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CONCEPTUALIZING THE INNOVATION PROCESS – TRENDS AND OUTLOOK

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CONCEPTUALIZING THE INNOVATION PROCESS – TRENDS AND OUTLOOK

This paper introduces the evolving understanding and conceptualization of innovation process models. From the discussion of different approaches towards the innovation process understanding and modeling two types of approaches to the evolution of innovation models are developed and discussed. First the so-called innovation management approach which focuses on the evolution of the company innovation management strategies in different socioeconomic environments. Second is the analysis the evolution of innovation models themselves in conceptual sense (conceptual approach) as well as analysis of theoretical backgrounds and requirements for these models.

The main focus of analysis in this approach is on advantages and disadvantages of different innovation models in their ability to describe the reality of innovation processes.

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

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Keywords: innovation models, innovation process, generations of innovation models, process dimension of innovation, innovation models evolution; innovation management.

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1. Introduction

Innovation has been a phenomenon for centuries which serves the only purpose of making live of human beings more comfortable. Ever in 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 in some cases even for whole civilizations and nations.

Over the last decades the understanding of innovation and the overall impact of innovation on national welfare has changed considerably. Innovation was understood as "… 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 term free of values and comprehensive covering the whole spectrum of activities from discovery to first time practical application of new knowledge of any kind which aims at the fulfillment of requirements and meeting the goals of recipients in a new fashion and way there risk and uncertainty is inherent at any stage.

Following the development of innovation concepts [Godin, 2008; Kotsemir and Abroskin, 2013] models of innovation and innovation processes evolved [for example Carlsson et al., 2002; Godin, 2006]. Meanwhile there is a broad range of innovation process models. All models share the common understanding that innovation activities can more or less correctly be described and visualized in process models. Some models describe the life cycle of innovation by S-shaped logistic function, which consists of three separate phases reflecting the application aspect of its development: the emergence, growth and maturity [Howard and Guile, 1992]. Other studies, emphasize the characteristics of innovation which are defined according to innovation development stages, e.g. Maidique distinguishes the recognition of the invention, development, realization and distribution as phases of innovation process [Maidique, 1980]. Linear models of innovation in general distinguish the discovery (invention), the definition of areas of application of the results of innovation, its development, design and use as phases of the innovation process (see for example [Niosi, 1999; Godin, 2006] for simplistic description of innovation process).

The evolving understanding of innovation as a process of activities raises new challenges to innovators. 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 analyze and process more information for the same purpose.

The paper discusses the evolution of the innovation process understanding and thinking in the first chapter. In the second chapter these approaches are discussed in the light of a innovation management and a broader conceptual discussion. The paper concludes with an outlook of future challenges and their impact on the innovation process model.

2. Evolution of innovation process understanding

The evolution of innovation is characterized by a high complexity requiring unorthodox thinking and in result social acceptance. 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 applicable and are being used. Therefore knowledge and ideas are essential components of the term innovation.

A reasonable share of innovation management literature describes the innovation process as somewhat linear approaches including linear innovation diffusion (table 1). Such simple representation of innovation processes can be found in early works [Usher, 1954, 1955] as well as in more recent papers [Kamal, 2008; Baregheh, Rowley and Sambrook, 2009]. These simple models vary in the number and shape of steps and stages of the innovation process. In general three major steps can be distinguished:

- idea (or invention) of "something new" (product, service or process (organizational or technological));
- development (production, "doing") of "something new";
- commercialization (diffusion, "selling") of "something new".

Table 1: Innovation models evolution in historical perspective

Generation	Period	Authors of fundamental ideas	Innovation model	Essence of the model
1	1950-s – late 1960-s		Technology push	Linear process
2	Late 1960-s – first half of 1970-s	Myers and Marquis, 1969	Market (Need) pull	R&D on customer wishes
3	Second half of 1970-er – end of 1980-s	Mowery and Rosenberg, 1979	Coupling model	Interaction of different functions
		Rothwell and Zegveld, 1985	Interactive model	Interaction with research institutions and market
4	End of 1980s – early 1990-s	Kline and Rosenberg, 1986	Integrated model	simultaneous process with feedback loops; "Chain-linked" Model"
5	1990-s	Rothwell, 1992	Networking-model	System integration and networks (SIN)
6	2000-s	Chesbrough, 2003	Open innovation	Innovation collaboration and multiple exploitation paths
7 (emerging, not formed yet)	2010-s		Open innovator	Focus on the individual and framework conditions under which to become innovative

Source: authors' adaptation from Camodall'Orto and Ghiglione (1997) and Rothwell (1992).

Literature pays much attention to "Need for Idea Driven" innovation processes since the second half of the XX 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]. Kinght (1967), Bessant and Tidd (2007) consider the recognition of needs for innovation the first stage 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 product to customers. Carlsson et. al. (1976) make the process more concrete by including a phase of application of research/technology after the initial discovery (need for idea) concluding with development, design and utilization activities. In Marquis' model [Marquis, 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 being the initial driver for innovation complemented by the search for invention availability for technological inventions and the primary innovation adoption process embedded in 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 about innovation, formal proposals to the organization about innovation adoption before entering into the actual adoption decision stage. After that the implementation is launched with the confirmation of the innovation idea, the test of the user acceptance of the technology and the integration of innovative technology with other information system applications.

Other linear approaches are considered "Invention-led" processes, e.g. Carlsson et al. (1986). A more simplified linear process was postulated by Merrifield (1986) who includes the steps invention, translation and commercialization. Niosi (1999) and Godin (2006) introduce the definition of areas of innovation application after the initial discovery (invention) stage in their work. After the application definition stage the development of innovation, design of innovation and use of innovation follow.

"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 generation, acceptance and implementation. Howard and Guile (1992) first show the S-shaped logistic function of emergence, growth and maturity while Baregheh at al. (2009) distinguish creation, generation, implementation, development and adoption.

However these simplistic approaches cannot be treated as real models of the innovation process but rather as the schematic description of innovation process. Although genuine models which are more complex were developed in the scientific literature in the second half of the 20ties and the beginning of the 21st century these models remain idealistic descriptions of the overall innovation generation. Such process models have certain implications for the organization of innovation in companies and also in research institutes and engineering companies. However these models will change each time a new innovation project is started. One can also argue that there is no definite innovation project at all but rather overlapping activities of different shape and intensity which form the basis for the next generation of innovation.

In general the innovation processes developed thus far share the varying relevance and importance of sources for and of innovation, e.g. sources of inspiration, which have changed considerably in the innovation process theory. Moreover over time the understanding of the innovation generation process deepened eventually showing that at the one hand the meaning of the sources (trigger) of innovation has changed, on the other hand, the different phases of the innovation process were substantially redefined. Another new feature is the departure from the understanding of the innovation process as a linear sequence of different phases to an integrated view of the process. This means that the individual phases overlap each other and in part it is between the individual phases as well backward loops ("feedback loops"). In terms of knowledge and technology transfer interactive models that enrich basic research, applied research and development mutually but not sequential are emphasized.

All approaches share the distinction between the geneses of the market phase. In this understanding the real innovation process is completed with the first economic approach or use and the associated transition from the development cycle of a product or process in its market cycle. The market cycle of an innovation can be divided into the diffusion and adoption of innovation. Under diffusion an early communication of the innovation is understood (i.e. in the model of Rogers 1995) followed by physical diffusion of innovation in the market. Diffusion includes both the diffusion of an innovation in a geographical sense as well as within specific industries or markets [OECD, Eurostat, 1997]. Adoption of innovation by the user means the actual use [Rogers, 1995]. This is not to be equated with the general and permanent application of innovation rather users can disregard innovation because of unfulfilled expectations, substitution technologies or for other reasons from further use of the technology. In the mid 20th Century the view that innovation is entirely due to technological breakthroughs that will automatically generate a demand (technology push approach) dominated. The essential feature of these models of the first generation is the assumed linear sequence of individual process steps of the research to market introduction.

Myers and Marquis opened late 1960-s years the "technology push" view of market-relevant aspects (2nd generation). They reasoned that innovations resulting from R&D activities are targeted towards the satisfaction of customer needs (market pull approach) [Myers and

Marquis, 1969]. As a consequence, Mowery and Rosenberg (1978) first described the importance of interactions of the innovation process of corporate functions involved. Rothwell and Zegveld (1985) extended shortly afterwards the traditional linear approach to connecting businesses with external research institutions and the market (3rd Generation). The "chain-linked" model of Kline and Rosenberg (1986) (4th generation) considered the innovation process a fundamentally parallel process in which the parties (corporate) functions through numerous backward loops (feedback loops) are connected [Kline and Rosenberg, 1986]. In addition they cause interactions of internal innovation activities with external research / science system at all stages of the process. They differ, however, between direct external research services and the general (publicly) available knowledge base. The two authors come to the conclusion that science and technology were interdependent and suggestible. Thus, in the first place, science is based on new technologies, while allowing the development of new technological breakthroughs in science fields. The innovation process of the "fifth generation" is based on the "chain-linked" model of Kline and Rosenberg (1986) and adds a strategic component of the integration of cooperating companies, the growing importance of information and communication technologies and the use of expert systems and networks [Rothwell, 1992].

The generation of innovation at company level thus far was mainly considered a company internal process and function. Chesbrough (2003) established the currently predominating thinking of open innovation 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]. Hence one of the most promising forms lies in the collaboration within the model of open innovation. Innovations are no longer "just" seen as a process, involving various functions. Rather, the process is explained by the participation of a number of different institutions. Here cooperating companies (including suppliers) and customers with varying degrees of intensity are involved continuously in the various phases of the overall activity, public R&D facilities and (business) external R&D facilities are included only at certain stages in the innovation process. In course of the development of new technologies and knowledge companies become increasingly dependent on external knowledge and external technology, this knowledge and technologies can be either publicly accessible or be privately owned by other companies, individuals or research institutions. Furthermore, external knowledge and external technologies are available either in a codified or personal and published or 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". The role of universities as employer and educator of highly skilled workers and researchers especially for R&D needs further consideration. These institutions also provide a partner and/or service provider for external innovation-related activities (especially R&D activities), the company represents for the company's internal R&D activities – as part of the innovation process – is available in the company knowledge and existing technologies prerequisite for the implementation of in-house innovation activities, but also a prerequisite for the use of external sources for innovation [Gokhberg, Kuznetsova and Roud, 2012].

3. Innovation models analysis: two approaches in comparison

It was shown that the understanding of innovation processes has changed considerably over the years. More recently two major approaches of innovation process thinking can be distinguished:

- Innovation management approach
- Conceptual approach

The "innovation management" approach doesn't focuses on the development of innovation in the essence of models themselves but rather on the evolution of companies' innovation management strategies under different socioeconomic and political circumstances. One of the most well-known examples of such approach is 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 socio-economic policymaking and management strategy framework. Other major papers on the analysis of evolution of innovation management models are Niosi (1999), Verloop (2004), Cagnazzo, Botarelli and Taticchi (2008), Jacobs and Snijders (2008), Eveleeens (2010). The distinctive feature of Rothwell's model is the comprehensive analysis of innovation management models themselves and their socioeconomic framework. Rothwell (1994) focuses on the evolutionary development of innovation strategies of companies in different economic conditions. He identifies the following five generations of innovation management models (a detailed description of Rothwell framework of analysis in the format of thesis is presented in the Table A.1 in the Annex):

- first generation – technology-push models (1950-s – first half of 1960-s);
- second generation – market-pull models (second half of 1960-s – early 1970-s);
- third generation – coupling model (early 1970-s – early 1980-s);
- fourth generation – integrated innovation process models (early 1980-s – early 1980-s);
- fifth generation models – integrated, interconnected, parallel and flexible innovation process models (since early 1990-s).

This framework proposed by Rothwell can be considered almost universal. For example in Jacobs and Snijders (2008) the last (4th 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 comprehensive review of literature on innovation management models Cagnazzo, Botarelli and Taticchi (2008) all papers on innovation management model reviewed by these authors work in the framework of Rothwell 5 generations sequence. In other words for nearly 20 years that have passed since the publication of

Rothwell's article in 1994 there was no proposals on the sixth (or may be already the seventh) generation of innovation management models. The reason for this may be that the recent trends in innovation strategies such as networking, outsourcing, globalization, customer involvement can be treated as "flexible", "parallel", "interactive" and "interconnected" process. Such a logic eliminates the need for building a new generation of innovation management models.

The "conceptual approach" focuses on the conceptual essence of models, analyzes the theoretical backgrounds of them as well as their advantages and disadvantages. Possibly the best example of such comprehensive analysis is Marinova and Phillimore (2003). Analysis of related literature shows that in most cases 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 [Immarino, 2005; Asheim, Smith and Oughton, 2011]. In contrast Marinova and Phillimore work encompasses the whole sequence of innovation models since the earliest stages. Research analyzed innovation models per se, models as conceptual and theoretical constructs. Some scholars also analyze the theoretical background for each generation of models, their explanatory power and finally the potential directions for future development of the models.

Marinova and Phillimore who take the conceptual approach identify the following six generations of innovation models (a detailed description of Rothwell framework of analysis in the format of thesis is presented in the Table A.2 in the Annex):

- first generation (black box model);
- second generation (linear model);
- third generation (interactive models);
- fourth generation (system model);
- fifth generation (evolutionary model);
- six generation (innovation milieu model).

Therefore, the main difference between Rothwell's and Marinova-Phillimore's work is the scope, namely the focus of analysis. Rothwell analyses primarily not the innovation models themselves but more the strategies of innovation activity of firms under different socio-economic and political circumstances. Therefore, Rothwell model is primarily "for company" models. Marinova and Phillimore work analyses the models themselves as well as the theoretical background and main advantages and disadvantages of the models. Therefore in the framework of this work innovation models are "for the whole economy" models.

However the similarities in the generation of models highlighted by Rothwell and Marinova and Phillimore are also of high importance. The evolution of innovation models starts from "in search" (or simplistic) models of the first two generations[3], than goes to macro-level (3rd generation models in Rothwell's work[4] as well as to some extent in the 4th and 5th generation level models in Marinova and Phillimore's work) and shifts to the micro level (6th generation in Marinova and Phillimore's work and 4th and 5th generation in Rothwell's work). The first two generation models in Rothwell as well as in Marinova and Phillimore's work can be treated as meso-level models since they assume that the processes described are generally identical for all firms.

Key drivers for the development of models of 3rd generation were the oil price shock and high inflation on the "economic" side and need for upgrading the models of the previous two generations. In other words there was a need for a model that can explain the essence of innovation process itself. Therefore the 3rd generation models were rather "for economy" than "for company" models. The 4th generation models are "case study" models. The "case" here is the example of success of Japanese companies in development of innovation strategies and the penetration of the market of high-tech production. These models are already micro-level models since their key building blocks are integration of supplier into the product development process and integration of activities and functions between companies. Fifth generation models are also the micro-level models, they emphasis the network features of innovation process and the parallelism in the dynamics of innovation processes.

In Marinova and Phillimore work, the evolution of the innovation models is generally about the same (Table A.2). The third generation models (interactive models) are "transition models" which "correct the mistakes" of the models of the first two generation but they still lack some fundamentalism. System models (4th generation of models) are in general macro-level fundamental models. The innovation models of the last two generations gradually drift from macro-level to the micro-level. Evolutionary models are kind of meso-level models: they analyze the behavior of a big number of 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 region.

A closer look at the history of innovation models is well described by Marinova and Phillimore (2003, Table A.2). It shows that the evolution of generations of these model is non linear. Only the first three generations of innovation models are the sequence of each other while the last three generations of models are not directly sequential. In other words the evolutionary generation can also be seen at the "additional fourth generation" in innovation

[3] In Marinova and Phillimore framework of analysis 3rd generation models can be described as "transition" models from first "immature" models to the more mature models.

[4] Rothwell 3rd generation model cannot be treated as purely macro models they are rather meso-level models.

models development, “the second 4th generation”, “4th generation B”, etc. The explanation is the following: Evolutionary models as well as system models analyze the actors in the innovation process in their relationships with each other. However, system models look more closely on the system of these relationships and on the driving factors of its (the system’s) development. On the other hand, evolutionary models concentrate on the interactions between the actors of innovation process on 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 3rd generation innovation models rather than the further development of evolutionary models. Innovation milieu models cannot be treaded directly as the development of 3rd generation innovation models since they firstly shift from the meso-level to the micro level and secondly focus on the importance of geographical location of the firm but not on the processes of interaction of firm within or across some geographical borders.

In contrast, in Rothwell’s work all generations of innovation management models are really a sequence of each other. However the changes of scope (from meso- to micro-level) of between 3rd and 4th generations models are obvious. These models follow one another.

The analysis reveals several common features in the understanding of the innovation processes from different points of view. Despite these commonalities the implications for management tools and instruments vary significantly. The innovation management centered 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 side is a more innovation (management) framework condition focused approach hence requiring instruments and tools for designing framework conditions conducive innovation at different levels.

4. Innovation models – possible future trends and key driving forces of development

Based on the analysis of the evolution of innovation models in their conceptual sense several ways of further development of these concepts are plausible:

a) clusteral national innovation system
b) ecological innovation system
c) incorporating the "location matters" dimension into the evolutionary model
d) innovation process models not related to the models of previous generations

A) Clusteral national innovation system

Clusteral national innovation systems are a combination of the regional innovation system model and the innovation milieu model. The logic of this model should be to place the right innovative companies on the right places (innovation milieu model) and then organize these companies into the efficient network (innovation clusters). It is reasonable to assume that all innovation clusters should be in efficient modes incorporated into national innovation system. Such a hypothesis links the innovation milieu models with national innovation system models. Some progress in research in this direction should be mentioned (for example Montresor and Marzetti, 2008; Bas and Kunc, 2009]).

B) Ecological innovation system.

Since the "white spots" of the innovation milieu is the "ecofriendliness" of innovative companies it follows that not only companies should take the benefits from places where they are located but also companies should work in regime that is friendly for the environment of its location. Stimulating such innovation behavior in companies will also stimulate eco-friendly innovations. Some first analysis in this direction was done already [Coenen and Lopez, 2010; Cooke, 2011; Gee and McMeekin, 2011; Chave, Ozier-Lafontaine and Noel, 2012].

C) Incorporating the "location matters" dimension into the evolutionary model.

This extension of evolutionary models gives more scope for network analysis since additional dimension of differentiation (variation) of locations (and its unique characteristics) of each unit of analysis are "inserted". This line of development of evolutionary models brings it more closely to the concept of the Darwinian theory of evolution: now our "animals" (innovative companies) are struggling to survive in different geographical locations like in real wildlife.

D) Innovation process models not related to the models of previous generations

The next generation of innovation models may not be related to the models of previous generations directly. In example the value chain evolution theory developed by Christensen and Raynor (2003); the strategic innovation process model proposed by Allan Afuah (2002); the Geoffrey Moore category-maturity life cycle model (2005), or the Gary Hammel business strategy innovation model (2000) show potential to incorporate innovation process model thinking and vice versa. These models can hardly be treated as descendants of the six-generation models. These models take some features from system model or evolutionary model but only take. These models are not the "application" of system or evolutionary models on the micro level but are rather the development of the 3rd generation models with the addition of some new developments such as network infrastructure or more emphasis on outsourcing.

There are four key driving forces emerging behind the evolution of innovation models (in conceptual understanding) which have been identified in the last decade. These are:

- change of the essence of scientific society;
- lack of comparable country-level data;
- shifts in innovation policy and
- change in the concept and understanding of innovation itself.

1. **Change of the essence of scientific society**.

Nowadays the scope of "places" for discussion of any theme (including the problems of innovation process and innovation at all) has considerably expanded. It is not only international and national scientific conferences, and peer-reviewed journals but also different "about innovation" blogs (such as http://bigthink.com/blogs/endless-innovation/, http://www.ideachampions.com/weblogs/ http://www.innovationinpractice.com/innovation_in_practice/ and many others) and special thematic web-sites (such as http://www.innovation-creativity.com/ http://www.innovation-management.org/ http://www.innovationexcellence.com/ and so on). The main goals of these websites are entertainment, attraction of clients, broadcasting of vivid and memorable ideas on innovation. Therefore, they will rarely propose fundamental and well-developed complex models of innovation to the audience. Instead, they take the simple but vivid and colorful model of innovation such as proposed by Moore (2005) or Doblin Group in order to explain how the innovation process works. The expansion of the audience of discussion puts new requirements on the innovation models. These models should be clear and simple to understand. The possibility of their application in mathematical modeling in most cases does not matter for developers of these models as well as for the audience of these sites. Since such models are developed "for audience", "for sale" they intrinsically are not fundamental and work on micro-level or even for a specific product or idea.

2. **The lack of comparable country-level data**.

System models as well as evolutionary models require high quality, reliable and comparable data on country-level. However, there is a lack of this data in the international statistical practice. Comparable freely available country-level data mainly exist for scientific activity, e.g. UNESCO Institute for Statistics, OECD, SCImago Journal and Country Rank and for patent data, e.g. WIPO and EPO databases and a little on the high tech export, e.g. the UN Comtrade data for disaggregated data and World Bank for aggregated data. More or less comparable data on innovation activities can be found in Eurostat or OECD publications or from national statistical services database. However these data are point wise and collected on non-regular basis and the last data can be obsolete (for example in 2012 the "last and newest" data are only for 2005 or 2006). In such constellation the usefulness of system and evolutionary models is seriously diminished. In case of analysis of innovation processes at national level researchers possess complex well-developed models, strong mathematical tools, but they do not have adequate data and cannot run these models in full force. Therefore, the models "had to" shift to the micro-level to become descriptive but not purely computational models. In analogy with computer games the new micro-level innovation models developed 5-10 years ago are like modern puzzles or arcade flash-games. These games have a beautiful interface, 3d graphics, attractive visual and sound effects but all they are based on old Tetris brick game, developed by Alexander Pazhitnov from USSR in 1984. New micro-level models in essence are simliar. They are brisk, attractively simple, have beautiful graphical representation, but they are based on 3rd generation of innovation models and in addition cannot be "run" in mathematical sense because they are not computable. Since they are company-level based they cannot be fundamental in scope and thus cannot describe the whole economy. These models were specially designed for analysis of the innovation processes and innovation management strategies at the firm (and sometimes specific product) level. For the macro and meso-level system models and evolutionary models were developed.

3. **Shifts in innovation policy.**

National innovation policy in the EU and other developed countries gradual shifts from the "from top STI policy setting" mode to coordinated policies with responses to Grand Challenges. Responses to these challenges are linked with the specific, sometimes uniquely localized segments (sectors, parts) of the national innovation system. Thus this change in STI policy requires new models that can work with and in the specific parts and segments of national innovation system. For example in modeling the responses towards the climate change challenges new innovation models arise taking into account the stimulation of eco-friendly innovation. Since such new models will be developed for a specific segment of the national innovation system connected with the specific challenges these new models will be mostly at meso-level and in some cases at micro-level. The main challenge for STI policy in this constellation will be the efficient coordination of policy measures developed for particular segments of the national innovation system. Therefore the new macro-level model of innovation can be a model that aggregates the numerous meso- and micro-level models into one complex construct.

4. Change in the concept and understanding of innovation itself

The concept and understanding of innovation has significantly changed over the last decade [Godin, 2008; Kotsemir and Abroskin, 2013]. During this period the concept of innovation gradually shifted from a strong scientific definition to a rather vague concept and buzzword. There is also no unified and commonly accepted understanding of the innovation concept. The innovation typology also shifted from a more or less well-structured system to a system with a big number of very different elements. Now along with the already well-established types of innovation (such as product or process innovation), there are also completely new types of innovation (such as frugal innovation or organic innovation). These new types of innovations require the appropriate models for the description and explaining of their development. Since these exotic types of innovation are connected with company innovation strategies and behavior they by definition will be micro-level not macro-level models.

Conclusion

In this paper the comparison of two basic approaches of analysis of the innovation process model evolution was undertaken. The first approach is the “innovation management” approach focusing on the analysis of innovation management strategies on firm level in different socioeconomic frameworks. The second approach is the “conceptual approach”. The focus of analysis here is on the evolution of innovation models themselves (in conceptual sense) as well as on the analysis of the theoretical background and requirements for these models. This approach concentrates on advantages and disadvantages of different innovation models in their ability to describe the reality of innovation processes.

Analysis of these two approaches shows that there was a shift from macro (meso-level) to a micro level in theoretical innovation models and models of innovation management. Eventually it also shows that during the last 15 – 20 years the dynamic of evolution of conceptual innovation models was nonlinear.

In course of the evolution of the innovation process models it has become a widespread and common understanding how innovation actually occurs, that innovation itself is not a result but a process and a flow of activities which aim at solving a problem be it known or unknown, be it understood or not understood in all its implications to society at different levels. As such innovation is in simple words the combination of existing knowledge, the generation of knew knowledge and the targeted use of the combination of the above two into a solution which has not existed before. As the vast amount of existing knowledge and along with competences to use that knowledge increases with tremendous speed new challenges arise for the generation of innovation.

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Annex. Thesis description of "innovation management" and "conceptual" approaches to the evolution of innovation models [Rothwell, 1994; Marinova and Phillimore, 2003].

Table A.1. Rothwell (1994) five-generation framework of innovation management models evolution (first generation)

First generation: technology-push models (1950-s – 1960-s, first half)	
Environment for the models	**Essence of the model**
Technologies: - emergence of new industries based largely on new technological opportunities (pharmaceutical and semiconductor industry, electronics, new materials); - technology-led regeneration of "old" sectors (steel and textile industry); - rapid application of technology to enhance the productivity and quality of agricultural production. **Economic conditions:** - rapid employment creation; - rising prosperity; - consumer boom of "new products" (consumer electronics and automobile industry). **Perceptions of science and innovation:** - favor towards scientific advance and industrial innovation; - perception of science and technology as instruments for solving society's greatest ills. **Government STI policy:** - supporting measures on the supply side; - stimulating scientific advance in universities and government laboratories as well as the supply of skilled manpower; - some financial support for major R&D programmes in companies linked with defense and space industry. **Corporate strategies:** - main corporate emphasis in manufacturing sector: - R&D (creation of new product ranges); - manufacturing build-up (satisfying the booming demand for them).	**Logic of technology-push model:** the more R&D "in input" the more success for new products "in output". Processes of technological change (industrial innovation) are linear: scientific discovery → technological development of product → selling of product on market. Almost no analysis to the internal characteristics of this process: - process of transformation itself [Carter and Williams, 1957] (main focus for evolutionary models in the end of 1990-s); - role of the marketplace in this process [Cook and Morrison, 1961] (main focus for innovation milieu models in 2000-s).

Source: This table was prepared on the basis of Rothwell (1994) paper.

Table A.1 (continued). Rothwell (1994) five-generation framework of innovation management models evolution (second and third generations)

<table>
<tr><th colspan="2">Second generation: market-pull models (second half of 1960-s – early 1970-s)</th></tr>
<tr><th>Environment for the models</th><th>Essence of the model</th></tr>
<tr><td>Technologies:
- deceleration of growth of new products market;
- some balancing of demand and supply on new product markets;
- new products are based on the existing technologies.
Economic conditions:
- further growth of manufacturing output;
- deceleration or stagnation of manufacturing employment all over the world;
- rapid growth of productivity in manufacturing (as a consequence of two above mentioned tendencies);
- high general levels of prosperity [Rothwell and Soete, 1983];
- intensifying of competition.
Perceptions of science and technologies:
-shifts to the more emphasis on demand-side factors (firstly market-place);
- sifts to perception of innovation as need-driven process.
Government STI policy:
- more focus on the demand-side factors of innovation process;
- using public procurement as a means to stimulate industrial innovation (at national and local levels).
Corporate strategies:
- shift of investments from new products and expansionary technological change towards rationalization technological change;
- focusing of strategic emphasis on the marketing [Clark, 1979; Mensch et al., 1980].</td><td>Logic of market-pull models: Market is the driver for ideas. These ideas determine the deriction of R&D. R&D itself has a passive role in this process.

Innovation process is also linear as in the first generation models: market need → development → manufacturing →sales.

Main risks of model:
- risk of neglecting of long-term R&D programs;
- locking into a regime of technological incrementalism;
- losing the capacity to adapt to any radical market or technological changes [Hayes and Abernathy, 1980].</td></tr>
<tr><th colspan="2">Third generation: coupling model (early 1970-s – early 1980-s)</th></tr>
<tr><td>Economic conditions:
- two major oil crises;
- high rates of inflation;
- demand saturation (stagflation);
- supply capacity is more than demand;
- growing structural unemployment.
Perceptions of science and technologies:
- need for understanding the basis of successful innovation;
- stream of empirical studies of the innovation process [Cooper, 1980; Hayvaert, 1973; Langrish et al., 1972; Myers and Marquis, 1969; Rothwell et al., 1974; Rothwell, 1976; Rubenstein et al., 1976; Schock, 1974; Szakasits, 1974; Utterback, 1975].
Corporate strategies:
- consolidation and rationalization;
- more emphasis on scale and experience benefits;
- more close focus on accountancy and financing issues;
- emphasis on cost control and cost reduction.</td><td>Logic of the model:
- technology-push and need-pull models are perceived as extreme and atypical models of innovation process;
- the basis for innovation process models is the complex of wide-ranging and systematic innovation studies covering many sectors and countries;
- the essence of innovation process interaction between technological capabilities and market needs;
- confluence of technological capabilities and market-needs within the framework of the innovating firm.

Features of innovation [Rothwell and Zegveld, 1985]
- innovation process can functionally distinct but interacting and interdependent stages;
- the process itself can be logically sequential, though not necessarily continuous;
- the process as whole is seen as complex net of intra-organizational and extra-organizational communication path.</td></tr>
</table>

Source: This table was prepared on the basis of Rothwell (1994) paper.

Table A.1 (continued). Rothwell (1994) five-generation framework of innovation management models evolution (fourth and fifth generations)

Fourth generation: integrated innovation process model (early 1980-s – early 1990-s)	
Environment for the models	**Essence of the model**
Technologies: - growth of the generic technologies; - emergence of new generations of IT-based manufacturing equipment; - shortening of the product life cycles. **Economic conditions:** - economic recovery/ **Perceptions of science and technologies:** - recognition of innovation potential of the Japanese companies by the West World; - regocnition of higher efficiency of Japanese management strategies for successful innovations. **Corporate strategies:** **- r**apid growth in the number of strategic alliances between companies [Contractor and Lorange, 1988; Dodgson, 1993; Hagedoorn, 1990]; **-** emphasis on technological accumulation (technology strategy); - emergence of the notion of global strategy emerged [Hood and Vahlne, 1988]; - networking activity of the small innovation firms [Docter and Stokman, 1987; Rothwell, 1991]; - emphasis on core businesses and core technologies [Peters and Waterman, 1982]; - adoption of time-based strategies [Dumaine, 1989].	**Key factors of success of Japanese innovation companies in the framework of the 4-th generation models:** - integration of suppliers into the new product development process; - in-parallel integration of activities of different in-house departments; - "rugby" approach to new product development through the process of "design for manufacturability" [Imai *et al.,* 1985]; - functional overlap between different departments.
Fifth generation: integrated, parallel, flexible and interconnected innovation process (since early 1990-s)	
Economic conditions: - flattering of the world economy; - fast growth of the levels of unemployment and business failure rates; - severe competitions in the business sector. **Perceptions of science and technologies:** - concerns about the consequences of innovation activity on physical environment; - perception of innovation as networking process. **Corporate strategies:** - technological accumulation (technology strategy); - strategic networking continues; - more emphasis speed to time-based strategy; - firms are striving towards increasingly better integrated product and manufacturing strategies (design for manufacturability); - emphasis on greater flexibility and adaptability; - more focus on quality and performance features in product strategies.	**Factors of success of innovation strategy of the company in the framework of the 5-th generation model:** - centrally, integrated and parallel development processes; - strong and early vertical linkages; - devolved corporate structures; - use of electronics-based design and information systems. **Key horizontal R&D linkages in 5th generation model:** - collaborative precompetitive research; - joint R&D ventures; - R&D-based strategic alliances. **Dimensions of differentiation of impacts of above mentioned factors of success:** - development speed/development efficiency; - radical new product developments/developments along established design trajectories; - industry sectors; - all firms within a sector.

Source: This table was prepared on the basis of Rothwell (1994) paper.

Table A.2. Marinova and Phillimore six-generation framework of innovation models evolution (first generation)

Background	***Model***	***Explanatory Power***	***Related Models and Concepts***	***Further Research***
		First generation (black box model)		
Solow production function (1957) – first attempt to incorporate technological progress in the economic equation; - the component of economic growth, which changes in capital and labor could not explain, is due to technological advances; - 90% of the per capita output could be attributed to technological change. **Black box innovation model "starting point"**: apparent invisibility of what happens when investing in science and technology. **Background from cybernetics:** black box as any apparatus whose internal design is unknown.	**Black box innovation model logic**: technological phenomena are events transpiring inside a black box [Rosenberg, 1982]. **Basic statement of black box innovation model:** - innovation process itself is not important; - the only things that count are its inputs and outputs. **Example:** money invested in R&D (input into the black box) will generate, as a rule of thumb, new technological products (outputs) but economists do not need to analyze the actual mechanisms of transformation.	- innovation as an important economic activity for firms; - no explanation of research and development characteristics; - black box model coupled with the appropriate and timely management activities makes certain firms more successful than others [Mansfield, 1995].	**- sociological theories of science** (emphasis on the importance of scientific autonomy and independence as essential for the flourishing of science) [Merton, 1973]; - black box model **as a protective cover** within which scientific inquiry could flourish; **- management of innovation models** (inner workings of research laboratories in large corporations were only partially understood by corporate management.	**Major factors in the lack of public policy encouraging innovation:** - reluctance of researchers to address the link between science, technology and industrial development; - reliance of policymakers on market mechanisms to support technological developments; - reference of black box model generally on R&D components of innovation activity. **Stimulus for further research**: - need to open the black box and explore its interior; - need for understanding the links between S&T and industrial development.

Source: This table was prepared on the basis of Marinova and Phillimore (2003) paper.

Table A.2 (continued). Marinova and Phillimore (2003) six-generation framework of innovation models evolution (second generation)

Background	***Model***	***Explanatory Power***	***Related Models and Concepts***	***Further Research***
Second generation (linear models)				
Main trend in innovation studies in 1960s and 1970s: - opening of the black box of innovation; - more focus on specific processes that generate new technologies; - learning involved in technological change. **Main expectation**: innovations open the road to formulating policies, which would stimulate R&D and consequently the development of new products and processes. **New look at innovation**: a step by step process, as a sequence of activities that lead to the technologies being adopted by the markets.	- '**science push'** model of science policy: discoveries in basic science lead eventually to technological developments which result in a flow of new products and processes to the market place [Rothwell & Zegveld, 1985]; **- technology push model:** 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]; - **'need pull' ('market-driven') model**: causes of innovation are existing demands [Rothwell & Zegveld, 1985]. **Theoretical background:** - Schumpeterian technology-push models; - Schmookler's demand-pull models.	**Directions of explanation of technology-push/need-pull dichotomy:** - wide range of successfully introduced new technologies; - numerous cases of failure [Coombs et al., 1987]. **Use in policymaking:** - adoption of many variants of the simplistic linear 'technology push' model because of its clear message and economic rationale (market failure as the main justification for public investment in research and development).	- '**barriers to innovation'** or factors which impede the adoption of new technologies [Hadjimanolis, 2003]; - **factors for successful innovation**: understanding user needs, attention to marketing and publicity, good communications and the existence of key individuals within the firm [Freeman, 1982; Cooper, 2003]. Barriers and success factors can be on the push or pull side of the innovation process.	**Main "achievements" of linear models:** - development of very easy and clear model of innovation; - setting the direction for further research. **Unanswered questions:** what was the first: technology push or market pull?

Source: This table was prepared on the basis of Marinova and Phillimore (2003) paper.

Table A.2 (continued). Marinova and Phillimore (2003) six-generation framework of innovation models evolution (third and fourth generations)

Background	*Model*	*Explanatory Power*	*Related Models and Concepts*	*Further Research*
Third generation (interactive models)				
Main disadvantage of previous models: extremely simplified picture of the generally complex interactions between science, technology and the market. **Main expectation:** deeper understanding and a more thorough description of all the aspects and actors of the innovation process. **New look at innovation:** a process subdivided into separate stages, each of them interacting with the others.	**Essence of interactive models**: - innovation is no longer the end product of a final stage of activity but can occur at various places throughout the process [Rothwell and Zegveld, 1985; Beije, 1998]; - innovation can also be circular (iterative) rather than sequential [Kline & Rosenberg, 1986].	**Directions of explanation:** - variety of interactions necessary for the success of innovation; - insight into the iterative nature of innovation.	- **models with lag** between new technological ideas and economic outcomes; - '**technological gap' studies** [Dodgson & Bessant, 1996] (deficiencies in firms' competences in relation to the various components and interactions required to make innovation happen).	**Main "achievements" of linear models:** - bringing together the technology-push and market-pull approaches into a comprehensive model of innovation; - development of a more complete and nuanced approach to the issue of the factors and players involved in innovation. **Unanswered questions:** - driving forces for the engine of innovation; - why some companies are better at doing it than others; - strategies of learning for organizations; - role of company operational environment for success of innovation.
Fourth generation (system model)				
Main disadvantage of previous models: inability of hierarchical mechanisms to explain the linkages between cross between organizational boundaries as well as market entities [Marceau, 1992] as well as existence of dynamic, industrial, strategic or innovation networks [Sako, 1992]. **Main expectation:** explaining and confirmation 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/ **New look at innovation:** a system, which includes emphasis on interactions, inter-connectedness and synergies.	**Main arguments of system model:** - 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:** national systems of innovation [Freeman, 1991; Lundvall, 1992; Nelson, 1993, 2000].	**Directions of explanation:** - place and role of small firms in innovation; - means of surviving of small firms in the competition and from pressures from large companies; - synergetic effect from innovation network; - differences between countries and the various role governments play; - highlighting specific patterns of scientific, technological and industrial specialization, institutional profiles and structures; - patterns of learning for different countries.	**- innovation chains** [Marceau, 1992; Dodgson, 1993] (manufacturer – distributor relationships); - **innovation complexes** [Gann, 1991, 2000] (integration of firms); - **strategic networks** (alliances) [Jarillo, 1988; Sako, 1992] (long-term strategic contracts between companies and third parties from external environment); - **regional network** [Dodgson, 1993] (focus on geographic location of innovators); -**regional system of innovations** [Cooke, 1998] (influence of specific regional environment on modes of innovation process).	**Unanswered questions:** - length of live of innovation networks; - potential of networks in promoting innovation in large firms; - trust building in the networked innovation, and the ways of its achievement; - mechanisms of simultaneous cooperation and competition within the innovation network; - role of government, proactive policies and the regulatory environment in creating favorable conditions for such linkages and interactions.

Source: This table was prepared on the basis of Marinova and Phillimore (2003) paper.

Table A.2 (continued). Marinova and Phillimore (2003) six-generation framework of innovation models evolution (fifth generation)

Background	***Model***	***Explanatory Power***	***Related Models and Concepts***	***Further Research***
		Fifth generation (evolutionary models)		
Main disadvantage of previous models: **-** failures in neoclassical economics to deal with dynamic qualitative changes [Saviotti, 1996]; - weak explanatory power of mechanical metaphor adopted in orthodox economic thinking for innovation dynamics [Hodgson, 1993]. **Main expectation:** analysis the dynamics aspects of innovation process/ **Background from other fields of science**: - biological metaphor of Darwinian evolution of species [Nelson, 1995; Dosi & Nelson, 1994]; - combination of fundamentals from equilibrium thermodynamics, organizational theory and heterodox approaches in economics. **New look at innovation:** - innovations are treated as mutations; - firm behavior is subject to the Darwinian law of natural selection.	**Key elements of evolutionary models** [Saviotti, 1996]**:** - **external environment** (patent regimes, market structures, standards and regulations as well as natural environment) in which technologies are developed; - **population perspective and variation:** not only average values but also variances in the population of firms/products are in focus of analysis. **Other essential concepts** related with evolutionary models are [Saviotti, 1996]: - **generation of variety** – continuously generation of new products, processes and forms what contributes to the increase of variety. - **selection** – 'survival' of those products, technologies and firms which adapt to the environment in which they operate, and the demise of “non-adapters”. - **reproduction and inheritance** – continuity in which organizations make decisions, develop products and generally do their business. - **fitness and adaptation** – propensity of an economic unit to be successful in a given environment (Darwinian law in business).	**General statements of evolutionary models:** - innovation by definition involves change; - decisions on innovations are made not merely on price; - imperfections are necessary conditions for technical change to occur in a market economy [Metcalfe, 1995]; - process is as important as the results from R&D [OECD, 1996]; - outcomes are to a large degree determined by the evolutionary process (at country or firm level); - technological opportunities, and established decision-making rules, firms can be dynamic self-organized systems [Dosi & Orsenigo, 1994]. **Directions of explanation:** - explaining of 'bounded rationality' problem [Dosi & Egibi, 1991]; - highlighting the value of diversity [Dowrick,1995]; - explaining the processes of failure of generally fit technologies and the success of “overlooked” technologies [Tisdell, 1995]; - shedding light on decision-making schemes and interaction of participants modes in innovation processes.	**Related concepts:** - technological imperatives [Rosenberg, 1976]; - innovation avenues [Sahal, 1981], - technological trajectories [e.g. Biondi & Galli, 1992; Pavitt et al., 1989], - technological paradigms [Dosi, 1982, 1988]; - technoeconomic paradigms [Freeman & Perez, 1988; Perez, 1983]. **Main argument of related concepts:** Some 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.	**Stimulus for further research:** - need for explaining the mechanisms supporting the continuity of the old and the introduction of new equilibriums in modeled innovation processes; - need for characterization of turning points in the modeled innovation process in the framework of evolutionary models; - solution of the above mentioned problems can help to use evolutionary models in some extent for forecasting purposes.

Source: This table was prepared on the basis of Marinova and Phillimore (2003) paper.

Table A.1 (continued) Marinova and Phillimore (2003) six-generation framework of innovation models evolution (sixth generation)

Background	***Model***	***Explanatory Power***	***Related Models and Concepts***	***Further Research***
Sixth generation (innovation milieu)				
Key background aspects: - theories of growth of regional clusters of innovation and high technology [Feldman, 1994; Keeble & Wilkinson, 2000]; - importance of geographical location for knowledge generation. **New look at innovation:** - not only networking and linkages, as well as natural and social environment but also quality-of-life factors and built environment matter for innovation.	**Main arguments of system model:** - territorial organization is crucially important element for innovation process [Bramanti & Ratti, 1997]; - innovation is geographically localized and territorial concept [Longhi & Keeble, 2000]; - innovation processes is highly-dependent from specific resources which are unique for each location [Longhi & Keeble, 2000]. **Key elements of innovation milieu mode [Camagni, 1991]:** - productive system; - 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; - dynamic local collective learning process.	**Directions of explanation:** - factors of success of small and medium-sized enterprises; - mechanisms through which certain localities give birth to a large number of small innovative firms; - explaining how different localities have different patterns and paths in knowledge development and transfer of high technology.	**Related concepts** - innovation clusters [OECD, 1999] (groups of innovative firms located in one region); - learning regions [e.g. Florida, 1995; Kirat & Lung, 1999; Macleod, 1996; Simmie, 1977]; - collective learning [Keeble, 2000; Lawson, 2000]. **Main argument of "learning" concepts:** - learning is the most important feature of any economy; - 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.	**Unanswered questions:** - links between innovation and ecology; - issues of harmony of innovation systems with the natural environment.

Source: This table was prepared on the basis of Marinova and Phillimore (2003) paper.

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