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Evolution of the Innovation Process Models

Mikhaylova Anna Alekseevna*

Immanuel Kant Baltic Federal University, Kaliningrad, Russia
*Corresponding author: tikhonova.1989@mail.ru

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Abstract The article provides a review of the evolution of scientific concepts on the innovation process. Two main approaches to the innovation process are presented: linear and non-linear, and their distinctive features are defined. Within each approach the main types of models of the innovation process are considered. The stages of formation and development of a linear model of the innovation process are reviewed. Analyzed the influence of various factors on the occurrence of non-linear models of the innovation process. Highlighted the advantages and disadvantages of linear and non-linear approaches to the development of models of the innovation process. The effect of trends in the localization of the innovation process in the current models of the innovation process are studied. The modeling of the innovation process at the present stage is proposed to be considered as a complex, interactive, nonlinear localized learning process.

Keywords: *innovation process, linear model of innovation, non-linear model innovation, innovation*

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1. Introduction

In the modern conditions, when there is increased manifestations of globalization and a backward process – the regionalization, innovation is increasingly seen as a phenomenon that can take roots in a particular area. Over the years were elaborated a number of concepts that describe the innovation process from the perspective of the importance of factors of spatial proximity and social embeddedness of the economy to ensure a similar institutional, political and socio-cultural context of the activities of its members. At the heart of the shift in focus towards the study of the interdependencies between the territorial locations of productive forces and the innovation capacity of the economy is the idea that the concentration of economic entities within the same geographical area contributes to the rapid growth of their innovative activity. We assume that these trends were reflected in the models of the innovation process. In this article, author tries to see how did the model of the innovation process evolve from the beginning of the twentieth century to the present, and to understand why at the present stage the innovation process is being increasingly correlated with a particular territory.

2. The Innovation Process in the Logic of Linear Approach

The traditional model of the innovation process is a linear model of innovation, which has proliferated in the era of Henry Ford. It assumes great significance of codified scientific knowledge, the dominance of basic research as a source of innovation, consistency in innovation process, and technocratic nature of innovation. The linear model can be regarded in three aspects [22]:

- As a methodological basis for the allocation of certain categories of the process of creating new knowledge (basic research, applied research, developments);
- As a theory of knowledge production, in which each subsequent level is connected with the previous via direct one-way links (i.e., the knowledge obtained in the output of the first stage is the input to the second stage, etc.);
- As epistemology, that characterizes the process of knowledge transfer from the universal principles and a comprehensive theory to particular cases.

Since the linear model is not the result of a scientific thought of an individual scientist, its formation took place in several stages. Professor Benoî Godin, while studying the history of science and innovation statistics, identified three of such stages and tied them with a sequential inclusion to the investigation of the innovation process of different categories of scientific communities (Table 1) [10].

Formation of the linear model was happening within the rhetoric around the importance of progress in science for the future of the industry, business and commerce. The concept of a pure science was developing, which resulted in the consideration of the cause-and-effect relationship between fundamental and applied science as a direct and unidirectional. After the First World War, there was a growing interest in the development of industrial research. Enterprises set up special research laboratories whose staff combined the functions of researcher, developer, and technician. Initially, during the statistical surveys (until a uniform methodology was accepted) it created certain difficulties in gathering information in the context of the individual stages of the innovation process, considered from the standpoint of linearity.

Firms had to individually assign the indicators to groups "research" or "development", which did not allow to ensure comparability of the data. It should be noted that prior to the statistical formalization of a three-stage model of the research process, the number of stages and their names varied. For example, J. S. Huxley distinguished preparatory, basic, special research and the development stage [14]. J. D. Bernal wrote about pure or basic science and applied research [3]. Taxonomy by R.N. Anthony and G.S. Day included unfinished research, applied research and developments [1].

Table 1. Stages of formation and development of a linear model of the innovation process

Characteristics	I stage	II stage	III stage
period	beginning – 40-th XX century	30-th - 60-th XX century	second half of the XX century
Leading category of the scientific community	naturalists	industrial researchers and engineers	economists
Major idea	Fundamental research - the source the development of applied research and technologies	Development of research activities on the basis of an industrial enterprise	The linear model - the mechanism to explain innovation
Researchers	H. A. Rowland, J. J. Carty, V. Bush, J. S. Huxley, J. D. Bernal	C. Mees, R. Stevens 1941, F. R. Bichowsky, C. Furnas, J.A. Leermakers, R. N. Anthony, J. S. Day	V. W. Ruttan, Y. Brozen, W. R. Maclaurin, E. Ames, F. M. Scherer, J. Schmookler, E. Mansfield, S. Myers, D. G. Marquis, J. M. Utterback
The level of development of a linear model	fragmented, lack of formal description	the first complete description and the following variations	finalization
main results	- Justification for state funding of pure science, centered at the University; - The introduction of the concept of basic research; - Distinction between basic research and applied research	- Introduced the term 'development', that came from industry; - Consolidation of the three-step model: basic research - applied research - development; - Consolidation of a definition of "research" and its components, similar in different countries	- In economics adopted an established in the statistics definition and taxonomy of research; - Extension of the model due to the stage of "production" and "diffusion of innovations", drawing on the ideas of J. Schumpeter, who suggested to allocate novelty, innovation and imitation
Statistics of innovative activity	In the 1920's there was no common methodology or a universally accepted definition of "research", "basic research", and "applied research"	- The National Science Foundation of the USA formed one of the first standards for measuring scientific and technical activities (1953). Developed a taxonomy of research. - Frascati Manual of the OECD (1963) has developed and consolidated the common methodological framework for the collection of statistics in the field of science and innovation in the framework of a three-stage linear model	Formation of a large statistical database in the field of science and innovation in the framework of a unified methodological basis enabled to consolidate the linear approach to the process of innovation in economic science

In economics, interest in the study of the innovation process in the second half of the twentieth century, not least was caused by a significant amount of accumulated statistical material. Based on the works of J. Schumpeter, economists got involved in the debate about the nature and stages of the innovation process, including voicing criticism of the adequacy of the linear approach to innovation (e.g. works of Schmookler, Price, Bass, Myers, Marquis).

The result of scientific debate has been the allocation of two types of linear models of the innovation process (in the logic of Roy Rothwell – two generations). The first type is a technology push model, which appeared in 1950s and has gained wide popularity among manufacturing companies in the 1960s. The main features of this model lies in the fact that innovation is seen as the final result of sequential processes, which are based on the free pursuit of science not being limited by strategic objective; there is no common control of the entire chain of innovation and market impact is minimized, i.e. 'buy what is sold'.

Since the 1960s, as a result of an increased competition and diversification of production the second type of linear models of the innovation process has been developed. It suggests that innovations are driven by the market and its needs (i.e. the market pull model). In comparison with the first type, these models did not rely on the results of scientific research, but on information obtained from the diagnosis of market preferences. This approach was consistent with the ideas of J. Schumpeter, who noted that innovation is possible without the inventions and the inventions do not necessarily lead to innovation [25]. Consequence of the spread of the second approach was the increasing number of short-term projects aimed at improving the generation of innovation, i.e. modification of an already existing products and processes. As a rule, the market-oriented model of the innovation process did not take into account the corporate interests of the firm, however, it already implied certain elements of the overall management of the stages of the innovation process [2].

3. Change in the Role of Knowledge and Its Impact on the Innovation Process

The growing influence of globalization reflected in the changing perceptions of the innovation process. The linear model of innovation is increasingly complemented by a new evolutionary approach based on the recognition of "knowledge" as a fundamental resource of the modern economy. In the academic environment was introduced the concept of 'knowledge economy', which symbolizes the addition to such traditional factors of production as labor and capital, of a new factor – knowledge. According to Peter Drucker and his colleagues, the knowledge economy has three key features that qualitatively distinguishes it from the industrial economics [7]: first, a higher mobility of knowledge in comparison with the traditional factors of production; second, the wide availability of different kinds of knowledge and the availability of acquisition opportunities in the learning process; third, the increased importance of the ability to use knowledge effectively to achieve the goal. Scientists point out that innovation is increasingly born in various fields of science, and acquire the interdisciplinary nature. Model of the innovation process, reflecting the changes, began to acquire non-linear mode, by including a feedback mechanism.

Since the mid-1970s under the influence of the desire to reduce costs and consolidate the business, an interactive model (equally known as the coupling model) became widespread. It allowed to combine both the technological push approach and focus on the market needs. The result of its implementation was the ability to control all stages of the innovation process through feedback, while the stages were considered as equally significant. The innovation process in this model represents a fusion of technological capabilities and market needs inside an innovative firm [24]. Despite the fact that in its basis remained the sequential principle, it can still be generally conceived as transitional towards non-linear models.

The development of ideas about the superior efficiency of the parallel over sequential innovation process from the perspective of saving time led to the emergence of a number of integrated business process models [31]. The organization of innovation in accordance with the principle of parallelism involves the development of horizontal partnerships between researchers, developers and manufacturers with the involvement of the most important customers in the process of generating innovations. The transition to the present generation of models allowed to benefit from the integration of external and internal resources of the company, significantly reducing the time spent. The changes are displayed in the perception of knowledge. It started to be seen in the wider context – as a result of the interaction between the participants (separate divisions of the company, its external and internal environment) at all stages of the innovation process, not only as a result of scientific activity.

An example of the integrated model is the chained model of S. Kline and N. Rosenberg (1985), in which the innovation process is seen through a number of chains of innovation: the central, feedback, side, and additional [18]. This model demonstrates the diversity of sources of innovation: existing or new knowledge; scientific discoveries; information from the consumer; knowledge gained in the course of training. At the same time, it reflects the contribution of product of innovative activity in science.

The Kline-Rosenberg model is based on the concepts of innovation as a complex process characterized by a high degree of uncertainty. The level of this uncertainty depends on many factors: the nature of innovation, the level of scientific development, the stage of the innovation process, etc. At the initial stages of creating innovation, this level is usually higher than at the final. One of the objectives is to demonstrate the chain pattern of the places where the uncertainty can be reduced, for example by additional research.

Since the late 80s of the twentieth century a network partnership has developed. Creation of networks and participation in them was seen as one of the ways to maintain competitiveness. Increased the number of strategic alliances. Top management of large companies turned to the development of global strategies aimed at reducing the time required for new product development and quality improvement. The development of information and communication technologies has increased the intensity of the exchange of information.

Active market position in the world arena occupied Asian companies, the key success factors of which were: to maintenance of the intensity of external networking, the strategy of technological imitation, the implementation of high quality standards and systems of “just-in-time” in dealing with suppliers, analysis of future demand. Japanese approach to creating innovation became the basis of a number of scientific models of the innovation process, the main of which – a model of the 4th generation of R. Roswell and the model of F. Kadam [12,15,20,24]. Features of the innovation process in the first model related to the implementation a "rugby" approach, involving parallel participation of various departments of the company in the creation of a new product; involvement of suppliers in the early stages; focus on the reduction of the period from concept to commercialization; combination of vertical and horizontal linkages. It should be noted that this approach is most effective for areas such as engineering, automotive, instrumentation, aeronautics, ICT and to a lesser extent for biotechnology and pharmaceutical industries, which are closely related to the results of basic scientific research.

The innovation process in the second model is associated with the needs of the market: at first, the market demand for new goods is projected, and in the final stages – the company itself has an impact on its formation. According to F. Kadam, the world economic conditions have identified two areas for innovation: investing in new "breakthrough" technology (i.e. breakthrough approach); the development of hybrid technologies by combining the existing ones (i.e. technology fusion approach) [19]. In the first case, the linear approach is predominant, characterized by sequential replacement of one technology by another. The second approach – non-linear, focused on intersectoral collaboration and the development of horizontal linkages. The greatest effect can be achieved with a combination of the two approaches, which requires firms to increase confidence in the external innovation, the development of international scientific and technological cooperation and technology transfer. However, the study of F. Kadam, showed that many Western companies, traditionally focused on breakthrough technologies, are often not ready to focus on joint development of innovation, despite the benefits of the Japanese model.

In the 1990s, the desire of companies to improve the quality, productivity, and reduce the time to create a new product was becoming more evident. Speed control of the development process gained the status of the most important skill, as untimely entry into the market means a significant loss of profit. Strategies of companies have acquired a comprehensive and global nature, bringing together different types of strategies: technological, networked, advanced entry into the market, production. During this period were extended the cyclic model of the innovation process, such as the "cycle of innovation journey" of A. Van De Ven and colleagues [28], cyclic model of R. Gomory [11], etc. All of these models determined the innovation as a continuous process of ever-increasing improvements. In the 1990s some other models of the innovation process were proposed, such as the "funnel" model of S. Wheelwright and K. Clark [29], the "Stage-Gate" model of R. Cooper [6], models of networking and system integration of R. Roswell [24], the neural network model of J. Zeeman [30].

4. The Innovation Process in the Innovation Economy

At the present stage the steady exchange of knowledge acquires a global scale, promotes the formation of specific information channels between key centers of competence in the world. The degree of integration in them defines the region’s ability to resist the strengthening of innovative hyper-competition – a qualitatively new type of competition, as expressed in the "dynamic inclusive process of innovation competition in global markets", which is caused by build-up rate of innovation processes (reduction of life cycle of innovation, enhancing innovation policy, etc.) [[8]; p. 45]. The increasing complexity of ideas about competitiveness in the global economy has led to the need for continuing search by regional actors in finding new strategic advantages in the field of innovation, the so-called systematic diagnosis of "areas of change" [7].

In response to the challenges of globalization unfolds the process of regionalization that acts as a counterbalance to the overall integration through the disclosure of local competences and ability to be creative. Creativity is a key factor of production in the innovation economy, no less important than the knowledge in the knowledge economy. It is a creative approach, according to some scholars (e.g., [2,9]), that allows to improve the quality of innovation processes and decisions, and is a major catalyst for economic growth. The essence of the innovation economy can be expressed in the effective connection of knowledge, creativity and entrepreneurial skills, socially rooted in the region.

In science, it is decided to allocate codified and tacit knowledge, that are characterized by different properties, but are closely linked to each other in the framework of the "spiral of knowledge", proposed by I. Nonaka and H. Takeuchi [23]. Strategic competitive advantages of the region are usually associated with tacit knowledge, which cannot be partially or completely alienated from its creator, codified or systematized. They are expressed in the skills, abilities, experience, qualified personnel, technical practices, formalized norms of behavior, culture, etc. Scholars distinguish the pure tacit knowledge that cannot be codified, formulated or explicated, and the implicit explicit knowledge, which at the moment is implicit, but in the future can be explicated [4]. Typically, in a broad sense, tacit knowledge means the combination of the two types mentioned above.

The primary feature of tacit knowledge is the causal ambiguity generated by the inability of the formal expression. The dual nature of this kind of knowledge is related to four key characteristics [26]:

- Tacitness, suggesting that the higher the degree of implicitness in the transmitted tacit knowledge, the greater the ambiguity of its perception is;

- Complexity, determined largely by the recipient of knowledge based on personal perception and ability to absorb;

- Stability, expressed on the one hand, in the absence of sensitivity of tacit knowledge to changes in the environment, since their formation occurs over a long period of time in the mind of the owner through a better understanding of the processes and on the other - the current state of tacit knowledge available to adapt to the requirements of the current the situation;

- The integrity of the transmission, ensuring perfection, completeness and continuity of the process of tacit knowledge transfer.

The process of diffusion of tacit knowledge reveals yet another special feature - "stickiness", characterized by increased complexity of their transmission. Exchange of accumulated tacit knowledge between actors occurs through a process of collective learning, which tends to be localized, and can be submitted through the "learning loop" of David Kolb: "Actions" - "Reflections" - "Connections" - "Decisions" - "Actions" [17]. At the stage of "connections" occurs a transformation of information obtained in the course of analyzing the results of the acts committed, into the previous experience. Then it influences the following decisions. In this context, the innovation process can be conceptualized as a complex, interactive, nonlinear localized learning process [16].

The effectiveness of training depends on many factors: the difference in technological processes of regional firms (knowledge base, speed of technological change, the nature of technology), dependence on external sources of knowledge or information, such as other firms, suppliers, and others; on the difference in the level of technological development [21]. Examples of contemporary models of the innovation process, taking into account the changes in the perception of innovation may include: a model of integrated product development by M.M. Andreasen and L. Hein [13]; model "TAMO" by F. Jansen [17]; model of the innovation process elaborated by J. Tiddo et al. [27]; model of "open innovation" by H. Chesbrough [5]; cyclic model of innovation developed by A.J. Berkhouta and colleagues [2].

5. Conclusion

Development of representations about the innovation process in science led to the identification of two main approaches: linear and nonlinear, which for the past several decades are being refined in parallel. The author highlights the strengths and weaknesses of each approach, which are presented in Table 2. Thus, there is no replacement of one approach by another. A large variety of models proposed in the framework of each approach, points to a failure to develop a universal model of the innovation process that meets all the requirements of a particular company and time. However, non-linear models are closer to real innovation process at the present stage, and, therefore, are better able to transmit qualitative changes that occur in the economy. So the idea of a rooted innovation process is reflected in particular in the non-linear models. The main features of non-linear models, with regards to the localization of the innovation process, relate to: first, takes into account the nature of the networked relations between regional actors; second, reflection of models of triple, quadruple, and quintuple helices in the structure of the innovation network; third, the multiple changes of types of knowledge in the innovation process; fourth, the ambiguity and variability of the source of innovation.

Table 2. Comparative analysis of the innovation process approach

	Approach to the innovation process	
	Linear	Non-linear
Advantages	- relative ease of constructing the models, the ability to use highly generalized description of the relationship between basic science and industrial innovation; - a broad statistical material, since it is fixed in a single methodological approach for collecting statistics; - dominates in the allocation of funds for research activities and in the evaluation of scientific, technological and innovation potential of the regions	- closeer to the real-life innovation processes that are rarely linear nor ordered, often chaotic and have gaps; - includes a feedback loop, alternative ways to innovate; - takes into account the social value of innovation and the consumer as a co-producer of value; - reflects the embeddedness of innovation processes in the region and its systemic nature; - focuses on processes (interactions) rather than on the structure (individual actors); - effective in decision-making and managing the innovation process
Disadvantages	- distortion of the real innovation process and its formalization; - it is impossible to transmit high-quality communication between the components of the innovation process; - distracts attention from the economic and social determinants of research activities; - ignores the role of technology in the choice of goals and methods of research, productivity growth of science; - insufficient attention to the stage of engineering design and re-engineering as a source of innovation; - does not take into account the features of innovation processes in different industries, regions	- not yet formed a statistical base for research and has no single methodological approach for the collection of information; - models are mostly descriptive rather than evaluation nature due to the high complexity of construction; - it is impossible to develop a universal model for all variety of real innovation processes

References

[1] Anthony, R.N., Day, J.S., *Management controls in industrial research organizations*. Harvard University, Boston. 1952.

[2] Berkhout, A.J., Hartmann, D., van der Duin, P. Ortt, R. "Innovating the innovation process", *Int. J. Technology Management*, 34 (3/4). 390-404. 2006.

[3] Bernal, J.D., *The social function of science*. Reprint. MIT Press, Cambridge, MA. 1973.

[4] Brokel, T., Binder, M., "The Regional Dimension of Knowledge Transfers – A Behavioral Approach ", *Industry and Innovation*. 14 (2). 151-175. 2007.

[5] Chesbrough, H.,*Open Innovation: The New Imperative for Creating and Profiting from Technology*.Harvard Business Press. 2006.

[6] Cooper, R.G., *Stage-Gate Systems: A New Tool for Managing New Products*. Business Horizons (5/6). 1990.

[7] Drucker, P.F., *Management Revised*. Harper Business. 2008.

[8] Dyatlov, S.A., "Global innovation hypercompetition as a factor of transformation and development of economic systems", *Theoretical economy*. 6. 39-54. 2012.

[9] Florida, R., *The Rise of the Creative Class*. Basic Books, New York. 2003.

[10] Godin, B., "The Linear Model of Innovation. The Historical Construction of an Analytical Framework", *Science, Technology, & Human Values*. 31 (6). 639-667. 2006.

[11] Gomory, R., *From the Ladder of Science to the Product Development Cycle*. Harvard Business Review. 1989.

[12] Graves, A., "*Comparative Trends in Automotive Research and Development*", DRC Discussion Paper No. 54, Sussex University, Brighton, Sussex. 1987.

[13] Hein, L., Andreasen, M., *Integrated Product Development*. IPU, Lyngby. 2000.

[14] Huxley, J.S., *Scientific research and social needs*. Watts and Co, London. 1934.

[15] Imai, K., Nonaka, I., Fakeuchi, H., "Managing the New Product Development ", in Clark, K. and Hayes, F. (Eds), *The Uneasy Alliance*. Harvard Business School Press, Boston, MA. 1985.

[16] Isaksen, A., "Building Regional Innovation Systems: Is Endogenous Indus trial Development Possible in the Global Economy?", *Canadian Journal of Regional Science*. 24(1). 101-120. 2011.

[17] Janszen, F., *The Age of Innovation*. Financial Times Prentice Hall. 2000.

[18] Kline, S., Rosenberg, N. "An Overview of innovation", in Landau R, Rosenberg N, editors. *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. National Academy of Sciences, Washington, DC. 275-306. 1986.

[19] Kodama, F., *Technology Fusion and the New R&D*. [Online]. Available: http://hbr.org/1992/07/technology-fusion-and-the-new-rd/ar/1

[20] Kodama, F., *Emerging patterns of innovation: source of Japan technological edge*. Harvard Business School Press, 1995.

[21] Lall, S., *Competitiveness, Technology and Skills*. Edward Elgar, Cheltenham. 2001.

[22] Mahdjoubi, D., *The linear model of technological innovation: background and taxonomy*. 1997. [Online]. Available: https://www.ischool.utexas.edu/~darius/04-Linear%20Model.pdf.

[23] Murray, A., Hanlon, P., An Investigation into the Stickiness of Tacit Knowledge Transfer. in *13th. Annual conference of the Irish Academy of Management*, Cork institute of technology, 1-3 September, 2010.

[24] Rothwell, R., "Towards the fifth-generation innovation process", *International Marketing Review*. 11(7). 7-31. 1994.

[25] Schumpeter, J., *Business cycles: A theoretical, historical, and statistical analysis of the capitalist process.* McGraw-Hill, New York. 1939.

[26] Szulanski, G., "Exploring internal Stickiness: Impediments to the transfer of best practice within the firm", *Strategic Management Journal*.17, 27-43. 1996.

[27] Tidd. J., Bessant, J., Pavitt, K., *Managing innovation: integrating technological, market and organizational change*. Wiley. 2005.

[28] Van De Ven, A.H., Polley, D.E., Garud, R., Venkataraman, S., *The Innovation Journey. Administrative Science Quarterly*. Oxford University Press, 1999.

[29] Wheelwright, S.C., Clark K.B., *Revolutionizing product development: Quantum leaps in speed, efficiency and quality*. The Free Press, NY. 1992.

[30] Ziman, H., "A Neural Model of Innovation", *Science and Public Policy*, 18 (1). 65-75. 1991.

[31] Žižlavsky, O., "Past, Present and Future of the Innovation Process", *International Journal of Engineering Business Management*. 5(47). 2013. [Online]. Available: http://cdn.intechopen.com/pdfs-wm/45701.pdf