovation processes at the firm level [59].

A key issue in this regard is the fact that external and internal selection theories focus upon different units of selection, with the former looking at the selection of firms, while the latter focus on selection of routines, initiatives and single projects [35, 59]. Both "firms" and "routines" are however related to each other in a nested multilevel structure. As an example, it has been shown that firms gain positive learning by proactively discarding production techniques and routines that do not enjoy the expected level of commercial success [59]. To analyze this multilevel nested structure between "routines" and "firms" emerges as an important research challenge in relation to innovation and selection.

Another interesting challenge is to look at the relationship between the market and the innovation system as two different kinds of external selection forces. In biological theory it is argued that variety is generated independent of selection. Whether this applies to economic evolution is actually debated within the social sciences [104, 105, 85, 41, 47]. A question that might shed some light over this issue is whether firms that draw upon "users" and "customers" in the innovation process also have superior economic performance. If so, this would imply that two important external selection forces are aligned with each other.

A related issue is whether new innovations and routines are generated randomly. In the biological world mutations and new variations are the outcome of random processes [47]. It is debated whether this perspective really fits economic evolution [106]. At the extreme, a pure biological approach to economic evolution would exclude human intentionality. Many evolutionary economists thus argue for a Lamarckian type of economic evolution where the generation of new variations is not independent of actors' intentions and strategies [14, 105]. Although Lamarckian evolution fit within the broad parameters set by the Darwinian variation-selection-retention model [84] there has been little

research on this issue in the context of innovation. Are new innovations generated independent of actors' strategies and perspectives? This is an empirically researchable question. More empirical research on this issue is needed in order to "settle the debate" [85].

What emerges from this section is that both internal and external selection is important for evolutionary reasoning around the nature, diffusion and impacts of innovation processes because these forces can either enable or inhibit innovation and variety creation at the firm level. The main research challenge ahead is arguably to study the inter-relationships between internal and external selection with references to innovation, firm survival, and growth in a multilevel framework.

5.3 Retention & diffusion

A key aspect of evolutionary reasoning with respect to innovation is that knowledge and information gained from learning and experience is stored within the firm and encoded in its routines [35]. Retention processes are important because such processes address the ability of firms to learn and store knowledge relevant for industrial innovation and variety creation. If firms are not able to learn from own mistakes and from each other, there is basically no way to ensure that positively selected variations are reproduced and diffused in the firm population and in the economy [43, 14]. Both economic and technological development will break down without retention and diffusion processes [35, 25].

A key aspect in this regard is to what extent organizational routines and search efforts are persistent and path-dependent. In Nelson & Winter's evolutionary theory firms tend to follow the same search approach to innovation because they mainly use retained knowledge and experience in the innovation search process. Statistics we have presented in this paper suggest that there may be a rather strong empirical relevance to such an evolutionary-theoretical account of firm behavior. But real world examples also suggest that incumbent firms are able to initiate radical search efforts that do not build strongly upon selectively-retained knowledge and experience.

5.3.1 Research challenges in relation to "retention" and innovation

An emerging research issue in relation to "innovation" and "retention" is therefore to examine under what circumstances firms are able to pursue a more radical approach to innovation. Although the notion of local search has been confirmed by many empirical studies, more recent research efforts are now attempting to unravel under what circumstances firms move beyond localized search [86]. What are the factors that cause industrial enterprises to pursue "distant" and radical search efforts to innovation?

Some tentative answers to this question may be found in the systemic approach to innovation, especially in the version developed by [62, 68]. One way firms can change the content of their search routines is by interacting with suppliers, customers and so on, and store that knowledge in their routines. Continuous interaction and incremental learning can then over time have a considerable influence over the type of information, experience and knowledge firms have encoded in their routines. Although seminal research contributions in innovation studies have highlighted the importance of being able to access external knowledge and to integrate such knowledge with internally developed technology [89, 90] – we still do not know much about how firms actually draw upon and use external knowledge in the innovation process. To explore along which theoretical and empirical channels firms' access and use external knowledge is thus a key research challenge.

How external knowledge enters the firm, how such knowledge is stored and retained in organizational routines, and whether this is a source of incremental and radical change and firm survival in the longer run are important issues that evolutionary theories of innovation needs to address.

5.4 Competition for scarce resources

Selection is linked to the struggle and competition for scarce resources [35]. This is an important feature of any evolutionary theory of innovation, mainly because there is an assumption in evolutionary economic theory that at least some innovators will be rewarded with higher profitability and market shares (e.g. resources) [14, 43]. Innovation should, at least in some cases, be associated with some kind of a positive outcome at the firm level. If innovation never "pays-off" in the sense that innovating firms never acquire more resources, firms have no incentive to create new variations. Evolutionary theories of innovation therefore need to include a positive association between "innovation" and access to "resources".

A "problem" is that only a small fraction of all innovations actually experience (strong) commercial success. This can be explained by the fact that innovation is not a homogenous entity [56]. Due to the heterogeneous nature of the innovation it is problematic to include a measure of innovation in econometric research that aims to explain firm performance, such as profitability, sales growth or market shares. The problem is that while most econometric research builds upon analyses of "averages" – there is no such thing as an "average" innovation. In order to further develop evolutionary perspectives on innovation, there is a need to more clearly develop the relationship between "innovation" and "competition for resources". Developing new taxonomies of innovation may be a step forward in this regard. Taking a closer look at what kinds of knowledge sources firms' use in the "innovation recombination process" can be a solution in this regard.

5.4.1 Research challenges in relation to "innovation" and "competition"

In order to advance the relationship between innovation and competition for resources it is necessary to take into account that firms innovate for different purposes and have different objectives in mind when they search for new innovations. Such an approach would make it possible to take into account that innovation is a heterogeneous entity and that innovations can have different kinds of positive effects upon firms ability to succeed in the competition with other firms.

There is especially a need to develop the relationship between "innovation" and "competition" in relation to policy and management practice. From the policy side it is usually expected that there is a strong and positive relationship between innovation and commercial success. When no such links can be provided, the policy relevance of evolutionary theories of innovation is minor and can easily be discarded by policymakers. For managers in innovative firms the implications are rather similar. Perhaps the most important "evolutionary" implication for innovation management is that many of the driving forces behind both success and failure in innovation are the same.

6. Conclusion

In this paper I have attempted to outline (some of) the distinguishing characteristics of an evolutionary theory of innovation. This has been a timely exercise given the fact that "innovation" is an important social force that has a tremendous influence on economic and social evolution. Understanding innovation is thus an important task for scholars, as well as policymakers and businessmen / women. Theory is used in our endeavour to understand complex socio-economic phenomena, such as technological change. Two theories, neoclassical economic and evolutionary theory, stand in sometimes stark contrast to each other when it comes to understanding innovation [14]. In this outline I have focused on the latter.

I have attempted to show in this outline that the individual entrepreneur, the firm, the industry, the regional, technological, and country levels influence the creation and diffusion of innovation. Multilevel theorizing where the firm is placed in the forefront, but where processes at different levels also influence the creation, nature and diffusion of innovation, is a key distinguishing feature of an evolutionary theory of innovation. In such a theory the firm is the main actor – but there is no such thing as a representative firm. Firm heterogeneity is thus another key distinguishing characteristic of an evolutionary theory of innovation. Because firms and their managers have different perceptions and because they tend to search along idiosyncratic trajectories, different types of innovations are constantly developed in the business sector. Innovation is thus not a homogenous entity. In this perspective small, young, old and large firms contribute to innovation, although in a diverse way. It is nevertheless clear that more work needs to be done in order to develop the evolutionary perspective on innovation. As I have discussed in section 5, puzzles and research challenges abound.

I quoted Arrow [19] in the introduction and his argument that the evolutionary perspective is a "point of view" rather than a complete economic theory. Responding to this and similar views, this paper has discussed notions of theory in relation to innovation and evolutionary interpretations of innovation processes. What this discussion has showed is that evolutionary theories of innovation may be formulated at different levels, at both the "low" and "high range". It may be based on appreciative theorizing from empirical studies and abstract formal theory in the high range.

I have in this paper tried to show that most evolutionary perspectives or theories of innovation, is at present, close to appreciative theorizing and reasoning based on empirical data. Yet, such theories are not necessarily "under-theorized". Most evolutionary theories of innovation based on appreciative reasoning are closely linked to the generic variation-selection-retention model that can explain both social and economic evolution at an abstract level in the theoretical high range. A distinguishing characteristic of an evolutionary theory of innovation is therefore the presence of several appreciative theories of innovation within a single evolutionary and Darwinian framework in the theoretical high range.

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Table 1. Proportion of enterprises where innovation activity was highly hampered, EU27 (%).

	Enterprises with innovation activity	Enterprises without innovation activity
Excessive perceived economic risks	17	14
Innovation costs too high	24	19
Lack of appropriate sources of finance	19	13
Organizational rigidities	6	5
Lack of qualified personnel	16	11
Lack of information on technology	4	5
Lack of information on markets	5	4
Insufficient flexibility of regulations or standards	11	8
Lack of customer responsiveness to new goods	6	8

*Multiple answers allowed

Table 2: Correlation between past and current innovative activity.

		(1)	(2)	(3)	(4)	(5)
(1)	Product innovation 1999-2001	1				
(2)	Process innovation 1999-2001	0,69*	1			
(3)	Product R&D in 2001 (log)	0,65*	0,44*	1		
(4)	Process R&D in 2001 (log)	0,47*	0,49*	0,64*	1	
(5)	Anticipated internal R&D in 2002 (log)	0,65*	0,48*	0,96*	0,75*	1
(6)	Internal R&D in 2001 (log)	0,61*	0,46*	0,89*	0,71*	0,92*

* Correlation significant at the 0,01 level. N = 3899.

Table 3. Percentage of innovating firms answering "highly important" to the displayed factor

	% Yes
Improved quality in goods and services	37,6
Increased range of goods and services	34
Entered new markets or increased market share	29,2
Improved flexibility of production or service production	24,6
Increased capacity of production or service production	24,2
Reduced labour costs per unit output	17,6
Reduced materials and energy per unit output	9,5

* Multiple answers allowed

Table 4. Correlations between innovations developed, abandoned and ongoing innovation activity.

		(1)	(2)	(3)	(4)
(1)	Product innovation 1999-2001	1			
(2)	Process innovation 1999-2001	0,68*	1		
(3)	Abandoned innovation activity 1999-2001	0,34*	0,29*	1	
(4)	Ongoing innovative activity at the end of 2001	0,6*	0,48*	0,4*	1

*Sig at 0,01 level

Table 5. Sources of industrial innovation

	% Yes
Within the enterprise	45,7
Suppliers	23,2
Clients or customers	26,7
Competitors	12,2
Consultants	5,7
Universities	3,6
Public research institutes	2,7
Conferences	11,5
Scientific journal	8,3
Professional and industry associations	5,5

* Multiple answers allowed

[i] We use "innovation" and "technological change" interchangeably.
[ii] I thank Elaine Allen for providing the exact statistics
[iii] I thank Svein Myro in Statistics Norway for providing these statistics.
[iv] Original scale goes from 0 (not relevant) to 3 (high importance).