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Conceptualizing the innovation process towards the 'active innovation paradigm'—trends and outlook

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Abstract

This paper introduces the evolving understanding and conceptualization of innovation process models. We categorize the different approaches to understand and model innovation processes into two types. First, the so-called innovation management approach focuses on the evolution of corporate innovation management strategies in different social and economic environments. The second type is the conceptual approach which analyses the evolution of innovation models themselves as well as the models' theoretical backgrounds and requirements. The focus in this second approach is the advantages and disadvantages of different innovation models in how far they can describe the reality of innovation processes.

The paper focuses on the advantages and disadvantages as well as the potential and limitations of the approaches. It also proposes potential future developments of innovation models as well as the analysis of the driving forces that underlie the evolution of innovation models.

The article concludes that the predominant open innovation paradigm requires rethinking and further development towards an 'active innovation' paradigm.

Keywords: Active innovation, Innovation models, Innovation process, Generations of innovation models, Process dimension of innovation, Evolution of innovation models, Innovation management

JEL Classification: O14, O30, O31, O32, O33, Q55

Background

Innovation has been a phenomenon which for centuries serves the only purpose of making human beings' lives more comfortable. Throughout history, supporting, generating and implementing innovation has been of outstanding importance not only for the well-being but sometimes the survival of individuals, entities and even for whole civilizations and nations.

Over the last few decades, our understanding of innovation and its overall impact on national welfare has changed considerably. Innovation has commonly been understood as the '… implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations.' (OECD, Eurostat 2005). Innovation practice today shows that innovation is by nature a value-free term and comprehensively covers the

whole spectrum of activities from discovery to first time practical application of new knowledge. Moreover, innovation aims to fulfil recipients' requirements and goals in a new way; and it stresses that risk and uncertainty are inherent at all stages of innovation processes.

In light of the development of innovation concepts, models of innovation and innovation processes have evolved (for example, Carlsson et al. 2002; Godin 2006). Meanwhile, there is a broad range of models about innovation processes. All these models share a common understanding that innovation activities can broadly be described and visualized in process models. Some models describe the life cycle of innovation by an S-shaped logistic function, which consists of three separate phases reflecting the application phases of its development: emergence, growth and maturity (Howard and Guile 1992; Mitrova et al. 2015; Perani and Sirilli 2008). Other studies emphasize the characteristics of innovation which are defined according to innovation development stages. For example, Maidique (1980) distinguishes the recognition of the invention, development, realization and distribution as phases of innovation process. In general, linear models of innovation distinguish the discovery (invention), the definition of possible spheres of applications of the results of innovation, its development, design and use as phases of the innovation process (see for example, Niosi (1999); Godin (2006); Meissner (2015); Carayannis et al. (2015)) for simplistic description of innovation processes).

The evolving understanding of innovation as a *process* of activities raises new challenges to innovators. Although innovation is commonly regarded the outcome of a process of activities, these are by no means always succeeding in linear shape but involve several feedback loops. Hence, typical activities and steps are common for many innovation projects but the uncertainty of achieving results and finishing an activity with the required quality force innovators to feedback between the activities in order to improve the final solution. These challenges are expressed in the increasing complexity of innovations which are in turn also determined by the complexity of the surrounding, 'framework' conditions. Consequently, the complexity—expressed by the number—of information sources, knowledge and application fields for innovation is rising. In this light, innovators need to analyse and process more information for the same purpose (Carayannis and Campbell 2011; Carayannis and Turner 2006; Gokhberg et al. 2010; Gault 2009; Godin 2010).

Furthermore, until recently, innovation was considered as a process or a sequence of activities and steps but the surrounding factors such as company culture for innovation and the meaning of human resources for innovation were only partially reflected. Therefore, the authors consider it important to review the existing academic works which analyse the understanding of the emergence of innovation from a management perspective (innovation management) and from the macro perspective. The article hence aims at the following research issues:

- How did the understanding of the innovation process change?
- Which features were included in the innovation process understanding?
- Which issues remain open and deserve further elaboration to include in the innovation process understanding?

The article contributes to the understanding and academic and practical discussion of innovation processes by reviewing the emergence of innovation models. It discusses

the potentials and limitations of the different innovation process models and derives proposals for future work on the innovation models.

The work proceeds as follows. The second section discusses how the understanding and thinking of the innovation process has evolved. In the third section, we discuss these approaches in light of the innovation management literature and a broader conceptual discussion and examine the future challenges and their impact on the innovation process model. We end with a summary and elaboration of future work.

Methods

In order to give a representative review of works, a literature search was conducted to identify influential papers. We started with the identification of leading articles that look at the models and trends of innovation processes and innovation models. The literature search covers a 50-year period based on the rationale that this is certainly long enough to describe reliable trends in innovation model and process understanding and perception.

In order to conduct a review of influential papers, a literature survey was done. First, we identified the most prominent articles that discuss innovation models and processes and their meaning for innovation management. For literature search, we used ISI Web of Science, Emerald text, Science Direct and Inderscience which we consider provide sufficient information on articles in leading scholarly journals in the area. The literature search was done using the keywords 'innovation process' and 'innovation model' which in our understanding are reasonable broad to cover the related publications. Second, we scanned articles published up to January 2013 and cited more than 200 times. Third, we narrowed the findings of the search by assessing the articles abstracts. The assessment criteria used were the article's focus on the search term and the relevance of the search terms for the full article. Finally, from the article analysis, two groups were defined including the 'innovation process models' which have a clear relevance to innovation management and the 'conceptual approaches' which aim at explaining the emergence of innovation in conceptual sense.

Findings and Discussion - Understandings of the innovation process

Innovation is characterized by a high complexity that requires unorthodox thinking and must be socially accepted to succeed. Hence, the term innovation includes new technological, economic, organizational and social solutions which are not necessarily marketable in an economic sense with direct monetary impact but are applied and used. Therefore, knowledge and ideas are essential components of the term innovation.

The literature has devoted much attention around 'idea driven' innovation processes since the second half of the twentieth century. Usher describes the innovation process as the perception of an unsatisfied need, setting the stage following the primary act of insight, critical revision and development (Usher 1954, 1955). Knight (1967) and Bessant and Tidd (2007) consider the first stage to be recognizing the need for innovation, followed by innovation generation, innovation adoption and the use of innovation. Based on the recognition of the invention, Maidique (1980) assumes immediate action taken for the development of new products followed by the market realization of product and the distribution of products to customers. Carlsson et al. (1976)) make the process more concrete by including an application phase of research/technology after

the initial discovery (need for idea) concluding with development, design and utilization activities. In Marquis' model (1988), the process starts with the initial recognition of the technical feasibility and the assessment of potential market demands which in his view lead to idea formulation (fusion into design concept and evaluation), problem-solving (search, experimentation and calculation; readily available information), solution (solution through invention; solution through adoption), development (work out the bugs and scale up) and utilization and diffusion (implementation and use). Gallivan (2001) recognizes management objectives for change as the initial driver for innovation, complemented by the search for invention availability for technological inventions and the primary innovation adoption process embedded in a company's mandate to adopt other influences on innovation adoption which eventually leads to a secondary innovation adoption process. Kamal (2006) has a comparable understanding by first focusing on the motivation for innovation, then the specific conception of innovation and formal proposals to the organization about innovation adoption before entering into the actual adoption decision stage. Next, the implementation is launched with the confirmation of the innovation idea, the test of user acceptance of the technology and the integration of innovative technology with other information system applications.

Other linear approaches are considered 'invention-led' processes (see for example, Carlsson et al. 1976). A more simplified linear process was postulated by Merrifield (1986) who includes the steps of invention, translation and commercialization. Niosi (1999) and Godin (2006) introduce the definition of innovation application areas after the initial discovery (invention) stage. The application definition stage is followed by innovation development, design, and use.

'Creation-need' process models were developed by Aiken and Hage (1971) and Pierce and Delbecq (1977) who argue that the innovation process spans the stages of generation, acceptance and implementation. Howard and Guile (1992) first showed the S-shaped logistic function of emergence, growth and maturity while Baregheh et al. (2009) distinguish creation, generation, implementation, development and adoption.

Taking the large number of models together, we find that two main process models have emerged: (1) innovation management process models and (2) conceptual process models. These are described in the following.

Innovation management process models

These simplistic approaches cannot be treated as real models of the innovation process but rather as a schematic description. Although genuine models which are more complex were developed in the scientific literature in the second half of the twentieth and the early twenty-first centuries, these models remain idealistic descriptions of innovation generation. Such process models have certain implications for the organization of innovation in companies, research institutes, and engineering companies; however, they will change each time a new innovation project is started. One can also argue that there is in fact no definite innovation project but rather overlapping activities of different kinds and intensities which form the basis for the next generation of innovation. Table 1 shows a summary of these understandings of the innovation process. It is evident that significant share of the innovation management literature describes the innovation process as somewhat linear mainly in not only the early works (Usher 1954, 1955) but also in more recent

Table 1 Innovation models evolution in historical perspective

Generation	Innovation model	Period	Authors of fundamental ideas	Essence of the model
1	Technology push	1950s—late 1960s	Usher (1955)	Linear process
2	Market (need) pull	Late 1960s—first half of 1970s	Myers and Marquis (1969a, b)	R&D on customer wishes
3	Coupling model	Second half of 1970s—end of 1980s	Mowery and Rosenberg (1979)	Interaction of different functions
	Interactive model		Rothwell and Zegveld (1985)	Interaction with research institutions and market
4	Integrated model	End of 1980s—early 1990s	Kline and Rosenberg (1986)	Simultaneous process with feedback loops; 'Chain-linked model'
5	Networking-model	1990s	Rothwell (1992)	System integration and networks (SIN)
6	Open innovation	2000s	Chesbrough (2003a)	Innovation collaboration and multiple exploitation paths

Source: adapted by authors from Campodall'Orto and Ghiglione (1997) and Rothwell (1992)

papers (Kamal 2006; Baregheh et al. 2009). The full overview of innovation process models is shown in the Working Paper by Kotsemir and Meissner (2013) "Conceptualizing the innovation process—trends and outlook".

The first-generation 'technology push' model postulates that new industries mostly emerge from new technological opportunities which resulted in technology-led regeneration of 'old' sectors requiring rapid applications of technology to enhance the productivity and quality of production. This, in turn, led to rapid employment creation, rising prosperity, and a consumer boom of 'new products' (consumer electronics and automobile industry). Scientific advances were perceived in favour of industrial innovation and as instruments for solving society's greatest challenges. The logic of the 'technology-push' model approach was that the greater the R&D 'input', the more success for new products 'as output'; this model presupposes a linear process of technological change (industrial innovation), spanning scientific discovery, technological product development and product sales. However, the process of transformation became the object of study in itself (Carter and Williams 1957) and this later formed the main focus for the evolutionary models of the late 1990s as well as the role of the marketplace in processes of transformation (Cook and Morrison 1961), upon which the innovation milieu models of the 2000s were built.

In the late 1960s, Myers and Marquis developed the 'technology push' idea of market-relevant aspects (second generation). They reasoned that innovation resulting from R&D activities is targeted towards satisfying customer needs: the 'market-pull' approach (Myers and Marquis 1969a, b). Hence, the second generation, 'market-pull' models appeared in the second half of the 1960s, and early 1970s emphasized how technologies contribute to decelerated growth of new product markets and a balancing of supply and demand on new product markets, and how they assume that new products are based on existing technologies. Thus, innovation was still understood as a linear process, as in the first-generation models yet, the difference was that market needs were identified first, followed by development, manufacturing and sales. The main risks of this approach included the limited implementation of long-term R&D programmes

and the danger that companies could be locked into a regime of technological incrementalism and lose the capacity to adapt to any radical market or technological changes (Hayes and Abernathy 1980).

Mowery and Rosenberg (1979) first described the importance of corporate functions interacting in the innovation process. Shortly afterwards, Rothwell and Zegveld (1985) extended the traditional linear approach to connect businesses with external research institutions and the market in their 'coupling model' (third generation, of the early 1970s and early 1980s). This third generation saw two major oil crises, high rates of inflation and demand saturation (stagflation), which resulted in an oversupply of production capacities and growing structural unemployment. In this context, science and technologies were needed to understand the basis of successful innovation which was underlined by a stream of empirical studies of innovation processes (Cooper 1980; Hayvaert 1973; Langrish et al. 1972; Myers and Marquis 1969a, b; Rothwell et al. 1974; Rothwell 1976; Rubenstein 1957; Schock 1974; Szakasitz 1974; Utterback 1975). The model coupled the 'technology-push' and 'market-pull' models and was perceived as an extreme and atypical model of the innovation process. It strongly emphasized the interactions between technological capabilities and market needs, as well as the confluence of technological capabilities and market needs within the framework of the innovating firm. Rothwell and Zegveld (1985) argued that the innovation process can be functionally distinct but has interacting and interdependent stages; thus, the process itself can be logically sequential, although not necessarily continuous.

The 'chain-linked'/integrated innovation process model (fourth generation) considered the innovation process as fundamentally a parallel process in which the corporate functions are connected through numerous backward (feedback) loops (Kline and Rosenberg 1986). They saw a considerable growth of generic technologies, the emergence of new generations of IT-based manufacturing equipment, and a shortening of product life cycles. During this time, firms increasingly engaged in strategic alliances (Contractor and Lorange 1988; Dodgson 1993; Hagedoorn 1990) and emphasized technological accumulation, core businesses and key technologies (Peters and Waterman 1982). These activities were accompanied by greater networking activities of small innovative firms (Docter and Stokman 1987; Rothwell 1991).

The innovation process of the 'fifth generation' is based on the 'chain-linked' model and adds a strategic component—the integration of cooperating companies, the growing importance of information and communication technologies and the use of expert systems and networks (Rothwell 1992). This model is characterized by integrated, parallel, flexible and interconnected innovation processes since the early 1990s. It was recognized that successful corporate innovation strategies were driven by centrally integrated and parallel development processes, strong and early vertical linkages, and the use of electronics-based design and information systems. Integrated innovation models highlight a reasonably strong presence of collaborative, pre-competitive research, joint R&D ventures and R&D-based strategic alliances. As a result, the speed and efficiency of developing innovation increased with the emergence of radical new products and developments along established design trajectories.

The 'sixth-generation' model emerged when Chesbrough (2003a, b) postulated the open innovation paradigm, which highlights the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external

use of innovation, respectively. It assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology (Chesbrough 2006). Innovations are no longer 'just' seen as a process, involving various functions. Rather, it is explained by the participation of a number of different entities including suppliers, public R&D facilities and (business) external R&D facilities as well as customers with varying degrees of intensity.

Conceptual innovation process models

Marinova and Phillimore (2003) take a broader perspective in analysing the innovation process models. They find six generations of innovation models:

- Black box model—first generation
- Linear model—second generation
- Interactive models—third generation
- System model—fourth generation
- Evolutionary model—fifth generation
- Innovation milieu model—sixth generation

The black box model (first generation) is based on the Solow production function (Solow 1957) which was the first attempt to include technological progress in the economic equation. Innovation was understood as one driver of economic growth which could not be explained by changes in capital, and labour instead was assumed to be caused by technological advances. The black box term was a starting point for the innovation discussion postulating the apparent invisibility of what happens when investing in science and technology. Accordingly, the black box innovation model assumes that the innovation process itself is not important and that the only things that count are inputs and outputs, e.g., money invested in R&D (input into the black box) will generate, as a rule of thumb, new technological products (outputs). It is argued that the use of appropriate and timely adjusted management activities makes certain firms more successful than others (Rosenberg 1982; Mansfield 1995). Eventually, this understanding led to a reluctance of researchers to address the link between science, technology and industrial development, a reliance of policymakers on market mechanisms to support technological developments and a narrower understanding of innovation which was limited to R&D exclusively. Therefore, the need arose to open the black box and explore its interior.

The second-generation models in 1960s and 1970s emphasized mainly linear models which aimed at opening the black box of innovation, focusing on specific processes that generate new technologies and learning involved in technological change. It was expected that innovations open the road to formulating policies, which would stimulate R&D and consequently the development of new products and processes using a step-by-step process, e.g. a sequence of activities that lead to technologies being adopted by markets. This was reflected in three main models, the *science push* model in which basic science-based discoveries lead eventually to technological developments which result in a flow of new products and processes to the market place (Rothwell and Zegveld 1985), the *technology push* model emphasizing the entrepreneur as the person taking the risk

and overcoming the barriers in order to extract the monopolistic benefits from the introduction of new ideas (Coombs et al. 1987) and the *need pull* ('market-driven') model which postulates that the causes of innovation are existing demands (Rothwell and Zegveld 1985). The technology push/need pull dichotomy analysed a wide range of successfully introduced new technologies and numerous cases of failure (Coombs et al. 1987). The linear models achieved to developing an easy and clear model of innovation and setting the direction for further research.

The interactive models in the third generation build on the main disadvantage of previous models, namely the extremely simplified picture of the generally complex interactions between science, technology and market. These models were understood to giving a deeper understanding and a more thorough description of all the aspects and actors of the innovation process and providing a new look at innovation as a process subdivided into separate stages, each of them interacting with the others. In essence, the interactive models stressed that innovation is no longer the end product of a final stage of activities but can occur at various places throughout the process and the innovation process can also be circular (iterative) rather than purely sequential (Rothwell and Zegveld 1985; Beije 1998; Kline and Rosenberg 1986). The interactive models eventually brought together the technology push and market pull approaches into a comprehensive model of innovation and developed a more complete and nuanced approach to the issue of the factors and players involved in innovation. However, the interactive models still did not specify the driving forces for the innovation engine, why some companies are better at doing in innovation than others, strategies of learning for organizations and the role of the company's environment for the success of innovation.

Against these weaknesses, the system innovation model (fourth generation) emerged. The system innovation model claimed to explain and confirm the fact that complexity of innovation requires interactions not only from a wide spectrum of agents within the firm but also from cooperation amongst firms. This approach proved unique in its looking at innovation from a system perspective, which included an emphasis on interactions, inter-connectedness and synergies. It postulated that firms that do not have large resources to develop innovation in-house can benefit from establishing relationships with a network of other firms and organizations, the set of elements in the innovation system and their interconnectedness and ways of interaction are the key factors for success and functioning of this system. The most well-known system model was the national systems of innovation (Freeman 1991; Lundvall 1992; Nelson 1993, 2000). The system models mainly explained the place and role of small firms in innovation, the means of surviving of small firms in the competition and from pressures from large companies, synergetic effects from innovation networks, differences between countries and the various role governments play and highlighted specific patterns of scientific, technological and industrial specialization, institutional profiles and structures as well as patterns of learning for different countries. These features were described in the concepts of innovation chains for manufacturer-distributor relationships (Marceau 1992; Dodgson 1993), innovation complexes for the integration of firms (Gann 1991, 2000), strategic networks/alliances for long-term strategic contracts between companies and third parties from external environment (Jarillo 1988; Sako 1992), regional networks with a focus on geographic location of innovators (Dodgson 1993) and regional systems of innovation on the influence of specific regional environment on the modes of innovation processes (Cooke 1998). The system

models have been widely used although in their original shape, they did not stress the lifetime of innovation networks, the potential of networks for promoting innovation in large firms, the meaning of trust building in the networked innovation and the ways of its achievement, mechanisms of simultaneous cooperation and competition within the innovation network and partially only the role of governments, proactive policies and regulatory environments in creating favourable conditions for such linkages and interactions.

The fifth generation evolutionary models aimed to find approaches to challenge the main disadvantage of previous models which were identified as failures in neoclassical economics to deal with dynamic qualitative changes and weak explanatory power of the mechanical metaphor adopted in orthodox economic thinking for innovation dynamics (Hodgson 1993; Saviotti 1996). The key elements of evolutionary models are the external environment (patent regimes, market structures, standards and regulations as well as natural environment) in which technologies are developed, the population perspective and variation (not only average values but also variances in the population of firms/products are in focus of analysis). Evolutionary models commonly argue that innovation by definition involves change, decisions on innovations are made not merely based on price consideration, imperfections are necessary conditions for technical change to occur in a market economy, outcomes from innovation activities are to a large degree determined by the evolutionary process (at country or firm level) and that the innovation process is as important as the results from R&D as well as that firms can be dynamic self-organized systems (Dosi and Orsenigo 1994; Metcalfe 1995; OECD 1996). The models are directed to explaining the 'bounded rationality' problem (Dosi and Egibi 1991) and the processes of failure of generally fit technologies and the success of 'overlooked' technologies (Tisdell 1995) as well as highlighting the value of diversity (Dowrick 1995). Overall, they shed light on decision-making schemes and interaction of participants' modes in innovation processes. Related concepts to the evolutionary models are the concept of technological imperatives (Rosenberg 1976), innovation avenues (Sahal 1981), technological trajectories (Biondi and Galli 1992; Pavitt et al. 1989), technological paradigms (Dosi 1982, 1988) and technoeconomic paradigms (Freeman and Perez 1988; Perez 1983) which commonly argue that a certain extent of stable regularities in innovation process and technological development are the product of 'negotiations' between key institutions and result of adaptation to new conditions of work. These models provided reasonable stimulus for further research, especially they stressed the need for explaining the mechanisms supporting the continuity of the old and the introduction of new equilibriums in modeled innovation processes and the need for characterization of turning points in the innovation process in the framework of evolutionary models.

Eventually, the innovation milieu concepts (sixth generation) were developed which look at theories of growth of regional clusters of innovation and high technology and the importance of geographical location for knowledge generation (Feldman 1994; Keeble and Wilkinson 2000). Whereas previously territorial organization was assumed a crucially important element for innovation process (Bramanti and Ratti 1997) and innovation understood as being geographically localized and innovation processes highly dependent from specific resources which are unique for each location (Longhi and Keeble 2000), the innovation milieu model stresses active territorial relationships, e.g. inter-firm and inter-organizational interactions fostering innovation, different

territorial socio-economic actors, e.g. local private or public institutions supporting innovation, a specific culture and representation process and a dynamic local collective learning process (Camagni 1991). The innovation milieu approaches look at success factors of small- and medium-sized enterprises, mechanisms through which certain localities give birth to a large number of small innovative firms and provide explanation how different localities have different patterns and paths in knowledge development and transfer of high technology. This is especially apparent in the innovation clusters approach which emphasizes groups of innovative firms located in one region (OECD 1999), the learning regions approach (e.g. Florida 1995; Kirat and Lung 1999; Macleod 1996) and the collective learning concept (Keeble and Wilkinson 2000). The main argument of these concepts is that learning is the most important feature of any economy and that successful regions provide particular combinations of institutions and organizations to encourage knowledge development within the community and learning by local firms through conscious and unconscious mechanisms.

Summary

In general, the innovation process models developed to date are similar in that they all emphasize the key role of sources of innovation (such as sources of inspiration), which have changed considerably in innovation processes theory. Moreover, over time, the understanding of the process in which innovation is generated has deepened. On the one hand, the meaning of the sources (triggers) of innovation has changed, and on the other hand, the different phases/stages of the innovation process have been substantially redefined. Another new feature is moving away from understanding the innovation process as a linear sequence towards seeing it as made up of different, integrated phases. The individual phases overlap each other, and there are also backward loops ('feedback loops'). In terms of transferring knowledge and technology in course of innovation development, the literature emphasizes interactive models that mutually enrich basic research and applied research and development.

All approaches distinguish between the origins of the market phase. In this understanding, the real innovation process is completed with the first economic use and the associated transition from the development cycle of a product or process to its market cycle. The market cycle of an innovation can be divided into innovation diffusion and adoption. Under diffusion, an early communication of the innovation is understood (i.e. in the model of Rogers (1995)) followed by the physical diffusion of innovation in the market. Diffusion includes both the diffusion of an innovation geographically as well as within specific industries or markets (OECD, Eurostat 1997). Adoption of innovation by the user means actual use (Rogers 1995). This is not to be equated with the innovation's general and permanent application; rather, users can disregard innovation because of unfulfilled expectations, substitution technologies or other reasons connected with further use of the technology. In the mid-twentieth century, a view predominated that innovation is entirely due to technological breakthroughs that will automatically generate demand (the technology push approach). The essential feature of these first-generation models is the assumed linear sequence of individual steps from research to market introduction.

Currently, the predominant thinking is that innovation is the result of multiple relationships of different entities and organizations in the 'open innovation paradigm'.

Innovation models analysis: a discussion

In this paper, we compared two basic analytical approaches to the evolution of innovation process models. The first is the 'innovation management' approach focusing on the analysis of innovation management strategies at a firm level in different social and economic frameworks. The second is the 'conceptual approach', which focuses on the evolution of innovation models themselves (in a conceptual sense) as well as on the analysis of the models' theoretical backgrounds and requirements. This approach concentrates on the advantages and disadvantages of the different models in terms of their ability to describe the reality of innovation processes. Analysing these two approaches shows a shift from a macro (meso level) to a micro level in theoretical innovation models and models of innovation management. We also illustrated the non-linear nature of the dynamics of the evolution of conceptual innovation models during the last 15–20 years. In the previous section, we showed that the understanding of innovation processes has changed considerably over the years. More recently, the two major approaches of innovation process thinking, e.g. the innovation management approach and the conceptual approach, show remarkably different features.

'Innovation management' approach

The models following the 'innovation management' approach do not focus on the development of innovation but rather on the evolution of companies' innovation management strategies under different social, economic and political circumstances. One of the most well-known examples of such an approach is the so-called Rothwell five generations innovation model. In his seminal work, Rothwell (1994) identifies five generations of innovation management models and describes their evolutionary development as well as the respective social and economic policymaking and management strategy framework. Other major studies on the evolution of innovation management models are Niosi (1999), Verloop (2004), Cagnazzo et al. (2008), Jacobs and Snijders (2008) and Eveleens (2010). The distinctive feature of Rothwell's model is the comprehensive analysis of innovation management models themselves and their social and economic framework and focuses on the evolutionary development of innovation strategies of companies in different economic conditions. The framework proposed by Rothwell can be considered almost universal. For example, in Jacobs and Snijders (2008), the last (fourth in a row) generation of innovation management models is treated as 'learning and interaction' models—in line with the fifth generation of innovation models. Moreover, according to the comprehensive review of literature on innovation management models carried out by Cagnazzo et al. (2008), all papers on the innovation management model use Rothwell's five-generation sequence as a framework. In other words, in the nearly 20 years that have passed since the publication of Rothwell's article in 1994, there have not been any studies proposing a sixth (or even seventh) generation of innovation management models. The reason may be that recent trends in innovation strategies such as networking, outsourcing, globalization and customer

involvement can be treated as 'flexible', 'parallel', 'interactive' and an 'interconnected' process. Such logic eliminates the need for building a new generation of innovation management models.

'Conceptual' approach

The 'conceptual approach' focuses on the conceptual essence of models and analyses their theoretical backgrounds as well as their advantages and disadvantages (Marinova and Phillimore 2003). Analysis of the related literature shows that in most cases, the authors concentrate on the historical development of only one specific type of innovation model, i.e. the national innovation system (Bazalt and Hanush 2004; Sharif 2006; Godin 2009) or the regional innovation system (Iammarino 2005; Asheim et al. 2011). In contrast, Marinova and Phillimore (2003) encompass the whole sequence of innovation models from the earliest stages. The authors analysed innovation models per se, viewing the models as conceptual and theoretical constructs. Some scholars have also analysed the theoretical background and explanatory power for each generation of models, as well as the potential directions for the models' future development.

Differences and similarities of the management and conceptual approach

Therefore, the main difference between Rothwell's and Marinova-Phillimore's work is the scope, namely the focus of analysis. Rothwell primarily analyses not the innovation models themselves but rather the strategies of firms' innovation activity under different social, economic and political circumstances. Thus, Rothwell's model is primarily for companies. Marinova and Phillimore analyse the models themselves as well as the models' theoretical backgrounds and principal advantages and disadvantages. Therefore, in the framework of this work, innovation models are for the whole economy (Vishnevskiy et al. 2015; Proskuryakova et al. 2015; Gackstatter et al. 2014).

However, the similarities in the generation of models highlighted by Rothwell and Marinova and Phillimore are also very important. The evolution of innovation models starts from 'in search' (or simplistic) models of the first two generations, than goes to macro level (third-generation models in Rothwell's work as well as to some extent in the fourth- and fifth-generation level models in Marinova and Phillimore's work) and shifts to the micro level (sixth generation in Marinova and Phillimore's work and fourth and fifth generation in Rothwell). In Marinova and Phillimore's framework of analysis, third generation models can be described as 'transition' models from first 'immature' models to the more mature models. The first two generation models in both Rothwell and Marinova and Phillimore can be treated as meso-level models since they assume that the processes described are generally identical for all firms. Rothwell's third-generation models cannot be treated as purely macro models; rather, they are meso-level.

Key drivers for the development of models of the third generation were the oil price shock and high inflation on the 'economic' side and the need for upgrading the previous two generations of models. In other words, there was a need for a model that can explain the essence of the innovation process itself. Therefore, the third-generation models were more for the economy than for companies. The fourth-generation models are 'case study' models. The 'case' here is the example of Japanese companies' success

in developing innovation strategies and penetrating the high-tech production market. These models are already micro level since their key building blocks are integration of suppliers into the product development process and integration of activities and functions between companies. Fifth-generation models are also the micro level: they emphasize the network features of the innovation process and the parallelism in the dynamics of innovation processes.

Marinova and Phillimore (2003) treat the evolution of the innovation models in generally the same way. The third-generation models (interactive models) are 'transition models' which 'correct the mistakes' of the models of the first two generations but they still lack some fundamentalism. System models (fourth generation models) are in general macro-level fundamental models. The innovation models of the last two generations gradually drift from macro to micro level. Evolutionary models are a kind of meso-level models: they analyse the behaviour of many firms in the context of the environment which is more or less common to all firms. Innovation milieu models are already purely microeconomic models focused on separate firm locations within regions.

Marinova and Phillimore (2003) offer a closer look at the history of innovation models. They show that the evolution of the model generations is non-linear. Only the first three generations of innovation models are sequential to each other. The last three generations of models are not directly sequential. In other words, the evolutionary generation can also be seen as the 'additional fourth generation' in innovation models development: the 'second fourth generation', 'fourth generation B', etc. The explanation is as follows. Evolutionary models as well as system models analyse the actors in the innovation process and their interactions. However, system models look more closely at the system of these relationships and at the driving factors of the system's development. On the other hand, evolutionary models concentrate on the interactions between actors of innovation process and the diversity of these actors. The sixth generation of innovation models from a conceptual point of view can also be seen as an extension of the third-generation innovation models rather than the further development of evolutionary models. Innovation milieu models cannot be treated directly as the development of third-generation innovation models since they shift from the meso to the micro level. They also focus on the importance of firms' geographical location rather than on the processes of firms' interactions within or across some geographical borders.

In contrast, in Rothwell's work, all generations of innovation management models are really in sequence. However, the changes of scope (from meso to micro level) between the third- and fourth-generation models are clear. These models follow one another.

The analysis reveals several common features in the understanding of innovation processes. Despite these commonalities, the implications for management tools and instruments vary significantly. The innovation management-centred approaches require more operational management tools to initiate, guide, steer and monitor innovation processes which eventually result in economic impact. The conceptual approach, on the other hand, is more focused on the innovation (management) framework conditions; this latter approach hence requires instruments and tools for designing framework conditions conducive to innovation at different levels (Meissner 2014; Khripunova et al. 2014; Gokhberg and Meissner 2013; Carayannis et al. 2011; Zhang et al. 2015).

As innovation process models have evolved over time, we have gained a greater understanding of how innovation actually occurs. Furthermore, we have learned that

innovation itself is not a result but rather a process and flow of activities that aim to solve a known or unknown problem. This problem, as well as its societal implications at different levels, may or may not be widely understood. Innovation is essentially the combination of existing knowledge, the generation of new knowledge and the targeted use of existing and new knowledge to create a novel solution. Along with the rapid increase in existing knowledge and the competences to use that knowledge, new challenges arise for generating innovation.

Conclusions—revisiting innovation models towards the 'active innovation' paradigm

The most recent innovation models increasingly postulate external relationships of innovators in many different shapes including the acquisition and incorporation of knowledge and technology from outside the organization. Such knowledge and technologies can be either publicly accessible or privately owned by other companies, individuals or research institutions. Furthermore, external knowledge and technologies are available either in a codified or persona land published, undisclosed, form. R&D service providers and public and private research institutions and increasingly training institutions contribute much to build, develop and diffuse existing, publicly available 'knowledge and technology pools.' More studies are needed to examine the role of universities as employer and educator of highly skilled workers and researchers especially for R&D. These institutions also provide partners and/or service providers for external innovation-related activities (especially R&D activities). The company's internal R&D activities—as part of the innovation process—are available in the company's knowledge and existing technologies which are not only a prerequisite for implementing in-house innovation activities but also for the use of external sources for innovation.

The most recent generation of innovation models is not directly related to earlier ones. Examples of these models include the value chain evolution theory developed by Christensen and Raynor (2003), the strategic innovation process model proposed by Afuah (2002), the Moore (2005) 'category-maturity life cycle model' and the Hamel (2000) business strategy innovation model (2002). Moore's and Hamel's approaches show the potential to incorporate innovation process model thinking. These models cannot really be treated as descendants of sixth-generation models. They draw on some features from the system and evolutionary models. However, they do not apply system or evolutionary models at a micro level but rather develop third-generation models, with new aspects such as network infrastructure or a greater emphasis on outsourcing added. The models discussed in the article share the common feature that they all aim to explain the emergence of innovations from conceptual and process perspective but do not take account of the side resource of innovation. While the current open innovation paradigm remains dominant in innovation model thinking, we argue that even this innovation understanding and model (and thus innovation processes) needs to be extended by the human resource dimension and the meaning and impact of organizations' innovation milieus. A company's innovation milieu is strongly interrelated with human resources management and policies for attracting and retaining talent. Frequently, attracting talent to companies for innovation is less problematic than keeping talent on board and motivating people to perform outstandingly. This is challenging because firms lack staff who have capabilities that are directly related to not only actual innovation activities (e.g. often related

to R&D) but also capabilities in management and legal affairs. Firms need these additional competences in light of the increasingly external nature of innovation. Furthermore, the economic pressure on companies leads to higher expectations by the corporate leadership from the innovation-related activities by all company units. The instruments used for monitoring and assessing innovation projects are improving considerably. Firms' needs for innovation-related competences and corporate management's higher expectations for innovation are very important determinants of current corporate activities, although both inherit the danger that innovation is understood a self-fulfilling prophecy. In other words, once companies invest in innovative projects, the corporate leadership expects returns on investment in ever shorter periods to meet externally imposed expectations. Accordingly, it is important to reconsider how innovation and human resource management are organized internally to prepare staff to respond to these challenges.

Equally important is the incorporation of public attitudes and perception of innovation which developed into a major driver for the acceptance of innovation by society.

Therefore, we argue that the current predominantly open innovation paradigm needs to be modified to incorporate a stronger emphasis on the human resources involved in innovation. There are signs that companies are already paying more attention to the human factor for innovation and the public perception. Consequently, we are convinced that companies will strive for an 'active innovation' model which builds on the open innovation paradigm. In this respect, the scientific community should develop approaches which combine the open innovation concept with the human factor and the public perception, or in other words, the 'company innovation ecosystem' and the product innovation ecosystem. We understand 'product innovation ecosystem' as a community of users of an innovation which are driven by their specific agendas which are also embedded in society. Hence, in order to accelerate the understanding the relationship between 'company innovation ecosystems' and 'product innovation ecosystems', more efforts in research are required.

Competing interests
The authors declare that they have no competing interests.

Authors contribution
All authors read and approved the final manuscript. All authors contributed equally to the work.

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