

Open innovation model within public research and innovation programmes

Mateusz Bonecki

Abstract: The paper concerns the role of open innovation within public R&D&I programmes. The history of innovation management shows that the methods used to organize research and development work have evolved towards open innovation model. The first, original, concept of “open innovation” (Chesbrough) has been coined to explain how companies diversify technology sourcing and commercialization methods, and thus represents a perspective of industry. On the other hand, Open Innovation 2.0 approach emerged in the context of policy-making and displays features characteristic of innovation systems theory. It enables a more in-depth analysis of interactions between different types of actors involved in innovation process and complex R&D ecosystems.

Keywords: open innovation, open innovation 2.0, OI2, R&D, research and innovation policy, public policy, innovation system, innovation ecosystem, triple helix, quadruple helix

Introduction

Public research and innovation programmes are institution-alised mechanisms and instruments which, stemming from research and innovation policy, support the actors working

* Adam Mickiewicz University
mateusz.bonecki@amu.edu.pl

on research and development. Such programmes incentivize research and innovation sector with grants and subsidies, indicating research problems, priorities, social needs or challenges. Motivation of such programmes, depending on overarching innovation policy, may be diverse, starting with progress in defence domain, through strengthening of competitiveness of national economy, and ending with facing the societal challenges. Usually, these programmes are implemented on the level of national economies, however, they may also become the instruments of international integration, as it is with European Union's research and innovation policy (Caracostas & Muldur, 2001, pp. 160-161).

The beneficiaries of such grants are both public and private academic institutions and research and technology organizations. Beyond that, public programmes, offering support for small- and medium-sized enterprises (SMEs) as well as for large companies influence the direction of industry advancements. In this instance, exploitation of knowledge, aiming at practical applications, remains the crucial element of the process, which coincides with the understanding of research and development present in the OECD conceptual framework for R&D performance measurement. Here, research and (experimental) development comprise

creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. (OECD, 2002, p. 30)

Research covers both theoretical and experimental activities – those which are not guided by possible technical or social applications (*basic research*) and those oriented towards certain practical goal (*applied research*). Experimental development, on the other hand, refers to activities that exploit research results in order to produce or deliver new products, processes, systems, or services (OECD, 2002, p. 30). Hence, research and development covers creative and systematic knowledge-based activities that lead to new theoretical or practical achievements (discovery and invention, respectively) which are novel or display novel features. R&D process as such is therefore closely linked to *innovation*, where the latter is defined as

the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. (OECD, 2005, p. 46)

Conceptual framework proposed by OECD assumes that the “novelty” is a relative term in a sense that the innovation “must be *new (or significantly improved) to the firm*” regardless of whether it has been developed internally or adopted (e.g. through acquisition) from an external entity (OECD, 2005, p. 46). Some authors have opposed to this approach and stated that innovation needs to be both “new to the firm and new to the relevant market”, which helps to distinguish discoveries and inventions from innovations that “must be introduced into the market place so that consumers or other firms can benefit” (Greenhalgh & Rogers, 2010, pp. 4-5). The very assumption that innovation is necessarily marketable makes organizational and marketing innovations, mentioned in the OECD definition, come down to process innovation, which, in turn, is just a means of new product or service development: process innovation is nothing but “introduction of a new process for making or delivering goods and services” (Greenhalgh & Rogers, 2010, p. 4).

Given the above, an end-to-end process of new product development and marketing can be termed as R&D&I process. Hence, when one speaks of R&D&I, one refers to such R&D processes which aim is not only to increase new knowledge and technology but to gain in “new applications” which are marketable or simply able to provide value to their users.

With regard to open innovation model particular phases of entire R&D&I process are realised within separate entities (e.g. companies, universities, research centres), engaging diverse ways of transfer and exchange of intellectual property rights.

Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to markets, as the firms look to advance their technology. Open innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model. (Chesbrough, 2003a, p. xxiv)

In general, within the framework of open innovation, companies pursue innovation process in a distributed manner through insourcing and outsourcing of technologies (knowledge) on different levels of commercial maturity. Furthermore, in compliance with definitions of R&D and innovation, adopted by OECD (2002; 2005), open innovation approach treats R&D&I process as market-oriented. Introduction of a service or a product to the market is a culmination of all the stages of this very process. The reflection on innovation within this model is industry-centric with the company, frequently multinational, being the subject of innovation process. Nevertheless, the notion of open innovation in the context of small- and medium-sized enterprises (SMEs) has recently come into prominence (Vanhaverbeke, 2017).

Methodological note

This research constitutes an exploratory study of the role of open innovation model within research and innovation policy. The preliminary review of literature regarding historical changes in innovation management models has been performed. This overview illustrates how methodology of innovation management evolved from “closed” to “open” innovation model. Subsequently, Open Innovation 2.0 (OI2) paradigm has been analysed. It was formulated for the purposes of European Union research and innovation policy-making. Finally, the research delved into the role of the government within particular stages of development of innovation management methods and within OI2 model.

From closed to open innovation (industry perspective)

The history of 20th and 21st century industry shows that the development of innovation and R&D management methods display a tendency where initially hermetic, closed, and self-sufficient corporate R&D centres gradually become more market-driven, more cooperative, and more “open”. A thorough study by Rothwell (1994) proposes a periodization of this evolution in five stages. In the following section Rothwell’s study will be discussed and extended with

further phases encountered in the literature (Nobelius, 2004; Du Preez, Louw & Essmann, 2006) in order to demonstrate Chesbrough's open innovation model as a point of departure for the evolutionary process.

First generation innovation process (from 1950s to mid 1960s) is defined through "technology push" approach which assumes linear progress from discovery through industrial development to the introduction of new products to the marketplace. To that extent such linear model resembles typical academic practice of fundamental (basic) research leading to scientific discoveries which are further elaborated in order to deploy market and industrial applications (Rothwell, 1994, pp. 7-8).

Second generation (from the mid 1960s to the early 1970s) is characterized as "market pull" since R&D departments delivered products using existing technologies, paying more attention to demand side, and thus finding balance between technology supply and market needs (Rothwell, 1994, p. 8-9). According to OECD, this was the "golden age of corporate R&D" as almost all industrially-relevant knowledge and marketable inventions were produced inside corporate structures: in the 1970s approximately only 3% of the total industrial expenditure on R&D was allocated to source research from outside the company (OECD, 2008, p. 26).

From the early 1970s to the mid 1980s research and development was organized in line with "coupling" (interactive) model where "technology push" and "market pull" find their balance. In the *third generation* innovation process typical stages of innovation process (idea, design, development, prototyping, manufacturing, marketing) are interconnected through feedback loops. Furthermore, "coupling" model connects intra- and extra-organizational activities, bridging internal research capacity of the company and broader scientific and technological community. Essential factors determining the third generation innovation process are, just to mention a few, access to external know-how, emphasis on creating customer value, user education, and cross-project synergies (Rothwell, 1994, pp. 9-11). Roussel, Saad and Erickson (1991) have anticipated this "coupling model" in their concept of "integrated R&D strategic plans". These are conceived and executed through cooperation of corporate

and divisional management, R&D units, finances, human resources, legal affairs, manufacturing, and marketing and sales (p. 3-4).

The trend of both market orientation and communication with external environment is becoming even more explicit in the case of the *fourth generation* (from early 1980s to early 1990s). It is characteristic of Japanese companies of that period as they represent a paradigmatic example of “integration and parallel development”. Here, the innovation activities are horizontally distributed among different departments of the company and executed “in parallel” with focus on cross-functional coordination (Rothwell, 1994, p. 11). Since these activities are carried out in parallel, the sequential R&D model process is replaced with overlapping R&D stages which, in their analysis of innovation processes in Japanese companies, Nonaka and Takeuchi (1986) captured with the metaphor of *rugby*:

Under the rugby approach, the product development process emerges from the constant interaction of a hand-picked, multidisciplinary team whose members work together from start to finish. Rather than moving in defined, highly structured stages, the process is born out of the team members’ interplay. (p. 138)

The rugby approach to R&D abandons “waterfall model” of project management, where new product development phases are executed sequentially, and assumes that the steps of design, development, prototyping, manufacturing, and marketing overlap. Moreover, according to Rothwell (1994, pp. 11-12), the fourth generation displays cross-organizational linkages as it comprises strategic alliances between companies, involving key suppliers from the very beginning of the new product development process, interacting with active customers, and also benefiting from governmental support. Hence, the “holistic approach” (Nonaka & Takeuchi, 1986) appears to apply to both organizational and cross-organizational structures.

Rothwell (1994, p. 12) underlines that the trends inherent to the fourth generation innovation processes continue and pave the way towards the *fifth evolutionary phase* which begins in the 1990s. Rothwell has identified over twenty factors driving the fifth generation including shorter

time-to-market imperative, flexibility and adaptability of manufacturing process and products, strategic networking, accessibility to external know-how, involvement of leading-edge users in design, linkages with primary suppliers, or concurrent engineering (1994, pp. 15-22). In terms of the OECD report (2008, p. 24) this model of innovation holds to “multi-institutional networking”. Nobelius (2004), as he had observed the fifth generation almost a decade after Rothwell had grasped its basic features, defined it as a model of *cross-boundary alliances and systems integration* where R&D process is stretched between competitors, distributors, customers, and suppliers, and thus requires an “ability to coordinate and integrate systems from different parties” (p. 371).

In 2000 nine out of ten top R&D spending companies outsourced 15% of R&D activities to external entities, mostly to other companies (OECD, 2008, p. 25). In this context, beyond Rothwell’s periodization, the early 2000s bring the new, *sixth generation* (Nobelius, 2004). Paradigmatic exemplification of such an innovation process is Bluetooth Special Interest Group (SIG), the organization responsible for the development and maintenance of Bluetooth wireless communication standards and technology licensing to manufacturers.

The Bluetooth case represents a joint cross-industrial, open intellectual property-based, effort in developing and bringing a new technology to the market by utilizing the resources from more than one thousand companies. (Nobelius, 2004, p. 369)

This approach to R&D corresponds with the trend of “cross-boundary alliances” characteristic of the fifth generation. The alliances for new product development in the sixth generation require engagement from many actors, exchange of knowledge and intellectual property within cross-organizational ecosystems, development and maintenance of shared technology standards, etc.

The evolution of R&D management models, as Nobelius posits, is organized by the three generic factors, i.e. technology complexity, level of investments and degree of competence specialization, and commercial demand with regard to return of investment and cost optimization (Table 1). These drivers guide the development process in the three main lines

in such a way that subsequent evolutionary phases develop R&D management models which take into account more and more aspects of the product and technology, involve broadening spectrum of stakeholders, and introduce increasingly efficient methods of product and technology commercialization.

Table 1. Theoretical framework for the analysis of R&D management evolution (Nobelius, 2004)

driver	development line	sixth generation features
product and technology complexity	multi-aspect approach	interoperability, industrial design, environmental, manufacturability, after-market considerations
level of technological investments and rational specialization	multi-actor cooperation	interacting with marketing, manufacturing, suppliers, competitors, and distributors
rate-of-return demand and avoiding costs of being late	effective commercialization	timely, efficient deliveries of new products with predicted quality

The case of Bluetooth SIG shows how the sixth generation multi-technology ecosystems deliver value based on common standards underlying compatible products within various product lines in wide range of industries (from automotive to household appliances). To that end, networked innovators need to secure “broader multi-technology base for high-tech products and a more distributed technology-sourcing structure” (Nobelius, 2004, p. 375).

Other researchers, as claimed by Du Preez et al. (2006), interpret the sixth generation in terms of *open innovation*, where “internal idea generation and development, internal and external ideas as well as internal and external paths to market can be combined to advance the development of new technologies” (p. 9). This understanding of the sixth generation explicitly refers to Chesbrough and pays attention to collaboration, networking, openness, and agility

of networked or web communities. According to Chesbrough, the government is instanced in the innovation process as “innovation benefactor”: such a role, however, remains relatively insignificant and is confined to research funding, especially at early stages of technology development (Chesbrough, 2003b, p. 38).

The sixth generation broadens the scope and diversifies technology sourcing strategies (Nobelius, 2004; Granstrand & Sjölander, 1990), which now cover internal R&D, acquisitions of innovative firms, joint ventures, technology purchasing (e.g. contract R&D, licensing), and technology scanning. Furthermore, it also introduces a mix of exploitation strategies such as direct investment in production and marketing, creation of innovative firms (spin-offs), joint ventures, technology selling or licensing, divestment, and storage and leakage (Granstrand & Sjölander, 1990). Therefore, open and collaborative approach to both technology insourcing and technology exploitation bears marks of open innovation, combining internal and external assets to execute end-to-end process from idea to the market.

Open Innovation 2.0 (public policy perspective)

The concept of Open Innovation 2.0 (OI2) has been introduced by Open Innovation Strategy and Policy Group (OISPG) as an instrument of European Commission’s innovation policy. Whilst open innovation, as understood by Chesbrough (2003a), comes down to sourcing knowledge and technology from multiple sources and diversifying technology exploitation channels, open innovation 2.0 offers

an innovation model based on extensive networking and co-creative collaboration between all actors in society, spanning organizational boundaries well beyond normal licensing and collaboration schemes. (Curley & Salmelin, 2013, p. 5)

According to Curley and Salmelin (2013), OI2 is marked by, firstly, networking and co-creation, which, focusing on joint ventures, R&D consortia, common research agendas, etc., go beyond intellectual property rights operations (e.g. transfer or licensing). Secondly, OI2 adopts “quadruple helix

innovation approach”, within which academia, industry, government, and citizens jointly envision and co-create the future that is to be reached by innovation. It has been pointed out that such quadruple helix would “drive structural changes far beyond the scope of what any one organization or person could do alone” (Curley & Salmelin, 2013, p. 5). This notion comes to be an extension of the “triple helix”, concept put forward by Etzkowitz (2008), who showed that for knowledge society university begins to play a crucial role, of the same importance as the government and industry in industrial age. Triple helix involves, therefore, government, industry, and academia, whereas OI2 additively implements active participation of citizens.

Extensive networking and co-creation, involving “all actors in society”, which is supposed to “drive structural change” introduces entirely distinct approach. It does not focus on a single structure of industrial organization and on knowledge and technology flow within this structure. OI2 perspective approaches innovation holistically, in a mesoscale, capturing character and diversity of internal processes of all actors participating in interactions.

OI2 is a mash-up parallel process where the public policy maker needs to create the framework for this interaction (mash-up) to happen. OI2 is genuinely intersectional as innovation often happens in crossroads of technologies and applications (...). (Salmelin, 2013, p. 5)

Salmelin (2013) enumerates an entire array of OI2 features which separate this paradigm from closed innovation model and open innovation model proposed by Chesbrough (Table 2). Cross-fertilization replaces cross-licensing and multiple insourcing and exploitation strategies of standard open innovation. Hence, the exchange of intellectual property rights (IPR) is not basic interaction within OI2: this paradigm brings in equally important interactions such as joint initiating of R&D process, mutual inspiration of R&D actors, providing and updating product requirements, implementation of non-monetary values, identification of societal or environmental challenges, etc. This inclusive strategy, engaging citizens in the process of shaping of innovation agendas, could be pursued with the use of transdisciplinary foresight methods, due to which stakeholders would be able

to identify key societal challenges and envision how innovations could embrace them (Gudowsky & Peissl, 2016).

OI2 approach has an ecosystemic character. Isolated innovation funnel, present in Chesbrough's model, treated innovation environment as a context of innovation process of a single company. Now, in turn, it is the very environment that comes to be the explicit subject of reflection: in this manner OI2 presents multi-funnel approach, where multiple processes involving idea generation, research, development, and commercialization are orchestrated in the scale of the entire network of actors. That is precisely why, in the case of OI2, the emphasis is put on the role of public policy maker (the government), which is to facilitate co-operation and knowledge flow between actors. For this very reason many speak of value constellations that go beyond monetary exchange (e.g. data exchange in digital industries). According to Normann and Ramirez (1993), value constellation is a network of actor-nodes jointly creating value proposition.

Table 2. Comparison of selected features of open innovation and open innovation 2.0 (adapted from: Salmelin, 2013)

closed innovation	open innovation	open innovation 2.0
subcontracting	cross-licensing	cross-fertilization
solo	cluster	ecosystem
linear subcontracts	triple helix	quadruple helix
control	management	orchestration
single entity	single discipline	interdisciplinary
value chain	value network	value constellation

One may read the origins of OI2 ecosystemic approach into the theory of innovation systems (IS). Such systems encompass many actors constituting the environment of product and service companies, such as customers, suppliers, competitors, academic entities, and government institutions. These theories have been developed since 1980s (Lundvall, 1985; Freeman, 1988). The definition deriving from Lundvall (1985) projects that

system of innovation is constituted by elements and relationships that interact in the production, diffusion

and use of new and economically useful knowledge and that a national system encompasses elements and relationships, either located or rooted inside the borders of a nation state. (p. 86)

Lundvall adopts a perspective of *social systems* theory, where learning is positioned as core activity of the innovation process. Furthermore, IS is also a *dynamic system*, marked with, firstly, feedback between subsystems (facilitating or blocking innovation process) and, secondly, reproduction of both individual and collective knowledge (Lundvall, 1985, p. 86). This approach, with learning and cross-fertilization as its focal points, draws parallels with OI2 model. Moreover, Lundvall's work is also considered as predecessor of the studies on innovation openness. Cognately, innovation openness is put forward in the OECD report (2008), where regional or national innovation systems are referred to: "while open innovation looks at the innovation system from within the company, the literature on innovation systems looks at companies as black boxes" (p. 26). IS theory is concurrent with OI2 approach, since it alters the perspective: from micro-scale, focused on the analysis of knowledge and technology that function within the organization, to holistic level of analysis of the entire ecosystem, where the organization itself is treated as black box with input and output being only known values. The analysis is thus transferred from the level of organizational innovation funnel to cross-organizational level of mesh innovation network. And furthermore, where within such innovation there exists a cooperation between administration, industry, and academia, Etzkowitz's "triple helix" applies (OECD, 2008, p 26). If, in addition, one counts active participation of the citizens in designing research agendas or even directly in innovation activities, one observes the so-called "quadruple helix" typical of OI2.

Furthermore, the literature on open innovation has also addressed the concept of ecosystems. Simard and West (2006) perceived public bodies as entities responsible for "policy prescriptions" as well as facilitating "innovation creation and flows" and collaborative innovation through, for example, government-sponsored research. The authors, trying to explain also the role of nongovernmental institutions

within the innovation system, refer to Lundvall. This very role would rely on supporting innovativeness of companies through facilitation of “flow of tacit knowledge and organizational learning” (p. 227-228).

Discussion: the role of the government

Curley and Salmelin (2013, p. 5) summarize Chesbrough’s open innovation as a model that reflects interactions of knowledge transfer (exchange transactions including monetary value such as acquisitions, sublicensing or subcontracting) between organizations oriented towards commercialization of knowledge which, in turn, shall generate revenue. According to Chesbrough (2003b), in open innovation perspective the government performs primarily as “innovation benefactor” who provides “new sources of research funding” (p. 38). Additionally, the government and national institutions are supposed to sustain proper legal framework conditions for the transfer of intellectual property rights, since “national intellectual property policy including patent regulations” highly determine effectiveness of employment of open innovation model (West, Vanhaverbeke & Chesbrough, 2006, p. 300). Essentially, the literature pertaining to transitions in R&D&I management methods does not identify any role for the government in innovation process other than “external source of funding” (Table 3), regardless of whether it is direct funding or indirect financing through public procurement (Rothwell, 1994; Niosi, 1999).

However, the approach of OI2 is different. Apart from value seen from a market perspective, societal value is also anticipated:

innovation success is characterized by how well innovation ecosystems assembled from a multitude of participants create novel products and services that are quickly adopted. Once again we want to stress the importance of the creativity beyond organisational boundaries as essential to creating valuable components for innovation from a societal (market) perspective due to new co-creation processes across all stakeholders. (Curley & Salmelin, 2013, p. 5)

Table 3. Public involvement in industrial research and development

	public (governmental) involvement in industrial R&D
first generation	“some financial support for major R&D programmes in companies” (Rothwell, 1994)
second generation	“public procurement as a means to stimulate industrial innovation” (Rothwell, 1994)
third generation	“government encouragement and support” (Rothwell, 1994)
fourth generation	“government funds, directly or indirectly, a high proportion of R&D expenditures both in business and in the public sector” (Niosi, 1999)
fifth generation	“legislation to enable more rapid movement of scientific information into the private sector” (Rogers, 1996)
sixth generation (open innovation)	“innovation benefactors provide new sources of research funding” (Chesbrough, 2003b) “national intellectual property policy, including patent regulations” (West, Vanhaverbeke & Chesbrough, 2006)
open innovation 2.0 (OI2)	“role of the public sector is to create the environments for OI2 where the mash-up of the needed components can happen in a frictionless environment” (Curley & Salmelin, 2013) “public policy maker needs to create the framework for this interaction” (Salmelin, 2013)

Now, the government acts not only as an “innovation benefactor” (funding source for R&D) but also as innovation customer. OI2 perceives R&D&I as instrument of “structural” change (Salmelin, 2013), where the government and society to some extent appropriate “returns” of innovation in the shape of social value. The evolution of R&D management models, while ultimately leading to open innovation, shows how within planning of innovation process not only direct market environment (e.g. competitors, suppliers, customers), but also government organizations and public institutions are taken into account. In particular, gradual intensification of cooperation between private and public R&D (e.g.

academia, research and technology organizations) may be noted. The awareness of research-cooperation between private and public sector entails reflections on changes in legislation which are supposed to stimulate knowledge transfer from academia and public research and technology organizations to the private sector (Rogers, 1996).

In the light of innovation systems theory, the OECD study on open innovation puts forward that, in order to sustain well-functioning of national or regional innovation system, the role of the government and policy-makers “implies not only creating the necessary nodes of the system but also ensuring a continuous flow of ideas and facilitating the linkages that will favour an interactive environment” (OECD, 2008, p. 26). Thus the IS paradigm influences open innovation theory: West, Vanhaverbeke and Chesbrough (2006, p. 299) admit that development and diffusion of innovations occur within the network of institutions and actors that frequently cooperate, and that the objective of the government is to establish the framework and policies to influence the process. As far as the policy-making is concerned, open innovation model evolves towards ecosystemic model, which allows for inclusion of notion of policy into innovation process management. Within this broader perspective innovation environment is seen as a multitude of intertwining innovation processes that run through networked entities. The shift of the perspective was possible because the concept of open innovation has been invested with ideas drawn from the theory of regional, national, or even European innovation systems (Schuch, 1998).

Concluding remarks and future research

The overview of methods and approaches concerning R&D management leads to the conclusion that by virtue of increasing complexity of systems (products), progressive specialization of businesses' core competence and profitability imperative, organizations adopt increasingly inclusive approach to innovation, culminating in its open model. The analysis leads to the undermentioned conclusions which constitute starting hypotheses for further, detailed study

of the notion of open innovation in public R&D&I support programmes.

(1) It seems that open innovation studies are dominated by company-centric perspective, and the analysis of innovation process is conducted on the level of isolated organization. Chesbrough's (2003a) innovation funnel comes to be an exemplification of such methodology. It may stem from the definition accepted by OECD (*Oslo Manual*), deeply rooted within the literature: innovation is an implementation of a service or product which are *new to the firm*. This, to some extent, inhibits capturing the roles of other firms (suppliers, subcontractors, competitors) as actors involved in co-creation.

(2) Periodization of the development of innovation management methods shows that in the course of time the role of innovative company's environment is becoming more apparent. Thus along with the gradual opening of R&D&I process, the interactions between the company and its environment are analysed in a more detailed manner. Research shows that the open innovation model requires coordination of actions of all actors and stakeholders with regard to their strategic orientation and business models.

(3) In contradistinction to open innovation model, from the perspective of innovation systems theory, organizations are seen as black boxes since the research focuses on the interactions between network nodes (actors) rather than on the processes ongoing inside companies. Due to this ecosystemic approach it is possible to capture the complexity of dynamics of knowledge exchange, cross-organizational learning, and joint co-creation of innovations. In particular, OI2 paradigm puts a question of how to orchestrate individual innovation processes across the entire value network.

(4) The OI2 model allows to define the role of the government in a way that goes beyond a mere "innovation benefactor" responsible for R&D funding. Within this model the government actively supports and facilitates multi-actor cooperation, which may yield cross-boundary alliances developing wide range of products using common standards.

(5) Within the OI2 model, R&D work, carried out by industry, can be interpreted as a measure of public policy to tackle societal (e.g. climate change) and economic challenges

(e.g. strengthening the position of European industry). Public investments in large-scale ecosystem projects, various incentives to increase R&D expenditure in private sector as well as facilitation and financial support to increase venture capital investments in technology seem to support this conclusion.

References

- Caracostas, P., Muldur, U. (2001). The emergence of a new European Union research and innovation policy. In: P. Larédo, P. Mustar (Eds.), *Research and innovation policies in the new global economy. An international comparative analysis* (pp. 157-204). Cheltenham–Northampton: Edward Elgar Publishing.
- Chesbrough, H. (2003a). *Open innovation: The new imperative for creating and profiting from technology*. Boston: Harvard Business Press.
- Chesbrough, H. (2003b). The Era of Open Innovation. *Sloan Management Review*, 44(3), 35-41.
- Curley, M. (2015). The Evolution of Open Innovation. *Journal of Innovation Management*, 3(2), 9-16.
- Curley, M., Salmelin, B. (2013). *Open Innovation 2.0: A New Paradigm*. White Paper. The Open Innovation Strategy and Policy Group, 1-12.
- Du Preez, N.D., Louw, L., Essmann, H. (2006). An innovation process model for improving innovation capability. *Journal of High Technology Management Research*, 1-24.
- Etzkowitz, H. (2008). *The Triple Helix. University–Industry–Government. Innovation in Action*. New York–London: Routledge.
- Freeman, C. (1988). Japan: A new national innovation system? In: G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg, L. Soete (Eds.), *Technology and Economy Theory* (pp. 331-348). London: Pinter.
- Granstrand, O., Sjölander, S. (1990). Managing innovation in multi-technology corporations. *Research Policy*, 19(1), 35-60.
- Greenhalgh, C., Rogers, M. (2010). *Innovation, intellectual property, and economic growth*. Princeton: Princeton University Press.
- Gudowsky, N., Peissl, W. (2016). Human centred science and technology—transdisciplinary foresight and co-creation as tools for active needs-based innovation governance. *European Journal of Futures Research*, 4(1), 1-10.
- Lundvall, B.Å. (1985). *The Learning Economy and the Economics of Hope*. London-New York: Anthem Press.
- Niosi, J. (1999). Fourth-generation R&D: From linear models to flexible innovation. *Journal of Business Research*, 45(2), 111-117.

- Nobelius, D. (2004). Towards the sixth generation of R&D management. *International Journal of Project Management*, 22(5), 369-375.
- Nonaka, I., Takeuchi, H. (1986). New New Product Development Game. *Harvard Business Review*, 64, 137-146.
- Normann, R., Ramirez, R. (1993). From Value Chain to Value Constellation: Designing Interactive Strategy. *Harvard Business Review*, 71(4), 65-77.
- OECD (2002). *Frascati Manual. Proposed standard practice for surveys on research and experimental development*. Paris: Organisation for Economic Co-Operation and Development Publishing.
- OECD (2005). *Oslo Manual. Guidelines for collecting and interpreting innovation data*. Organisation for Economic Co-Operation and Development Publishing: Paris.
- OECD (2008). *Open Innovation in Global Networks*. Paris: Organisation for Economic Co-Operation and Development Publishing.
- Rogers, D.M.A. (1996). The challenge of fifth generation R&D. *Research-Technology Management*, 39(4), 33-41.
- Rothwell, R. (1994). Towards the fifth-generation innovation process. *International marketing review*, 11(1), 7-31.
- Roussel, P.A., Saad, K.N., Erickson, T.J. (1991). *Third generation R&D: managing the link to corporate strategy*. Boston: Harvard Business School Press.
- Salmelin, B. (2013). The Horizon 2020 framework and Open Innovation Ecosystems. *Journal of Innovation Management*, 1(2), 4-9.
- Schuch, K. (1998). The emergence of the European Innovation System and its impact on the Austrian S&T system. In: *Proceedings from the 38th Congress of the European Regional Science Association* (vol. 28).
- Simard, C., West, J. (2006). Knowledge Networks and the Geographic Locus of Innovation. In: H. Chesbrough, W. Vanhaverbeke, J. West (Eds.), *Open Innovation. Researching a New Paradigm* (pp. 220-240). Oxford: Oxford University Press.
- Simpson, T.W. (2004). Product platform design and customization: Status and promise. *Artificial intelligence for Engineering design, analysis and manufacturing*, 18(1), 3-20.
- Vanhaverbeke, W. (2017). *Managing Open Innovation in SMEs*. Cambridge: Cambridge University Press.
- West, J., Vanhaverbeke, W., Chesbrough, H. (2006). Open Innovation: A Research Agenda. In: H. Chesbrough, W. Vanhaverbeke, J. West (Eds.), *Open Innovation. Researching a New Paradigm* (pp. 285-307). Oxford: Oxford University Press.