Małgorzata Runiewicz-Wardyn

Open Innovation Ecosystem and Open Innovation Collaboration from the Perspective of the Polish High-Tech and Knowledge-Intensive Small and Medium-Sized Enterprises

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CONTENTS

Introduction

The innovation process is not created only by the individual actions of firms. Firms' relationships with other agents involved in the innovation system are an important dimension of business innovation. After all, the competitive advantages of firms also depend on the strength of the ecosystem in which they operate. The term 'open innovation', introduced by Henry Chesbrough, implies that companies can and should be using both external and internal ideas to create value and build their own competitive advantages (2006, 2003).

Open innovation (OI) is a complex function where both material factors, such as R&D investments, infrastructure, knowledge acquisition and competence development, and intangible factors, such as social and cognitive skills, play a role. Moreover, the importance of cooperation in the field of open innovation is growing not only due to the increasing process of globalisation, accelerated technological progress, limited access to capital resources and research and development (R&D) financing or epidemiological threats, but also due to the intensifying processes of technological convergence, the increasingly multidisciplinary, interdisciplinary and complex nature of innovation in the high-tech and knowledge-intensive industries (Runiewicz-Wardyn 2019, 2020; Kim and Choi 2018, Durst and Poutanen 2013, Duysters and Hagedoorn 2018; Zhao, Sun and Xu 2016).

The results of many empirical studies confirm the positive relationship between the openness of innovative processes and the achievements of enterprises in the field of innovative activity. In recent years, numerous publications have been actively discussing the works by Chesbrough (2003a, 2003b), Chesbrough and Rosenbloom (2002), Chesbrough and Brunswicker (2014), Lessl and Asadullah (2014), Holgersson et al. (2018) in the context of advanced technology sectors; Hossain and Kauranen (2016), Rahman (2016) in the context of SMEs; Fasnacht (2018), Rahman (2016), Mergel and Desouza (2013), Böhmer (2015), Curley and Salmelin (2020), Mercado-Lara and Rentería-Marín (2021) on the open innovation ecosystems. In Poland, these include the works of Janasz, Kozioł-Nadolna (2011), Janasz (2005, 2010), Poznańska and Sobiecki (2012), Kolterman (2013), Bojewska (2015), Matusiak et al. (2001), Janasz and Kozioł (2007), Witness (2007), Pichlak (2012). Several of these studies also touch upon the problems of the Polish SMEs sector, i.e. Bojewska (2009), Skowronek-Mielczarek (2013), Wach (2013), Lisowska and Ropęga (2016).

Despite the growing interest in both scientific and business applications of the open innovation concept, most of the above-mentioned studies still focus primarily on large companies, discussing managerial and strategic aspects of open innovation, considering the examples of the concrete case studies. In Poland, the empirical evidence on the open innovation is limited and practical prescription is overly general. Research ranges from individual case studies, which are difficult to generalise, to simple survey-based counts of external sources and partners, which reveal little about the conditions, mechanisms or limitations of open innovation.

More importantly, the concept of the 'open innovation ecosystem' and open innovation collaborative environment, especially in the context of small and medium-sized enterprises (SMEs), is still poorly documented in the Polish literature. Some relevant publications include the works by Lewandowska (2018), Roszkowska-Menkes (2015), Sopińska and Mierzejewska (2017), Romanowska and Cygler (2014), Mazur et al. (2008), Bogdanienko (2011), Weresa and Poznańska (2012), Wiśniewska and Janasz (2015), Runiewicz-Wardyn (2020). Partially, the innovation collaboration process and challenges related to the intellectual property sharing are discussed in the studies by Kozioł-Nadolna (2013), Szymury-Tyc (2015), Dogwood (2014), Witness and Wiśniewska (2015) and Okoń-Horodyńska et al. (2018, 2020). Given the specific nature that distinguish SMEs from the larger companies, it is relevant to explore the diversity of practices, benefits and challenges in the implementation of the open innovation paradigm with respect to the SMEs sector and relate them to their innovation environment. In this context, this study addresses the research gap and allows for a better understanding of the open innovation phenomenon and the establishment of public policies and recommendations to improve open innovation ecosystem environments.

The following monograph shares the latest empirical insights and knowledge about attitudes, practices and experiences, as well as identifies the level of openness, major drivers and barriers of open innovation collaboration from the perspective of the Polish high-tech and knowledge-intensive SMEs sector. The monograph is divided into four chapters. The introduction is followed by a presentation of the theoretical and conceptual framework of the open innovation paradigm, open innovation ecosystem and its major dimensions. Chapter two focuses on the specific features of high-tech and knowledge-intensive SMEs and their innovative collaboration with key stakeholders (with firms, academia, public authorities, end users, etc.) as well as the problem of knowledge sharing. Chapter three presents the dynamics, structure and development of the selected high-tech and knowledge-intensive industries in Poland. Finally, Chapter four presents the results of qualitative research conducted in the Polish SMEs sector. The monograph ends with conclusions and policy implications.

Chapter 1

A Conceptual Framework of 'Open Innovation' and the 'Open Innovation Ecosystem'

Introduction

In order to pursue a comprehensive research approach to study the open innovation environment in SMEs and the knowledge-advanced industries, this chapter draws on an overview of the open innovation concept, open innovation model, open innovation ecosystem (OIE) as well as the various dimensions that contribute to the successful open collaborative environment. The author presents an overview of the evolutionary path of the model of the innovation process from the beginning of the 20th century to the present times. The section presents an integrated approach to the role of the open innovation ecosystem by considering its business, institutional, technological, spatial, social and cultural dimensions, and it attempts to enrich the theoretical discussion over the interlinkages between these dimensions, and open innovation ecosystems performance.

1.1. The 'Open Innovation' Paradigm

The term 'innovation' was first introduced to the economic sciences in 1912 by Joseph Schumpeter, who described innovation as the process of the formation of a new 'production function'. The author called it a 'new combination' of production factors (Schumpeter 1960: 131). The subject scope of the 'innovation' defined by Schumpeter was extremely wide. In principle, it comprised all technical and socio-economic changes introduced by a given invention. Under the concept of innovation, Schumpeter understood the introduction of a new product, a new production method, entering a new market, gaining a new source of supply or making changes to the organisational processes of the particular industry. For Drucker (1985), Larson (2000), in turn, an innovation is a special tool of entrepreneurship, which does not have to be technical or material. It is rather a process by which individuals pursue opportunities beyond the current resources that they control. As Herbig et al. (1994) point out, entrepreneurs do not innovate purposely but 'intentionally seek opportunities'. Thus, the entrepreneurs capture ideas and collect resources, in order to combine them and transform them into new products and services that create value to their businesses. In Poland, a broad approach to the definition of innovation is presented by Gomulka (1998: 11–15), for whom innovations are a form of long-term investment and therefore refer only to the inventions that find application in economic practice. Moreover, the innovation or innovativeness can be analysed at the level of the enterprise, industry, sector and at the level of the economy as a whole. The literature emphasises that the concept of innovation may apply both to 'absolute' novelties, such as new and previously unknown solutions in the world (i.e. breakthrough innovations, innovations on a global scale), innovation as the new phenomena on a given geographic area (i.e. innovations on the specific local markets), and finally to the so-called innovations on the individual companies' level (i.e. by imitating the actions taken by their competitors) (Klincewicz 2014, Knell and Srholec 2009)[1]. The subject of innovation can be any positive and progressive novelty adopted by an organisation or individual person. It could be a production method, behaviour or any material object. In the functional sense, the innovation refers to the process of generating new ideas, creating, designing, implementing or adapting new solutions (innovation process). Furthermore, Kaminski (2018) identifies economic innovations, which cover the entire range of possible economic novelties, i.e. organisational, technical, marketing and eco-innovations. Finally, when considering the nature of the innovation, one could identify radical or incremental innovations (Gersick 1991). The first category involves large technological advancements and usually requires larger spending on R&D (for highly uncertain returns on investment). The successful radical innovations are capable of completely replacing old products and industries with new ones, e.g. replacing oil lamps with electric ones (Schumpeter 1942, Gersick 1991). The second type is incremental innovations, which focus on refining and exploiting the potential of already established products and processes.

Hence, innovation is a complex category and has a multidimensional nature. It is extremely difficult to fully define it. Selecting an appropriate definition of innovation for the needs of advanced technology industries would require the use of a whole range of definitions, appropriate to their specific nature and the level of details of the *theoretical considerations* and empirical research results. For the

[1] Innovation must not be confused with the imitation. Imitations that arise as a result of copying, imitating new solutions implemented by the pioneer entrepreneurs do not allow for the creation of the future value and impose other conditions of the market game (Wierzbicki 2017).

purposes of further discussion, innovation is defined as a dynamic process leading to the production of new or improved products, technological processes and organisational systems, implemented both for the benefit of the organisation as well as its environment.

1.2. From Linear Towards Networked: The Innovation Process

The traditional approach to the innovation process goes back to the era of Henry Ford. It assumes the high role of scientific knowledge and the dominance of basic research as a source of innovation. Rothwell has been one of the pioneers in industrial innovation to put forward a descriptive model of five generations of innovation models, starting from the 1950s onwards (1994). In the classical, linear-sequential model of innovation (from the 1950s to the mid-1960s), several successive phases can be distinguished: basic research, applied research, development phase, production and diffusion. The model assumes that the innovative ideas are developed by the individual companies as part of their R&D activities (Janasz et al. 2001: 195). In the early 1960s, and then the 1970s, the new concepts within the linear model of innovation emerged – the technology push innovation model and the market pull innovation models (first- and second-generation models). The first one takes into account the technological abilities of the enterprise, while the second one takes into account the importance of buyers and their needs (Rothwell 1992). The technology push innovation model was also the result of rapid economic growth in the 1960s. The US National Aeronautics and Space Administration developed this as a management tool in the 1960s. The idea was to break down complex processes of space projects, systemise the R&D work and gain control over each research activity. The push innovation process focused on the extensive R&D process and ignored the marketing phase.

Table 1. Rothwell's five generations of innovation models

Model	Description
First and second	The linear models – market pull and technology push
Third	Interaction between different elements and feedback loops between them, the coupling model
Fourth	The parallel lines model, integration within the firm, upstream with key suppliers and downstream with demanding and active customers, emphasis on linage and alliances
Fifth	Systems integration and extensive networking, flexible and customised response, continued innovation

Source: Entekhabi (2012).

In the early 1980s, the third-generation innovation model overcame the limitations of the previous two models and gained acceptance especially during the economic downturn – both the inflation phase and the stagflation phase of the economy. The innovators coupled technological innovation with market needs based on an interactive process and feedback from the market research and previous linear innovation models. Next, the fourth-generation innovation models introduced by the Japanese electronics and automobile industries in the early 1990s integrated various innovation activities run by different internal departments as well as integrated suppliers, customers and partners in the industrialisation process. Yet, in the fourth-generation-model innovation is generated on the basis of the companies' own resources and skills, and thus requires high expenditure on the R&D.

It also means that the fourth-generation model moved from the sequential process to the parallel R&D process, which may be ineffective if the problem one aimed to solve has already been solved by other research or business entities.

In fact, the rapid technological advancement and technological convergence proved that in reality the innovative process rarely follows a linear model and it is rather multisequential, with interdependence of its different phases (Janasz and Kozioł 2007: 37). Thus, the innovation researchers started pointing out to a more complex and non-linear nature of innovation. For instance, Dias et al. (2014) conclude that 'innovation is conceived in a context of conventions or rules and complexity' (p. 1). Innovation occurs across scientific, technological and economic domains in possibly interacting perspectives (Leydesdorff et al. 2013). For the same reason, they argue that innovation cannot be locked into one place or system. In fact, Leydesdorff and Rafols (2011) support this statement by providing the example of medical innovations, which can begin as new ideas and discoveries within a single or several isolated scientific groups. However, in the next phase, they spread to many scientists in a so-called 'chain reaction' and connect to a few leading global institutes, forming so-called 'oligopolistic centralization' or 'creative accumulation'. At this stage, basic research is complemented with interdisciplinary research and is translated into practice in clinical trials or registration of patents (Leydesdorff et al. 2013).

Consequently, in the early 1990s, linear models were replaced by fifth-generation (open) models, which are more complex, non-linear, networked or parallel models, favouring R&D integrated activities, involving both internal and external stakeholders at all stages of the innovation process (Kozioł-Nadolna 2013, Truskolaski 2014, Szymura-Tyc 2015, Rothwell 1994, Tidd and Bessant 2011). Thus, innovation has become a collective, collaborative and cross-functional process, requiring creative combination of both generic knowledge and specific competencies (Marinova and Phillimore 2003: 50–51, Bochma and Frederick 2010).

In such complex and highly interactive innovation environments, Chesbrough (2003) postulated the 'open innovation' paradigm, which highlights the use of purposive inflows and outflows of knowledge to accelerate internal innovation. The 'open innovation' concept is reflected in the sixth-generation innovation models which see innovation as a multidimensional process involving a number of different entities: suppliers, public R&D facilities, business (external and internal) R&D facilities, non-profit industry organisations as well as customers (Barbieri and Álvares 2016, Lewandowska 2017, Kozioł-Nadolna 2013, Weresa 2014).

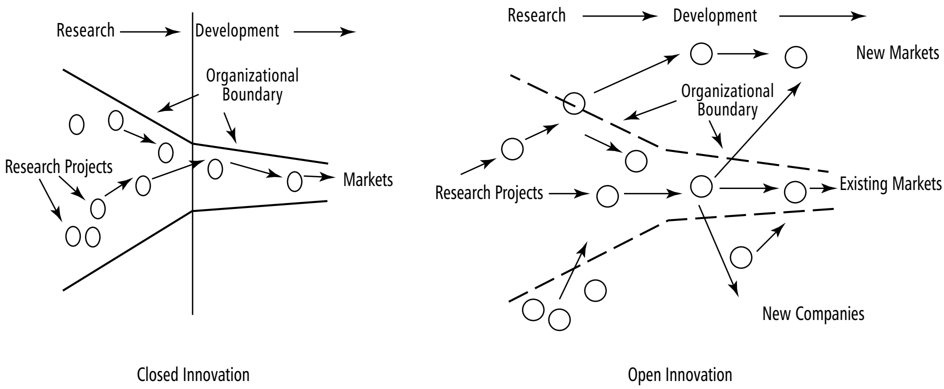
Chesbrough and the 'Open Innovation' Paradigm

Until recently, having an in-house R&D department was considered a strategic resource and perceived as a barrier of entry for other companies (this type of reasoning is present in all the five generations of innovation models). The individual R&D departments were responsible for all the innovation-related activities (development, design and marketing). After the generation and development of new ideas, financing and bringing them to the markets, companies had to further deal with their distribution and user support. In other words, they followed the slogan: 'If you want to do something right, do it yourself' (Chesbrough 2003, Gajewski 2010). This way of thinking implied a constant need for R&D investment funds, search for the best and smartest people as well as control of one's intellectual property so that competitors could not benefit from it. It is not surprising that such conditions could have only been met by large organisations with adequate resources and long-term R&D programmes.

The paradigm of the open innovation assumes that not all the best people work for one particular company, therefore it needs to cooperate with external R&D organisations and draw from their best ideas and competencies (Chesbrough 2003). Within this paradigm, creating a better business model based on sharing intellectual property with other organisations is more important than entering the market first. The accelerating globalisation processes, the development of modern technologies, especially information and communication technologies (ICT) and the related development of the knowledge-based economy force the companies to search for easier and quicker access to the latest knowledge. Moreover, in global 'networked' society, knowledge is widely disseminated and virtual communities are increasingly becoming a source of innovative ideas. In order to achieve its success, companies must learn to use the knowledge originating from the so-called the wisdom of the 'crowds' or a networked society. In such context emerges the new paradigm of 'open innovation'. The principal idea of the OI concept is the observation that the places where knowledge and new ideas arise are not exactly the places where new products or technologies are created and implemented (Kozarkiewicz 2010). Nevertheless, while the concept of open innovation and its forms of industry-universities cooperation and networks are being successfully diffused, they are also subject to criticism by some researchers. *Firstly,* the critics of the concept of 'open innovation' proposed by Henry Chesbrough question the originality of the whole concept, pointing out that its assumptions, related to the processes of 'knowledge sharing', are not new (Trott and Hartmann 2009, Fredberg et al. 2008, Gassmann and Reepmeyer 2005, Remneland and Wikhamn 2013). Others emphasise the limitations in the application of the open innovation model, e.g. in the case of enterprises operating in new, only emerging fields of knowledge (Wściubiak 2017). Yet, others point out into the difficulty in finding suitable partners for cooperation, the problem mutual trust and equal sharing of the benefits in working together towards a common goal (Oakey 2012).

The open innovation paradigm is still young concept. The following monograph focuses on the open innovation and its relationship to such concepts as collaboration, openness, knowledge and ideas sharing. In the open innovation model, the role of external partners is important at all the stages of innovation process, i.e. from the generation and selection of ideas, through developing and transforming them into innovative solutions, and finally the commercialisation and diffusion of innovation (Rojek 2014). The use of external partners in the innovative processes is dictated by the desire to reduce costs and risks associated with the time-consuming and cost-intensive R&D process as well as the advantages of the economies of scale and the ongoing processes of technological convergence and resource synergy. The primary partners in the open innovation models include: customers, suppliers, competitors, R&D units and universities (Sopińska 2013). The following diagrams (Charts 1a and 1b) demonstrate two extreme models of the innovation processes – closed (traditional) and open (networked). Model *a* is an innovation process carried out inside the company only with the use of its internal resources, while model *b* is a process that uses knowledge resources created both inside and outside the company, as well as uses the external ways of introducing the new technology to the market. In the closed model, both related R&D as well as the marketing efforts are carried out and strictly protected within the company. However, it is not possible to maintain knowledge within one organisation, i.e. employees hired in a new place also take their knowledge and experience with them. This means that it can be used by another entity or commercialised from venture capital funds, signing a licence agreement or as a result of establishing a spin-off company (Krause et al. 2012). The open innovation model of the innovation process is not based on a simple correlation between the R&D variable and innovation, but on a constant search for new ways of increasing the effectiveness and efficiency of innovative processes. Companies search for ideas and technologies outside their own company and undertake cooperation with external entities. On the other hand, they also make profit by selling licences to other companies that do not fit into the company's development strategy (De Jong et al. 2008) (model *b*).

Figure 1a and 1b. Closed and open innovation model



Source: Rahman and Ramos (2010).

One way to understand the innovation process under the paradigm of the open innovation model is to consider the general innovative product development process and its specific phases: 1) idea generation, 2) definition, 3) prototyping, 4) design, 5) validation and testing, and 6) commercialisation (Bruiyan and Nadia 2011, Kahn and Kenneth 2012). The final success of the innovative output requires the integration of various sources of knowledge and efforts in each specific phase. For instance, the phase of idea generation (1) requires the brainstorming of a new concept or idea, the phase of the definition and development (2) requires collaboration with end users in understanding their needs and expectations; similarly, the collaboration during the prototype, design and testing phases requires feedback from both end users and engineers (3, 4 and 5) in order to ensure that prototype works as planned. Finally, the phase of commercialisation, determining and implementing the operationalisation processes, selected modes and commercialisation strategies (6) requires partners to work closely together to manage the flow of products and services along the whole value-added chain. This means that the open innovation model constantly combines its own knowledge and resources with those from other partner organisations.

In simple terms, open innovation collaboration could be defined as the process of collaboration of enterprises with other firms (suppliers, customers, competitors and consultants) or organisations (such as universities or public research bodies) in developing and/or commercialising new innovation processes and products through integrating their internal and external knowledge resources necessary to innovate. The companies and R&D institutions introducing open innovation practices make better use of their innovative potential (i.e. R&D processes and outcomes). They also increase the overall productivity of their research teams, stimulate innovation and technological progress, especially in the fields at an early stage of technological life cycles. Many large, well-known companies are experimenting with the open innovation models with great success (among them are Philips, Nokia, Cisco, Boeing and many others). Yet, this is not a solution intended only for larger companies. Several studies show that the open innovation model is equally important in the SMEs sector, in both knowledge creation and transfer and diffusion processes (Gallaud 2013, Alvarez-Castanon 2019). Open innovations can take such forms as licences, patents, purchase of know-how, implementation of R&D contracts, cooperation with universities (in a formal manner and an informal one) in the introduction and implementation of new solutions as well as purchasing university spin-offs.

1.3. Entering Strategic Innovation Partnerships with External Partners

Partnerships are a form of commitment between two or more partners, in which cooperating sides share expertise and resources to achieve mutual benefit (Davies and Hentschke 2006). A partnership is created when both partners believe they can better achieve their goals when they work together. The benefit is therefore achieved through sharing the unique resources, shared R&D engagement, knowledge exchange and interorganisational learning. There are at least several forms of innovation partnerships between business and university stakeholders that could be identified: joint R&D/product development, strategic cooperative agreements, technology licensing, activities within technological incubator programmes, technology scouting agreements, which are further discussed in this section.

Entering strategic R&D partnerships with other firms

Much of the literature attempting to explain the external sourcing of innovation studies the benefits of coupled processes, such as R&D collaborations and technology alliances (Faems et al. 2010, Bayona et al. 2001; Un, Cuervo-Cazurra and Asakawa 2010). Bayona et al. (2001) show that cooperative R&D agreements between firms are more frequent in sectors with high technological complexity than in sectors with low technological complexity. Currently, most of high-tech companies have put greater focus on leveraging external knowledge, licensing, and changing their R&D models from primarily inside-driven to the one following the open innovation paradigm. As a consequence, the proportion of externally sourced R&D assets has increased in the past years, which also coincided with major downsizing in R&D departments, especially in the biopharma industry i.e. Merck, AstraZeneca and Pfizer (Schuhmacher 2018, Dankhar et al. 2012, Staton 2015, Caroll 2015, Sagonovsky 2017). In the biotechnology industry, *cooperative R&D agreements between firms* allow new technology-based firms to gain a foothold in this high-cost, high-risk industry. Seger (2013) analysed the biotechnology clustered firms in Belgium and concluded that despite their small size and relative immaturity, new biotechnology firms were able to adopt innovative business models by providing R&D and services to larger firms and openly cooperate with them through open innovation. A similar tendency was noticed in the software or electronic industries. Many companies like Procter and Gamble (PG), GSK, 3M, Siemens and GE decided to shift in their approach. For instance, in the late 1990s, PG shifted from the traditional inward-focused approach to ‘open innovation’, setting a goal to get 50% of innovations coming from outside the company. Moreover, R&D is no longer the province of the advanced industrial nations like the United States, Germany or Japan, but it is increasing most rapidly in the newly growing economies, such as India and China. Yet, in spite of these promising trends, strategic alliances may fail to succeed in open innovation. Das and Teng (2000) mention that the rate of failure in 2000 concerned 60% of all strategic innovation alliances, which had terminated within the first two years of cooperation. The reasons of the failure include: too high expectations and lack of resources and skills that enable partners to develop innovation cooperation, lack of a proper innovation-based strategy afterwards, poor management of the innovation process, including the knowledge transfer process, problem of the structural and cultural issues as well as interpersonal relationships and the individual learning process (Bucic and Gudergan 2002).

Entering Strategic R&D Partnerships with Universities

University-industry joint R&D collaboration, university-centred clusters and university-industry research centres represent a major channel through which universities contribute to the innovation partnerships with firms. Some other university-industry innovation and knowledge transfer mechanisms include informal interactions, participation in conferences, cooperation in education (training of business employees by academics), joint supervision of PhDs and master theses and joint publications, the sharing of R&D facilities, academic spin-offs and transfer of university-generated IP (scientific research results, patents, software, databases, etc.) to firms via licensing (Perkmann and Walsh 2007, and Bekkers and Freitas 2008). In many cases, collaborative research involving universities and firms is subsidised by public policy programmes or the EU ‘framework programmes’ (Caloghirou et al. 2001, Larédo and Mustar 2004), US federal-funded schemes, such as the Advanced Technology Programme (ATP) (Hall et al. 2000), or the UK National Health Service (Howells et al. 1998). The form of collaboration varies across science fields and industry sectors. University-industry partnerships can range from small-scale, temporary projects to permanent, large-scale ones, involving hundreds of industrial members (for instance, for partnerships between pharmaceutical companies and US research universities, see Stephan 2001).

The volume of each small project partnership is initiated and managed by individual university researchers and their research groups, also referred to as industry-sponsored research, which is especially popular in the medical field.

Entering university and industry cooperation has been also the main driver of the establishment of the joint R&D university-industry research centres, e.g. Hitachi Research Laboratory at Cambridge (supported by GlaxoSmithKline and British Nuclear Fuels), the Rolls-Royce network of University Technology Centres (UTCs) or the Systems Engineering Innovation Centre (supported by Loughborough University and funded by BAE SYSTEMS, see Brown and Ternouth 2006). These joint R&D centres stimulate a range of activities, i.e. collaborative research and co-authoring between university and industry members, academic consulting, applied R&D projects, educational training and the new technology transfer, patents, licences and spin-off companies (Adams et al. 2001). Accordingly, Cohen et al. (2002) found that patents and licences appear to be more important in the pharmaceutical industry followed by the communications equipment and aerospace fields (D'Este and Patel 2007, Cohen et al. 2002). D'Este and Patel (2007) conducted a large-scale survey of UK academic researchers and found that university researchers interact with industry through frequently engaging in consultancy and contract research, joint research and training, but less so in patenting or spin-out activities. Cohen et al. (2002) found that the most effective knowledge and innovation channels from university to the industry were the published papers and reports, conferences and meetings, informal information exchange and consulting. De Fuentes and Dutrénit (2012) revealed that all types of R&D interactions with the academic researchers profited the firms' R&D performance in Mexico, with the joint and contract R&D, IPR and human resource mobility (graduates and academics) having a higher impact on the long-term benefits for firms. Among the barriers, the individual and socio-cultural characteristics of researchers have also been found to have a strong impact on partnering with universities (Kozierkiewicz 2020, Perkmann et al. 2013, Bekkers and Bodas-Freitas 2008).

Technology Licensing

Technology acquisition through licence contracts may refer to a new product or process technology, designs or marketing expertise, and involves an agreement between a licensor (the owner of IP) and a licensee (established company). In the context of the new product, the contracts range through assembly from bought-in components to complete manufacture or the development of the technology that underpins a new range of improved or different products (Tsai and Wang 2007). A licensing agreement may involve a fee, a royalty (as a proportion of sales or a reciprocal flow of rights and knowledge) and the commitment to obligations by both parties over a certain period. It has usually focused either on firms exploiting their technology or on firms acquiring technology. In the first case, the companies recognise that a licensee has better capabilities to exploit a certain innovation or they aim to establish their technology as 'a standard'. The companies may also collaborate with others to expand the business into new sectors and locations. Finally, licensing out may also allow to keep off new entrants from inventing competing products.

The maturity of both technology and industry might influence the extent of licensing (Porter 1985). A dominant design or industry standard, especially in the mature stages of industry and technology growth, might be expected to lead to a concentration of technological assets or a concentration of enterprises (Lowe and Taylor 2002). Furthermore, buying-in technology may lower the long-term innovation capability if it reduces internal research skills and knowledge or strengthen such capability by speeding the processes of knowledge acquisition and building complementary assets (Quinn 1992, Lowe and Taylor 2002, Prahalad and Hamel 1990). If the transfer of proprietary rights (based on a licensing agreement) is to be successful, it has to be supported by the additional provision of training and technical assistance. 'Upstream complementary assets' are required to ensure that the firm can absorb the transferred technology, while 'downstream complementary assets' (e.g. marketing and manufacturing) may be required to exploit it (Lowe and Taylor 2002). Consequently, it may be more difficult for smaller firms to make inward licensing worthwhile. In sum, the greater the level of the firms' internal R&D efforts the stronger the positive effect will be of inward technology licensing on firm performance and the economic effectiveness of external technology usage (Cohen and Levinthal 1990, Duysters and Hagedoorn 2000, Tsai and Wang 2007).

Activities Within Technological Incubators/Parks

The European Commission (2007) developed a policy instrument based on the idea of the knowledge-intensive clusters introduced the form of R&D Intensive Parks and Science Parks, later evolved into smart specialisation platforms (Radosevic 2017). Albahari et al. (2017) classify science parks into four types: a) pure science parks (in which university stays a major shareholder); b) mixed parks (in which a university is a minority shareholder); c) technology parks (in which there is no university shareholding, but some university research facilities are located in the park) and d) pure technology parks (in which universities have no formal involvement). Albahari et al. (2017) found that 'pure science park' firms show the highest patenting performance, but the lowest product innovation levels, while the 'pure technology park' firms perform best in the sales of product innovations but are the worst in patenting. Another example is provided by a more recent study by Minguillo and Thelwall (2015). This bibliometric study analyses co-authorships (1975–2010) with organisations located in the UK Science Parks in order to identify the role universities play. The study revealed that the most collaborations of firms in science parks were conducted with off-park organisations. Nevertheless, it showed that the academic institutions were the primary source of knowledge and competence for on-park industries.

Technological Scouting

Technology scouting allows for analysing research conducted by universities in terms of commercialisation potential, and then attempting to utilise it. It is frequently seen as the logical response to the enlargement of the technological know-how market caused by the globalisation of R&D (Rohrbeck 2007). Technology scouting allows (through searching in specific technological fields) for identifying advances in science and technology that can be commercialised or used for the company. Moreover, technology scouting facilitates or executes the sourcing of technology (Duberman 1996, Wolff 1992, Rohrbeck 2007). A technology 'scout' can be either an employee of the company or a consultant, which may be involved in part or full-time in the scouting task (that person is knowledgeable both in their own field of science as well in related cross-disciplinary fields). The major goal of technology scouting is to build a competitive advantage by identifying opportunities and threats arising from technological developments at its early stage and mobilise the technological capabilities needed to face these challenges.

Investments in Start-Ups

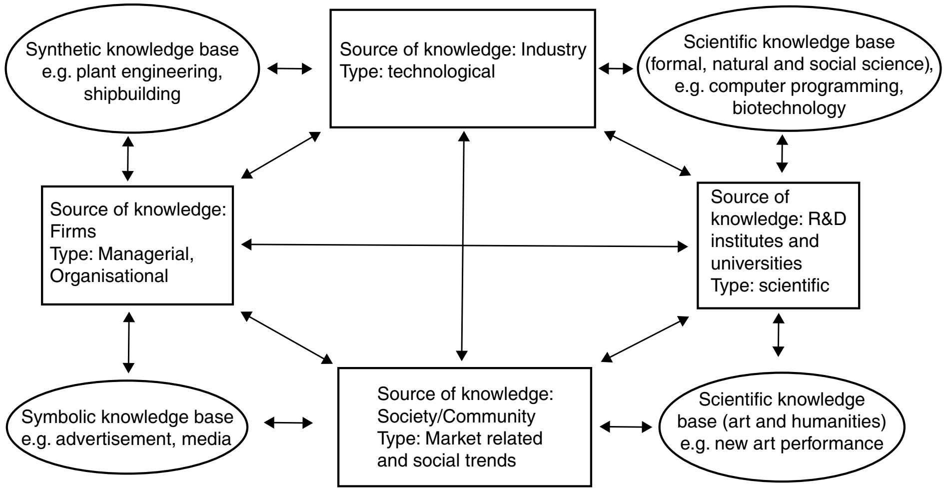
According to the definition by Blank (2010), a start-up is a company or temporary organisation designed to search for a repeatable and scalable business model (Spender et al. 2017). The existing studies show that forming a relationship with partners is key to the success of start-ups (Teece 2010, Wymer and Regan 2005). This is especially important for the deep tech start-ups whose emergence is linked to the new technologies based on scientific discoveries or meaningful engineering innovations which offer a substantial advance over established technologies and frequently seek to tackle some of the world's fundamental challenges (Siota and Prats 2021). Many deep tech start-ups have their roots in academia (e.g. developed by PhD holders) and are funded by public R&D grants. Open innovation could overcome the lack of resources allowing them to introduce new products in the market (Colombo and Piva 2008, Mustar et al. 2008). For instance, Zhang and Li (2010) found that having relations with technology service firms or talent search firms is positively related to the new product innovations. Perez Perez and Sánchez (2003) have found that start-ups' networks evolve over time. Simoes et al. (2012) and Spender et al. (2017) studied the role of higher education institutions as an intermediary between producers and consumers of knowledge. The authors concluded that higher education researchers play a key role in venturing start-ups, identifying opportunities and mobilising resources.

1.4. Open Innovation Ecosystem and Collaborative Innovation Environment

Given the still *relatively new phenomenon* of *open innovation,* there are still not many *studies* investigating open innovations from the perspective of the systemic institutional interlinkages in the *open innovation* ecosystem. The model of 'Open Innovations' (OI) can be compared with the 'Triple Helix of University-Industry-Government Relations' (TH) as attempts to find surplus value in bringing industrial innovation closer to public R&D. The model of Quadruple Helix (QH) complements this model with the fourth helix – users and, more generally, civil society – who equally contribute to the value creation processes. 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 market, as the firms look to advance their technology. Firms are thus the principal agents that uses the TH and QH knowledge infrastructure to accomplish their value creation related objectives. The two models – OI and TH – both depart from linear models such as a 'technology push' or 'demand pull' in favour of a focus on interactions and further development. Relations are no longer fixed and given, as in a channel between a supply and a demand side (Kline and Rosenberg 1986). The open innovation system can be referred to as the extended TH concept of QH. It is grounded in the idea that innovation is the outcome of an interactive and transdisciplinary process involving 'all stakeholders as active players in creating and experimenting new ways of doing things and creating new services and products' (*Open Innovation 2.0*, EC, 2018). Indeed, the increasingly complex and rapidly growing R&D and innovation processes require a large variety of knowledge types and sources. Moreover, the knowledge creation, exploitation and diffusion processes require a dynamic interplay of various types of knowledge sources as well as strong interaction between people within organisations and among them (Nonaka and Takeuchi 1995, Lundvall and Borrás (1998). Figure 2 highlights knowledge creation within the QH framework and shows that the process of innovation is the result of interaction between various actors and types of knowledge involved in this process.

For instance, studies by Veeckman and Ballon 2016, Cattacin and Zimmer (2016) and Arocena et al. (2017) provide some successful examples of industry-university collaboration in the context of Living Labs as open innovation systems that foster different knowledge transfers amongst the partnering actors. The authors use Sweden, Denmark, Italy, Germany and Spain, and cross-border Nordic-Baltic examples. The authors conclude that engaging students by external partners (including SMEs) in a collaborative knowledge creation process can be an important driver of innovations. Zaphiris and Ioannou (2018) bring evidence of how online networking sites and crowdsourcing platforms allow OIEs partners to create and evaluate ideas for innovative processes, services and products. In the context

Figure 2. The interactive model of the innovation process in the QH framework



Source: own elaboration (Runiewicz-Wardyn 2013).

of emerging technologies, especially in the communication and social media, consumers, user communities and firms use the communication platforms to share their opinions and interact in the innovation process (Cova and Dalli 2009). One example includes B2B, open-source or crowdfunding platforms. The B2B and other platform-based services for healthcare and biopharma companies may offer new ways to improve the patient-customer experience and develop innovations based on data. Another example is the open-source platforms and technologies, which allow developers to learn from each other, and therefore accelerate a further innovation process in the industry. The last but not least prominent example of open innovation collaboration is crowdfunding platforms that allow entrepreneurs to bring new products to market through broader discussion with large numbers of potential innovation backers. The field of LLs is still at an early stage (it was introduced only in 2006 and was led by the Finnish prime minister), but it has already become an important component of knowledge exploitation and facilitation strategies within the OIEs policies.

In sum, while the rationale behind the 'innovation system' focuses on the investments into R&D infrastructure, the open innovation ecosystem concept broadens attention to more intangible, qualitative interactions and relationships that affect the innovation process. Notably, the approach builds on the concept of QH. The OIE concept refers to the system of a heterogeneous group of actors (representatives of firms, universities, technology centres, development organisations, NGOs and broader community) that interact in order to boost the innovation capability of their communities. For that purpose, the research objective, the author defines the OIE as a complex set of relationships, both formal and informal, that foster and facilitate an inter-exchange of new and exploitable knowledge between the QH actors and lead to new collaborative (open) partnerships. Thus, as much as the QH model focuses on the institutional spheres, without going deeper to the specific actors within each sphere, their institutional identities OIE also focuses on the organisational, legal, technological and physical dimensions facilitating QH collaboration as well as the social interactions and trust that smoothen and make these interactions successful. The open innovation ecosystem and its various dimensions will be discussed in the next subsections.

Role of Universities and Academic Communities

The traditional model of university follows the old 'ivory tower' paradigm, isolating itself from its external environments. It is financed mainly from the public budget, often with no external control regarding the subject of the R&D process which is carried out on its own, with little or no cooperation with other centres, disseminating research results mainly through publications with little interest in the implementation of research results and protection of IP rights). As a consequence of such a model, especially in the context of limited university-business collaboration: human intellectual potential and experience remain unused, the efficiency of R&D expenditure is low; the quality of education deteriorates (based on too theoretical education programmes which have little applicability in practice; university faces a lack of funding (budget constraints) and thus ends up in pathological phenomena (e.g. scientists working in several jobs) (Santarek 2008). The idea of University in the open innovation model similar to the idea of Entrepreneurial University (Etzkowitz et al. 2017: 3) builds its entrepreneurial culture on the 'depth of interaction with surrounding society and business, and ability to create, interact and enhance the local, regional and national economic and societal vibrancy […]". Innovation industry-university networks are the critical factor influencing the Entrepreneurial University and its commercial activity (Rothaermel et al. 2007). University acts as an attractor for developing and transferring disruptive ideas through spin-offs or other partnerships with consolidated high-tech companies. The well-known cases of MIT in Boston (Massachusetts, USA) or Stanford University in Palo Alto (California, USA) are examples imitated in other places all over the world (Runiewicz-Wardyn 2020). Here, the driver depends on the high quality of the deal flow of disruptive technologies coming from the university and the cultural context where these ideas could develop. For instance, Huhtelin and Nenonen (2015) conclude that 'supportive spaces' are needed to support open innovation with other stakeholders. The authors proved that the establishment of co-creation spaces in university campuses were a useful element to bring together students, scientists, entrepreneurs and other industry partners and inspire each other with different perspectives on the same subject (Huhtelin and Nenonen 2015). University-driven open innovation ecosystems can also promote informal technology transfer between academia and industry (Frenkel et al. 2015), in contrast to more formal licensing and collaborative agreements. As Leon and Martínez (2016) point out, the university-driven open innovation ecosystem has the following characteristics: 1) a network of actors (industry, public administration, and user communities led by a university present at different levels of commitment); 2) a common (virtual or physical) space in which knowledge and talent flow through according to open innovation principles; 3) a common strategy driven by the university supporting the acceleration of the immature technologies through systems of sustained value co-creation; 4) an agreed governance scheme where each stakeholder remains autonomous, but the alignment of objectives is pursued; 5) the university acting as an intermediary, maintaining common infrastructures and programmes; 6) the university puts bigger emphasis on applied research and technology development than on fundamental research; 7) a driving role of public R&D support in universities due to its not-for-profit entity status; 8) technology specialisation to ensure the smooth connection between the university's research activities and the industry; 9) long-term commitments to ensure innovation activities merge both, with the educational support as well as the industrial interests (i.e. master and PhD theses). Last but not least, the university in the open innovation environment plays an important educative role of promoting open innovation culture willing to cooperate and co-create new products and services with other entities.

Role of User/Customer Communities

Wecht and Baloh's 2006 work has proved that thoroughly executed customer integration into new product development can be beneficial for a company's innovation performance. The same is also claimed by Thomke and von Hippel (2002), who defined users as a common source of innovations. User innovation is considered as one of open innovation's part fields (Gassmann et al. 2010). The main contribution of the customer is perceived as an enlargement and enrichment of information bases that can be utilised for the innovation process, especially the information on needs and solutions, applications that resides in the domain of the customers and users of a product or service (Piller and Ihl 2009). Thus, the customer involvement in a new product development and/or innovation process is widely analysed by a large group of innovation scholars in various social contexts and industries (Thomke and von Hippel 2002, Reichwald and Piller 2003, Franke and Piller 2004, Prahalad 2004, de Jong et al. 2007, Lettl 2007, Piller and Ihl 2009 and others). However, the management of customers' ability to innovate outside or within the business company as active participants of the innovation process remains complicated because of the lack of a conceptual framework.

Collaborating is defined as a process in which customers have the power to collectively develop and improve a new product's core components and underlying structure (Petraite 2011, O'Hern and Rindfleisch 2008). Customer co-design is a collaborative co-creation activity at the new product development conceptualisation and prototyping stage, where customers can define, configure, match or modify the product according to their needs. Consistent with the level of integration and involvement of customers in value co-creation processes, the special role is given to lead users. The lead user concept defines processes of customer integration in the idea generation and later product development phases, where cutting-edge customer ideas are needed. The living lab concept in the joint collaborative customer-business enterprise value creation process serves as a milieu for innovation. The concept integrates certain contributors, methodology, infrastructure and activities for a successful innovation co-creation process (Petraite 2011).

Role of Brokers and Intermediaries in Open Innovation Ecosystem Environments

Intermediaries in the context of open innovation ecosystems have created opportunities for matching financial sources to innovation capabilities, matching potential research partners or coordinating joint research projects, management contracts, supervision and control (Agrawal 2001, Yusuf 2008). The leading intermediary role of government also arises from its double role as the representative and guardian of the public interest and as a regulator of resource allocation in the economy and legal protection of IP rights.

Integrating the competencies of heterogeneous actors into network dynamics, enabling new processes of knowledge conversion emerge within the TH system. This is especially important when 'external structural holes' arise due to differences in culture, resources, competencies and knowledge profiles between players. These differences may enhance cognitive distance and keep various TH actors apart. Hence, intermediaries serve as 'bridge-builders' (Burt 2000). They transform external structural holes into 'weak ties' and create the opportunity for innovation through the combination of heterogeneous knowledge categories (Nonaka and Takeuchi 1995, Etzkowitz and Dzisah 2008, Pyka 2002, Knorringa and van Staveren 2006).

Intermediaries range from consultancies, governmental agencies and university technology transfer offices to venture capitalists and lawyers. All types of intermediaries frequently have different views on how to help companies in their open innovation efforts. Universities can serve as intermediaries between scientific knowledge and markets and in such a way, they promote the diffusion of innovations and foster competitiveness (see the works by Huggins et al. 2019, Johnston and Huggins 2017, Hughes and Kitson 2012, Garnsey and Heffernan 2010, Chapple et al. 2005, Feldman 1999, Kenney 2000). Universities, unlike industries, are characterised by open knowledge creation and dissemination environments, whereas companies limit access to their produced knowledge. As a result, universities and their ecosystems are considered to be natural environments for local knowledge spillovers.

Table 2. Role of intermediaries and brokers in the open innovation ecosystem and innovation process

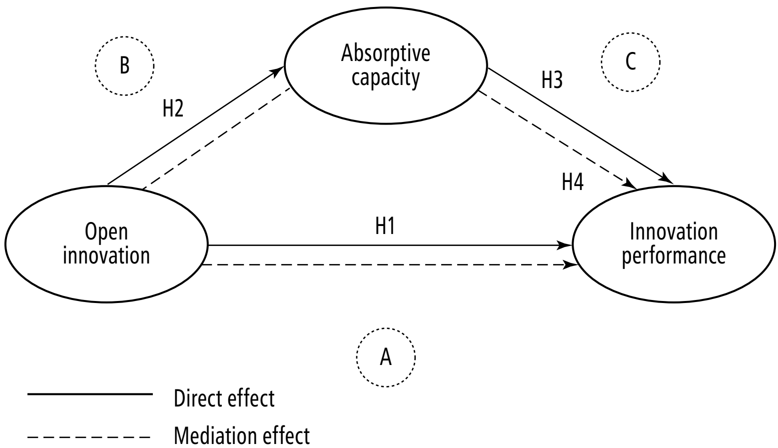
Type of agent	Role of agent	Type of stakeholder	Stage of innovation process
Brokers	– Facilitate information and knowledge provision and technology transfer across people, organisations and industries – Ensure standards setting, testing and evaluation – Provide connection of technologies and ideas to see how they may be used in different ways and in different markets, contributing with new breakthrough innovations – Facilitate commercialisation process through the building common trust and credibility	Academia, NGOs	Idea generation, development, commercialisation
Intermediary agents and firms	– Facilitate technology and knowledge transfer to firms and users – Enable the diffusion of the new ideas from outside the system – Assist in solving the problems in technology or innovation adaption (to needs of the final users) – Help to orient the science used in innovations towards meeting socio-economic objectives – Crowdsourcing and user involvement, structure and maintenance of innovation systems	Public and private organisations	idea generation, development, commercialisation

Source: own elaboration based on Howells (2006), Goodman et al. (2017), Agogue et al. (2013), Thomas (2012), Aarikka-Stenroos et al. (2014).

Organisational Dimension

The creation of new scientific or technological knowledge and innovations depend on the rate of the new knowledge diffusion across firms and institutions across time and over space. The delay of the diffusion of new knowledge within the OIE may be related to the poor capacity of agents to absorb the externally developed technology. The absorptive capacity is crucial in explaining why some companies and organisations are better at creating and capturing value from collaboration with innovation partners. Therefore, at the level of companies, the implementation of the OIE model requires having an appropriate organisational structure, resources and skills, at the same time influencing their further development. The company's key resource is the ability to absorb knowledge coming from outside and its assimilation (Winter 2003; Zahra, Sapienza and Davidson 2006). Cohena and Levinthal (1990) define the firm's absorptive capacity as the ability to identify, assimilate and exploit new knowledge. Enterprises with previous knowledge that determines its capabilities (technological, organisational or market) can better predict the future and be more successful. Hence, as Cohen and Levinthal (1990) note, enterprises should constantly seek investment to increase the level of knowledge absorption. The authors showed that firms need to substantially invest in R&D activities in order to understand and evaluate new technological trends and innovations. Furthermore, the process of the integration and application of knowledge cannot take place without qualified labour or human capital, hence the absorption feature is a feature of the entire organisation, not only of its individual parts (e.g. departments). Moreover, technology also diffuses through the transfer and mobility of skilled labour, the activities of professional societies and trade-investment relationships. The mobility of workers, especially highly skilled ones, within and across firms, is one of the most direct channels of open innovation. An important supplement to the concept of Choen and Levinthal (1990) is the work by Zahra and George (2002), for whom the absorptive capacity is 'a set of strategic processes and organizational routines through which the company acquires and assimilates knowledge, as well as transforms and uses it to creating the value of the organization' (Kozarkiewicz 2016). It introduces other important concepts, the potential absorption capacity (acquisition and assimilation of knowledge) and the absorption capacity realised (transformation and exploitation of knowledge in order to create value). The potential absorptive capacity is conditioned by external sources of knowledge and past experiences as well as the knowledge already accumulated in the organisation. In the opinion of Tether and Tajar (2008), 'open innovation enhances organisational absorptive capacity'. In fact, earlier studies by Zahra and George (2002) have shown that drivers of absorptive capacity are related to interaction with external knowledge sources, such as licensing and contractual agreements, as well as the collaboration with different partners, R&D consortia, alliances and joint ventures, that is, the greater the interaction with external sources, the more of the experiential knowledge is collected. Notably, the recent studies by Rangus et al. (2014) have evidenced the mediating effect of the absorptive capacity on the relationship between open innovation and a firm's innovation performance (Figure 3). The authors first demonstrated empirically the direct effect of open innovation on absorptive capacity (path B), then brought up the evidence supporting the positive impact of absorptive capacity on innovation performance (path C).

Figure 3. The relationship between absorptive capacity, open innovation and innovation performance



Source: Rangus et al. (2014).

Moreover, the authors concluded that the absorptive capacity is an important component of a firms' dynamic capabilities, as it enables to learn from partners, access external information, transform and integrate that information into its existing knowledge base (Wang and Ahmed 2007). Knowledge transformation refers to the processes of combining newly acquired knowledge with the existing new knowledge and its assimilation. On the other hand, the ability to exploit knowledge in creative ways transforms the knowledge into specific activities, such as new products and services. Thus, increasing organisational innovative performance depends on the results from individual innovativeness and innovative work behaviour (Hughes et al. 2018, Spanuth and Wald 2017, Dorenbosch et al. 2005, Janssen 2000).

Technological Dimension

In the previous section, one could see that firms need to invest significantly in R&D to understand and evaluate new technology trends and innovations. Moreover, the process of integrating and applying knowledge cannot take place without skilled labour or human capital. In other words, it also shows that the ability to productively use the knowledge resources of external entities largely depends on the degree of the similarity of cognitive and technological proximities (Cowan and Foray 1997, von Hippel 1998, Kremer et al. 2001). Each technology contains a kind of unique language and applies to a specific set of applications (Greunz 2003). Companies operating in a closed innovation model may not be able to recognise and appreciate the importance of novelty simply because industry knowledge is beyond the scope of their absorptive capacity (Ahuja and Lampert 2001). When these companies begin to open up their innovation process and expand their internal knowledge base, they are able to significantly increase their knowledge absorption. The newly acquired knowledge and experience complement the knowledge previously accumulated by a given enterprise, accelerating the learning processes and enabling the achievement of the synergy effect, i.e. mutual strengthening of the partners' knowledge bases. This knowledge may be complementary or supplementary. In the case of the former, the knowledge acquired from the outside is complementary and enriching for the company that conducts its own R&D activities. The knowledge that flows from the outside differs from that already possessed. Together, they are a good combination that increases the innovative potential of both partners in the long term; see Lewandowska (2014), Rothaermel (2001), Roper, Du and Love (2008), as well as Topkis (1978, 1998) by Milgrom and Roberts (1995). On the other hand, supplementary knowledge is characterised by a high degree of similarity, it can be useful and easy to absorb in the short term. The demand for a given type of knowledge and its various forms depends on the stage of a given innovation process. Long-term exchange of supplementary knowledge in the industry of its operation may reduce the level of knowledge specialisation and thus reduce the long-term innovative capacity of enterprises. Therefore, it is important to maintain the appropriate intensity of the inflow of supplementary and complementary knowledge coming from entities from outside the industry and institutional entities, bringing long-term benefits.

Legal Dimension

The growth of interest in the open innovation collaboration between enterprises and the potential advantages of the open innovation model make the issue of the adequate protection of intellectual property (IP) one of the key challenges. According to Chesbrough et al. (2006), strong IPR protection encourages disclosure and promotes efficient exchange of technological knowledge, whereas weak appropriability implies the widespread existence of knowledge externalities, in which each individual firm or research organisation has less incentive to conduct in-house R&D, increasing the amount of research surplus. The following section discusses the legal aspects of open innovation collaboration in relationship to both the IPRs, the advantage of IP protection and the possible risks related to the IP.

The OIE model emphasises the greater significance of sharing the created knowledge for a fee (via licensing) or free (via open-source initiatives) rather than obtaining a temporary monopoly's rent (von Hippel and von Krog 2003, 2006). However, the process of collecting all IP rights belonging to the partner parties (assembly problem) is especially complex and important in the case of OI cooperation. Equally complex and challenging is the process of the separation of IP rights at the final stage of the project (disassembly problem), which requires finding legal solutions that will favour a fair division of IP rights between the two partners involved.

The dominant view in the study of literature is that the effective IP protection is an indispensable condition for cooperation in the field of innovation. Faced with the danger of losing control over key intellectual assets, most enterprises would be not willing to share their knowledge with other entities, without adequate guarantees in the form of legal safeguards (Hurmelinna-Laukkanen 2011, Krupski 2014). In the OIEs the model, the idea of making IP available for free (in the spirit of free revealing economics) to all interested entities is gaining more and more popularity (Kozioł-Nadolna 2015). This approach seems rational, especially when the innovator wants to disseminate a given solution and strengthen his position in the market, or in a situation where the development of innovation requires the participation of the community of users involved. At the same time, it should be emphasised that the very idea of protecting IP is not in contradiction to the assumptions of the open innovation model, but it is even an important element of it. In fact, the results of several empirical studies (e.g. Laursen and Salter 2014, Hagedoorn and Zobel 2015) confirm that there is a relationship between the degree of the openness of entire innovative processes implemented by enterprises and the use of formal instruments for the protection of IP (e.g. patents). Patents are an important instrument for technology transfer, enabling companies to reap the benefits of sharing IP with third parties. This may take place through licensing, agreement to facilitate the mutual exchange of knowledge and technological assets or selling rights to protected solutions (Krupski 2014, Wsciubiak 2017, Ziegler et al. 2013, Krupski 2014). More importantly, the information contained in patent documents is an important guideline for other entities on the directions of R&D works and thus the level of technological advancement in the particular field is represented (Arora, Athreye and Huang 2016). Thus, IP rights may be used, inter alia, in order to acquire appropriate partners for cooperation. On the other hand, an aggressive corporate policy with regard to IP protection (i.e. using too broad a legal protection instrument) may also discourage other actors from entering into cooperation. Thus, it is possible to use the IP rights as a coordination mechanism in the course of the ongoing innovation cooperation. This is because it leads to ordering mutual relations and reducing the risk of opportunistic behaviour on the part of partners, allows for eliminating many potential disputes and facilitates partnership management, mainly thanks to the possibility of simplifying the negotiation and decision-making processes (Olander, Vanhala and Hurmelinna-Laukkanen 2014). Another possible solution is applying for legal protection of inventions that are jointly owned by entities involved in the innovation cooperation, via so-called ‘co-patenting’. Such activities are encountered relatively often in practice. Yet, some authors, such as Belderbos et al. (2014), consider them to be a kind of necessary evil, which is the source of two potential problems: the possibility of a conflict of interest between the joint patent owners and the risk of the rights to the protected solution falling into the wrong hands (e.g. in the event of capital control over one of the patent co-owners).

In sum, despite the availability of a wide range of instruments and comprehensive legal regulation, not all elements of intellectual capital can be effectively protected by legal instruments. This applies particularly to non-codified (tacit) knowledge, the exchange of which is an important element of interorganisational cooperation in the field of innovation. Some authors, such as Slowinsky et al. (2009) and Bogers (2011), have already emphasised that the protection of the non-codified idea in a partnership is related to totally different difficulties when compared to the codified and embodied technological knowledge. Here, the open innovation cooperation is directly related to the culture of knowledge sharing, mutual trust between the partners, the system of incentives applied in each organisation (impacting the knowledge transfer) as well as the role of formal and informal social networks.

Cognitive and Technological Dimensions

A relatively small number of researchers have investigated the role of cognitive and technological dimensions in the open innovation collaboration. Some names include the works by Nooteboom (2000), Petruzzelli (2011), Boschma (2005), Huber (2011), Nooteboom (2000) stated that cognitive proximity is manifested by the homogeneity of capabilities, competencies and skills as well as the homogeneity of knowledge bases. The first level of homogeneity refers to cognitive similarities between individuals: technical language, common professional or scientific backgrounds. Similarly to Nooteboom, Boschma (2005) considers that cognitive proximity facilitates effective communication. Therefore, in order to increase innovative performance, Petruzzelli (2011) suggests that a certain threshold of similar technological competencies between partners is required. The second level of homogeneity refers to the cognitive similarity between independent organisations (in their knowledge bases, capabilities, competences and experiences). People sharing same knowledge base may learn effectively from each other (Nooteboom 2000, Huber 2011).

The cognitive dimension may be particularly challenging in university-industry collaborations. The differences in culture, cognitive language and goals between academia and industry may infringe effective communication. Consequently, firms that invest in internal R&D assets are able to better overcome this barrier and collaborate more effectively with universities as they develop expertise in the same practice and share knowledge (Laursen and Salter 2004, Wasko and Faraj 2005).

In sum, similar technical language and an overlapping knowledge base is important for innovation. Yet, as several authors pointed out, too much similarity may detriment the incentives for the innovation collaboration since the development of valuable innovations may require dissimilar but also complementary sources of knowledge. In the same paradigm, an excessively high level of cognitive proximity may hinder firms to exploit new knowledge and weaken the effects of the interactive learning (Boschma 2005, Nooteboom 2000).

Physical and Geographical Dimensions

Over the last several decades, scientists have emphasised the local character of innovation processes. This was evidenced in the so-called new territorialised innovation concepts, such as 'innovative milieu', 'industrial districts' or regional innovation systems. All these theories assume that geographical proximity enables both relational or physical proximity and therefore facilitates the exchange of knowledge between local stakeholders, i.e. researchers, employees and other public and private agents. Moreover, geographical proximity can facilitate practical cooperation between various institutions and their agents, however, it is physical proximity, social interaction and trust that can smooth and make these interactions successful. The empirical literature on agglomerations and technological clustering largely supported this statement (Runiewicz-Wardyn 2020, Porter 2003, Glaeser 2000, Doloreux and Parto 2005, Moulaert and Sekia 2003). The recent studies by Alvarez-Castanon (2019), Gassmann et al. (2010) and Schroll and Mild (2011) in several clusters in Austria, Germany and Switzerland show that open innovation collaboration is facilitated amongst the agglomerated SMEs. Other authors, such as Huizingh (2011), Alvarez and Cruz (2016), Wang and Zhou (2012), conclude that open innovation helped clusters grow steadily and sustainably via the establishment of the organisations' alliances and all sorts of collaboration networks that helped to integrate the new knowledge and experience. The empirical evidence from Alvarez-Castanon (2019) shows that SMEs engaging in open innovation activities, especially in clusters, accelerate their technological and innovative capabilities. Yet, the authors conclude that SMEs in the cluster of traditional manufacturing industry (such as footwear) in an emerging country (such as Mexico) engage in open innovation activities, especially through collaboration with local universities and research centres, and they accelerate their technological capabilities and innovative performance. The authors further conclude that the study can have important implications for the understanding of open innovation processes in a traditional cluster of Latin American emerging economies. Yet, some studies provide evidence that clusters fail to collaborate despite their geographical proximity. There are authors who provide sufficient evidence that space as not the ultimate factor and determinant influencing knowledge spillovers and innovation collaboration. A number of studies tend to assume that the development of information and communication technologies (ICT), accelerated technological advance, technological convergence and competitive pressure to further reduce R&D costs encourage long-distance knowledge flows, as proposed by Castells (1996) and Cairncross (1997). In fact, Frenken et al. (2009) confirm this trend in a survey revealing an overall increase in the number of long-distance partnerships. Ponds et al. (2007)

show that long-distance partnerships are especially important in cases of collaboration between partners from different fields of activity. Singh (2005), in turn, argues that this relationship is weaker when the anteriority of collaborations is taken into account. The latter statement is also supported by Almeida and Kogut (1999), Autant-Bernard et al. (2007), Runiewicz-Wardyn (2020) and Grossetti (2005) who demonstrated that the effects of geographical proximity are a result of previous social relations between local partners. The studies by Breschi and Lissoni (2001, 2009) offer a critical discussion on 'Marshallian externalities' and conclude that the role of geographical distance in the economics of knowledge spillovers and innovation collaboration is still rather controversial. However, the authors do not provide any specific evidence denying such knowledge flows. Other studies, like the ones by Koopmann et al. (2021), Heinisch et al. (2016) and Nooteboom (2001), suggest that geographical co-location of innovation partners tends to be associated with other dimensions of proximity, such as cognitive proximity (similarity in prior knowledge) as well as social and organisational proximities. Yet, other researchers like Piergiovanni and Santarelli (2001), Harabi (1997) and Maurseth and Verspagen (2002) suggest that business R&D follow their own path of knowledge spillovers.

Altogether, despite the growing number of empirical studies, evidence of geographical patterns of open innovation collaboration and knowledge spillovers is very fragmented and devoted almost entirely to the experience of advanced regional economies, with little distinction of the sectors or industry-specific trends.

Socio-Cultural Dimension

The complexity of the open innovation process increases because open innovation also relies on nonformal activities, such as interaction between companies, shared experiences and technology adoption (Trott and Simms 2017). Recent studies suggest that social support and cultural norms have an influence on the diffusion of innovations and open innovation practices (Vejlgaard 2018, Kumar 2014, Chinweike and Egbue 2014, Gaftoneanu 2016, Dwyer and al. 2005). Moreover, some earlier studies by Erosa (2012), Florida and Cohen (1999), Cohen and Noll (1994), Blumenthal et al. (1996) and Brooks and Randazzese (1999) pointed to a lack of synergies between both academic research and business-related activities which represent two different socio-cultural operational environments; therefore, they face the 'conflicting nature of normative principles'. The idea of the 'conflicting nature of normative principles' has been at the roots of the 'corporate manipulation thesis' in the study by Mazza et al. (2008). Consequently, the positive attitude towards open innovation is not something obvious and natural in these two groups of stakeholders. The studies in the field of collaborative innovation demonstrate that successful open innovation partnerships require a cultural, social and behavioural foundations (Klein and Spychalska-Wojtkiewicz 2020, Herzog and Leker

2010, Witzeman et al. 2006). Henry Chesbrough – the founder of the 'open innovation' concept – concluded that in order to conduct successful collaborative innovation, firms must overcome the 'not-invented-here' syndrome (Chesbrough and Crowther 2006).

Herzog and Leker's (2010) study of innovation cultures, risk-taking, innovative behaviour and the cultural dimensions of the 'not-invented-here' syndrome found out that the employees in the open innovation units accept ideas from the outside more willingly and are more open to risks. Moreover, several other studies by Dhanarag and Parkhe (2006), Zaphiris and Ioannou (2018), Harris and Lyon (2013) and Pomponi et al. (2015) highlight that openness, interaction and communication are linked to people's beliefs, attitudes and mutual 'collaborative trust'. For instance, people who do not contribute proactively to open innovation are frequently afraid of losing power to a *more dominant partner and/*or becoming too dependent on the collaboration partners. Therefore, social and cultural (norms shaping individual behaviour) influence open innovation attitudes towards the partner and therefore must be considered in a complex analysis of the open innovation ecosystem. They also influence social expectations and help to build trust between collaborating parties (Paliszkiewicz 2018).

Trust and the Exchange of Knowledge

The concept of trust has many definitions and can be viewed from different perspectives. Usually, trust is defined as a state, belief, positive expectation and confidence that another party will behave in an ethical, predictable and fair manner (Sarwar and Mumtaz 2017). Tschannen-Moran and Hoy (2000) claimed that definitions of trust frequently include such aspects as vulnerability, reliability, honesty, competence and openness. Trust in the open innovation environment context can be analysed at least on two levels: the interpersonal level, i.e. between members of one organisation, and the interorganisational level – trust between members of different organisations. Several authors noticed that individual, organisational and interorganisational trustworthiness is interrelated. Halinen (1994), Anderson and Narus (1990) explain that at some point extensive trusting personal networks between companies lead to trust at the company level, as it is difficult to attribute trust to any person or persons in particular. Yet, they note that organisational relationships entail less intensity and personal commitment than personal relationships. Both the interpersonal and the interorganisational types of trust impact each other simultaneously (Whitener et al. 1998). This is because managers observe and learn from each other. Organisational culture – communication, coordination and decision-making – encourages or discourages managerial trustworthy behaviour. For instance, if a company has a good reputation in partnering, its new potential partner may expect to meet competent and trustworthy partner managers. In contrast, if either of the two types of trust (interpersonal or interorganisational) deteriorates, this will have a negative impact on both of them (Blomqvist and Stahle 2011).

Both interpersonal and interorganisational trust affect the exchange of knowledge. In both cases, individuals are more willing to donate their knowledge to partners and collect knowledge from their partners when they trust them. It would also seem logical to say that it is always the people and not organisations that trust each other. Exchanges between firms are exchanges between individuals or small groups of individuals (Barney and Hansen 1994). Zaheer et al. (1998: 142) define interpersonal trust as 'the extent of a boundary-spanning agent's trust in her counterpart in the partner organization'. They further define interorganisational trust as 'the extent of trust placed in the partner organization by the members of a focal organization'. Each individual's value system sets a ground for that person's experience on interorganisational trust.

There are numerous studies showing that trust is significantly positively associated with knowledge sharing (Abdelwhab Ali et al. 2019, Hsu and Chang 2014, Nerstad et al. 2018, Ouakouak and Ouedraogo 2019, Renzl 2008). Knowledge sharing is viewed as a behaviour (process or operation) through which individuals mutually exchange their knowledge (information, skills and expertise; see Mirzaee and Ghaffari 2018, van den Hooff and de Ridder 2004). In the context of organisations, knowledge sharing among employees involves valuable implicit or explicit knowledge, leads to new knowledge creation, develops organisational knowledge and brings benefits to the organisation. In particular, knowledge sharing enhances innovativeness at individual and organisational (Lin 2007, Kmieciak and Michna 2018, Pittino et al. 2018) levels.

As de Vries et al. (2006) noted, knowledge sharing behaviours greatly depend on one's attitude – that person's willingness to share knowledge. Willingness reflects an individual's preparation and readiness to grant others access to their intellectual capital. People who are willing to share knowledge are focused on the interest of a group and on expected reciprocity, that is, on the fact that other members of the group will also share knowledge. Knowledge sharing is supported by an appropriate organisational culture and climate (Al-Alawi et al. 2007, Suppiah and Singh Sandhu 2011), including a constructive communication climate (van den Hooff and de Ridder 2004), management support (Paroutis and Al Saleh 2009), reward systems (Amayah 2013) and employees' affective commitment to the organisation (Casimir et al. 2012). In addition, one of the factors most frequently indicated as affecting knowledge sharing is trust (Al-Alawi et al. 2007, Casimir et al. 2012, Chen and Hung 2010, Paroutis and Al Saleh 2009).

The influence of trust on the employees' propensity to share knowledge is important for the organisation's innovation. The more someone trusts another person, the greater their willingness to share knowledge with that person, for several reasons. First, when trusting a person, we believe that the knowledge transmitted to that person will be used appropriately (Staples and Webster 2008) and will not be used against us, even if this knowledge is incomplete, imperfect or containing errors. We believe that the knowledge provided will not be used to criticise or undermine our competences. For instance, a subordinate who trusts their supervisor will be more willing to reveal their limitations in skills, abilities and knowledge if they trust the superior not to use this knowledge against them (McEvily et al. 2003). What is more, if we trust a person, we expect reciprocity and believe that the other party will share knowledge with us. This expectation of reciprocity is confirmed in the literature on social exchange theory (see Cropanzano and Mitchell 2005) and social capital theory. Finally, trust affects knowledge collecting. The recipient of knowledge is less apt to verify the accuracy and truthfulness of knowledge that comes from a trusted source.

Managerial Philosophy of 'Open Innovation Culture'

Adopting open innovation in certain cases means doing things differently than it was done in the past. Managerial philosophy is an important element for supporting change. It is interesting to consider what incentives can be put in place to encourage people to adopt open practices.

The open innovation process starts with a mindset of managers. Managerial philosophy reflects an attitude towards innovation collaboration, which becomes visual via the consistency of management behaviour and organisational norms of e.g. honesty, openness and keeping promises. It is actualised in management behaviour, which should be reflected very carefully in respect to their impact on interorganisational trust (Sydow 1998). At the individual level, the propensity to trust involves the ability to accept changes, take risks, communicate feelings and expectations openly. Therefore, organisational culture and values must be seen in the consistency of organisational behaviour, decisions and values. Personal values are realised in attitudes, emotions and are finalised in choices made. In the philosophy of management, trustworthiness may be experienced at cognitive (enrooted in the competence, fairness or openness) and at affective (emotional; care and concern) levels of trust (Stahle and Blomqvist, 2005). The latter includes negative attitudes towards open innovation or something that was not invented in-house (the 'not-invented-here' syndrome). Other negative attitudes towards open innovation collaboration are related fear of quality issues and the wrong assumptions that someone must only gather good ideas, while ignoring the knowledge and experience from 'bad' ideas. The idea of open innovation collaboration is that it should not control the 'quality of ideas'. Building open innovation culture means overcoming the risk-taking aversion, organisational inertia or the 'not invented here' syndrome. Risk and trust are involved in every transaction where the simultaneous exchange is taking place (de Ven et al. 2000). Companies engage in a technology partnership exchange and share valuable information, which may not be legally protected by any agreements. Various types of risks may arise from such partnerships, e.g. failures in technology development, performance or market risk, unintended disclosure of proprietary information or the partner's opportunistic behaviour in e.g. imitating the technology.

Communication, Trust and Open Innovation Collaboration

Communication skills are especially important to enhance trust building, especially in partners in an asymmetric technology, which work separately or in different contexts or cultures. Successful communication builds trust and creates knowledge. Sydow (1998) states that organisational actors transact for a variety of reasons and exchange different contents, i.e. information and emotion. If a communicator is able to be clear and precise about the issue and simultaneously add and develop the dialogue, a trusting relationship is about to develop. Combination of tacit knowledge (subjective) and explicit knowledge (objective and rational) is also at the heart of Nonaka and Takeuchi (1995) knowledge creation. Although the problems of trust are important throughout the lifecycle stages of collaborative development projects, the issue of trust may vary across particular stages. The literature on the innovation process as well as innovation collaboration reveals that most approaches analysing the innovation process incorporate three generic steps: a phase where ideas are collected or generated (idea generation), another one to develop and specify those ideas (development) and finally the last one where value creation takes place by transforming ideas into products (commercialisation). The early collaboration stage paves the way for collaboration in later stages. Trust and collaboration intensity are strongly contingent on the specific stage of the innovation process. It is possible to assume that certain types of social externalities achieved through shared *trust* assist the specific stages of the innovation process. The risks of losing core knowledge may be particularly high for the collaborating partners at the development stage for suppliers and in operations for process firm. For instance, the study by Runiewicz-Wardyn (2020) showed that intensifying one's social ties and building trust with people from industry and academia, especially at the early stage of clinical trials (development) – phase I or II – will greatly increase the success of a given research project and its money value.

Summary and Conclusion

In sum, the objective of this section was to provide a comprehensive review of the progress on innovation literature reflecting the most essential topics: the open innovation paradigm, open innovation model, external sources of innovation, open innovation collaboration and its various dimensions within the open innovation ecosystem. Open innovation has emerged as an important strategic paradigm at the times of the increasing process of globalisation (accelerated by digitalisation), technological advancement, the rise of global technological competition, the multidisciplinary, interdisciplinary and complex nature of innovation (especially in high-tech industries) and the intensifying processes of technological convergence. Regardless of the chosen forms of the open innovation collaboration, the level of the in-house R&D efforts as well as the complementary knowledge sources determine the success of the open innovation partnerships. Moreover, the literature review shows that the open innovation paradigm promotes the bottom-up approach to the innovation systemic relationships, giving them the necessary knowledge to play their roles in the co-creative environment. The open innovation ecosystem then becomes a foundational cultural mindset and behaviour, and not a responsibility of a single stakeholder. Moreover, building trust among open innovation ecosystem players requires developing the communication skills and organisational culture where individuals treat each other fairly and honestly and share the knowledge in order to co-create and help to solve complex problems.

Chapter 2

High-Tech and Knowledge-Intensive SMEs and Their Innovation Environment

Introduction

The role of open innovation collaboration in the knowledge-intensive industries ecosystems is particularly difficult to understand. This is related to the complexity of many technological advances and the nature of knowledge interlinkages. Complex technological advances require the process of innovations to combine knowledge from several scientific disciplines and interaction between various actors. Knowledge-intensive industries companies, which include high- and medium high-tech enterprises, are innovative and knowledge-based entities that use knowledge to create and absorb innovations. These are creative units that manage their knowledge sources, develop and use intellectual capital and effectively cooperate with other enterprises, R&D centres and technology transfer organisations (TTOs). Moreover, it is somewhat problematic to separate these two types of enterprises – high- and medium high-tech ones – due to the fact that the majority of new technologies in these enterprises cross the border of this traditional division. Some examples include biotechnology and computer industries. Both of them are characterised by a high share of R&D expenses (typical for a high-tech sector), yet their commercial applications can be found in technologically less advanced industries, such as the food industry or electronics. Therefore, defining an enterprise as a company operating in a knowledge- and technology-intensive sector is not sufficient and requires a wider approach. The present chapter attempts to look at the nature and characteristics of the high-tech and knowledge-intensive industries' specific features as well as those characteristics which include their innovative activity and the extensive use of knowledge, R&D and modern technology.

2.1. High-Tech and Knowledge-Intensive Industries – Characteristics and Taxonomy

The knowledge-intensive enterprises require continuous and intense innovative activities as well as large R&D investments. The OECD studies the intensities in R&D for different industrial sectors, based on its ANalytical Business Enterprise Research and Development (ANBERD) database. The databases consider direct R&D expenses with respect to production and indirect R&D intensities multiplied by technical coefficients of sectors obtained from input-output matrices (OECD 2021). The latter also refers to the incorporation of technology that comes from the R&D intensities incorporated by the purchasing of intermediate equipment and capital goods from the third party. The observation of the R&D processes in a group of countries (i.e. Australia, France, Belgium, United States, Canada, Italy, Netherlands, Japan, United Kingdom, Sweden and Denmark). The use of indirect vs. direct R&D intensities may modify the position of some of the industries belonging to high-tech groups. The changes concerning the technological content of the different industries over these 25 years explain the distinction between the high-tech industry classifications in 1970–1980 and 1980–1995. The second list of sectors, the most recent period, differs from the first one mainly by the shift of the two branches – the electrical machinery and the scientific instruments – which moved from the high-technology group to the medium technology group. In 2001, the OECD presented a new classification with its denominations and ISIC (International Standard Industrial Classification) Rev-3 codes, based on the direct R&D intensities for 1991 and 1997. This new classification is described in Table 3.

Table 3. Knowledge and high R&D intensity sectors

1991–1997 period	ISIC Rev.3
High technology	
1. Manufacture of aircraft and space craft	353
2. Manufacture of Office, accounting and IT machinery	30
3. Manufacture of radio, television and Communications apparatus	32
4. Pharmaceutical Industry	2423
5. Manufacture of medical, optical and precision Instruments	33
Medium-high technology	
6. Manufacture of automobile vehicles, trailers and semi trailers	34
7. Manufacture of substances and Chemical products	24–2423
8. Manufacture of mechanical equipment and machinery n.c.p.	29
9. Manufacture of machinery and electrical apparatus n.c.p.	31
10. Manufacture of railway material and other transport material	352+359

Source: ISIC: International Standard Industrial Classification, OECD (2001).

In addition, the category of knowledge-intensive services (OECD 2001) includes activities related to the production of films, video, television programmes, sound and music recordings, broadcasting and subscription programmes, telecommunications, computer programming and consultancy activities and related activities, information services, research and development activities. Eurostat (2017), in its studies on the activities of the high-technology industry and knowledge-based services, in addition to the above-mentioned criterion of the level of a R&D intensity. It defines the new technology sector from the point of view of submitted patents. According to Eurostat (2017), many of the knowledge-intensive industries are classified as advanced technologies. These include aviation, communication technology, computers and automated equipment for companies, lasers, genetic engineering and semiconductors (Korpus 2017). Moreover, as many researchers of the advanced technology sector note, its important characteristic feature is the short life cycle of products and technologies, the high innovativeness of enterprises, a fast process of diffusion of innovation, a high level of rotation of technical equipment and large investment expenditures, increasing demand for highly qualified staff, a high investment risk and the growing number of patents and licences (Korpus and Banach 2017, Hagedoorn 1993; Powell, Koput and Smith-Doerr 1996).

These knowledge-intensive sector companies are also the world's most innovative companies. An innovative company is able both to create and absorb absolute innovations. These companies also demonstrate a great ability to adapt quickly to the changing environments and aim to achieve market leaderships through their innovative technologies. As a result, as Raymond and St-Pierre (2010) put it, high-tech enterprises seem to gain more benefits from the R&D investment in product development, whereas low-tech firms seem to gain benefits from investment into process innovations. Moreover, every advanced technology sector company widely uses and integrates modern information technologies (such as hardware, software, teleinformatics, etc.). An advanced technology company acquires, analyses, processes, stores, manages and transfers information in order to increase its innovative potential, productivity as well as cost efficiency (Zakrzewska-Bielawska 2010). Apart from the high R&D intensity and a generally high level of innovativeness, the studies by various authors allow for pointing out several other features enabling one to distinguish advanced technology sector companies from less technologically advanced companies (Weick 1990, Wojnicka et al. 2006, Zelny 1990), e.g. a high share of scientific and technical personnel; high capital investments and technology depreciation; intense domestic and international cooperation with other advanced technology enterprises and R&D organisations, patents and licences as innovation and competitiveness strategies.

In dynamic globalisation processes and increasing competition between the enterprises in the advanced technology, firms from the knowledge-intensive sector strive to possess and make the best use of the resources of the latest available knowledge by using internal R&D or external R&D development methods for this purpose. In addition, this sector is characterised by the rapid 'ageing' of investments, increasing competition and technological leadership, as well as by strategic cooperation with R&D centres and other enterprises at the local, regional and international levels (Niedbalska 1999, Matusiak 2008, Wojnicka et al. 2006, Zakrzewska-Bielawska 2012, Kogut and Zander 1992, Tsai 2000). The internationalisation of the business environment enables the acquisition of additional resources, cost optimisation, intensification of sales and acquisition of new markets and customers, as well as participation in the transformations of global technology (Pakulska and Poniatowska-Jaksch 2015). Hence, advanced technology and knowledge-intensive enterprises are characterised by the ability to early and quickly internationalise, compared to enterprises from traditional industries (Duliniec 2013). As noted by Tylżanowski (2012), the factor determining the competitiveness of this sector is cooperation with other entities and the transfer of the latest technology.

In recent years, the process of digitisation, accelerated by the COVID-19 pandemic, has been a factor in intensifying the collaboration in the knowledge-intensive sector, i.e. in both customer and supply-chain interactions. Digital transformation drove further up the open innovation and, more importantly, an open innovation culture. Many high-firms apply the open innovation approach by establishing corporate incubators that enabled their employees to collaborate with start-ups, tech suppliers and designers from around the world. Some examples of companies that use corporate incubators include Samsung, Next, LEGO Ventures or AT&T Foundry.

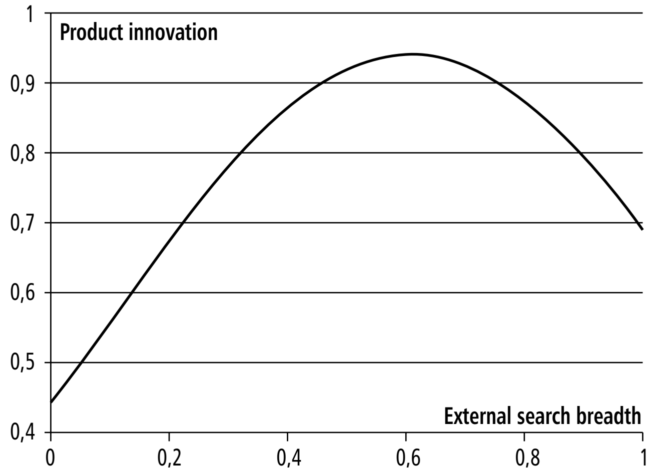
2.2. Innovation Performance and External Technology Sources in High-Tech and Knowledge-Intensive SMEs

Innovation processes in the high-tech and knowledge-intensive SMEs are different than in large enterprises. Although all entities must have the (internal) ability to create new products, technologies or organisational methods, they also have greater problems with internal innovation capacity than large enterprises – in particular, in finding and assessing, assimilating, transforming and applying various external knowledge resources. On the other hand, the specific features of SMEs allow them to gain a technical and market advantage, and their simple organisational structure, excellent knowledge of the market and close, often informal relationships with customers allow for learning and introducing innovations faster (Stawasz 2011). At the same time, undertaking and developing various forms of cooperation with external partners, aimed at gaining access to sources of new knowledge and skills as well as complementary resources. Studies by Becker et al. (2005) concluded that the likelihood of investing in R&D is much lower for SMEs than for big firms, showing that larger firms have a higher probability of being active in R&D. There are also studies (see Pierre et al. 2010) that show that the impact of the size and the age of the firm on the innovation performance must rather take into account the behaviour of SMEs management and their willingness to engage actively in the R&D process. The empirical study of innovation performance by firms in the high-tech sector conducted by Mairesse et al. (2005) concludes that a firm's size plays no significant role in R&D intensity and, if significant, it has only a small impact on the probability to innovate. Moreover, the effect of R&D intensity on innovation is simply more pronounced in the high-tech and knowledge-intensive sectors.

Recent studies have emphasised the importance of external knowledge sources and the use of innovation networks in the advanced technology firms (Cohen and Levinthal 1990, Nonaka 1994, George et al. 2002, Bamford et al. 2003, Caloghirou et al. 2004). In order to innovate, knowledge-intensive firms often need to collaborate with a large number of actors from outside their organisation: universities, technology agencies, suppliers, users, and even competitors. The type of innovation partners should also be introduced into the analysis since firms rely on specific knowledge sources and links for different kinds of innovations (Todtling et al. 2009). Firms introducing more advanced innovations are relying to a higher extent on R&D and patents, and they are cooperating more frequently with universities and research organisations. Firms that introduce incremental, not state-of-the-art innovations, rely more on knowledge links with business services (Todtling et al. 2009). The key benefits of engaging in innovative processes include: 1) shared learning process and access to new/complementary knowledge; 2) reducing the cost of technology development and market entrance; 3) acceleration of the commercialisation process – market launch of new products; 4) reduced risk related to the development of new technology and entering new markets; 5) achieving benefits of scale, specifically in production. Several authors linked external search strategy to innovative performance and found that searching widely and deeply is in a curvilinear way (an inverted U-shape) related to performance (Laursen and Salter 2006, Ardito et al. 2017, Hottenrott and Lopes-Bento 2016). Along with the growing openness of innovation processes, problems related to the risk of imitation or the loss of real control over the course of the implemented project may become apparent. The latter also related to the risk of the uncontrolled leakage of knowledge from the organisation, increasing the costs of coordination or the low absorption capacity of innovation (Laursen and Salter 2006).

Laursen and Salter (2006) have used the business innovation survey to explore the knowledge sources for innovation in the UK. The survey explores the innovation process inside manufacturing firms and it contains a sample of 2,707 manufacturing firms. The method of analysis is a double-truncated tobit model where

Figure 4. Possible inverse relationship between the openness of innovation processes (or external search breadth) and product innovation



Source: Laursen and Salter (2006).

the dependent variable is innovative performance, which is explained by a firm's external search strategies, R&D intensity and a number of control variables, such as market orientation and size. Chemicals, electrical and machinery industries exhibit the highest level of external search breath, indicating that firms in industries with medium to high levels of scientific and technological activity search widely. In contrast, firms in low-technology sectors, such as paper and printing, have the lowest levels of external search breadth. Search depth is the greatest in the machinery, chemicals and transport industries. Firms in textiles and wood product industries have little external search depth. The levels of external search breadth and depth are both the highest in industries with high levels of R&D intensity and rates of innovation. For instance, the chemical and electrical industries exhibit the highest rates of openness, the greatest percentage of radical innovators and the largest R&D intensity among all manufacturing industries. It reflects a wide range of sources of innovation, including suppliers, clients and competitors as well as general institutions operating inside the innovation system. The results of the regression model estimation showed a positive relationship showing that the breadth of the openness of firms' innovative search is an important factor in explaining innovative performance. At the same time, it was revealed that the more radical innovations are, the less effective the external search breadth will be on innovative performance. Another important conclusion of the study is that not all companies are able to equally benefit from cooperation. The reason for this may be the so-called phenomenon of 'over-searching', which may have a negative influence on performance (Koput 1997) (see Figure 4). For instance, it may lead to the absorptive capacity problem or the situation where there may be too many ideas for the firm to manage and choose between. Moreover, many innovative ideas may come at the wrong time and in the wrong place to be fully exploited. In addition, not all of the available ideas are taken seriously and are brought into implementation.

The decisive influence is the absorptive capacity, which expresses the predisposition of a given entity to absorb technical knowledge from the environment and use it for the purposes of its own business (Klincewicz 2014). Absorptive capacity that is linked to a company's own knowledge base through the integration of suppliers, customers and external knowledge sourcing can increase a company's innovativeness (Gassmann and Enkel 2006).

2.3. The Role of Innovation Capacity in the Open Innovation Model of High-Tech and Knowledge-Intensive SMEs

Open innovation collaboration and absorptive capacity are two concepts in contemporary innovation management literature that are rarely connected to each other. As it was mentioned in chapter 1, the inflow of new ideas into the organisation is an automatic or easy process which rather depends on the development of new routines and changes in the culture and the organisational structure of companies to facilitate open innovation processes (Dalander and Gann 2007). Nevertheless, the firms' absorptive capacity is the pre-condition of their ability to insource externally developed technology or ideas (Cohen and Levinthal 1990). In fact, absorptive capacity is crucial in understanding why some companies are much better than others at creating and capturing value from the technological collaboration with innovation partners. This is confirmed, among others, by a study survey conducted among 12,152 British companies, which showed that the lack of sufficient financial resources and qualified personnel limits the positive effects of the openness of innovation processes (Monteiro, Mol, and Birkinshaw 2016).

The innovative capacity of enterprises is presented as a complex concept relating to two categories: internal and external innovative capacity. Shaping the internal innovation capacity refers to the development of companies' skills in creating and implementing innovative solutions, formulating innovative strategies, conducting their own R&D works, building organisational structures and culture favouring the creation and absorption of innovation. On the other hand, building an external innovation capacity involves creating a network of connections with market partners in the field of innovation, including, inter alia, with the sphere of science and technology and the use of public support in the field of innovation. The latter type of capacity is particularly important from the point of view of open innovation processes: it is related to the processes of learning through networks, the ability to internalise partners' knowledge, building and maintaining trust between partners (Stawasz 2014). Yet, as Davenport and Prusak (1998) and Szulanski (1996) showed, the partner knowledge cannot be fully internalised without the support of absorptive capacity. Furthermore, the absorption of tacit knowledge is different from explicit knowledge. The subject of tacit knowledge generally requires extensive personal contact, regular interaction and trust. This kind of knowledge can only be revealed through practice in a particular context and transmitted through social networks. The subject of explicit or articulated knowledge, specified either verbally or in writing, e.g. in computer programmes, in patents and in drawings (Hedlund 1994, Sobczak 2005). In the case of explicit knowledge, the industry capacity of enterprises is related to the existing knowledge and the ability to modify and adapt external knowledge in order to further transform it into new combinations of knowledge (Forsman 2009). From the point of view of the entity receiving technologies, it is important not only to obtain these solutions, but above all to turn them into the competitive advantage (Glodek and Golebiowski 2006).

Moreover, in the open innovation model, knowledge can be obtained both from the organisation's environment as well as the user-supplier cooperation. This is also known as the process of co-innovation or developing innovative new products or technologies in cooperation between the supplier and its customer. Some innovation literature suggests that customer-supplier interaction can increase the success of new innovative products and services (Alam 2002, Gruner and Homburg 2000, von Hippel 1978). The network- and marketing-related literature provides evidence that information exchange and collaboration with users are the key drivers of the new product development (Achrol 1997, Biemans 1991, Comer and Zirger 1997). The latter is especially true for the user involvement in the service-based innovations (Sundbo 1997). Many knowledge-intensive service industries are facing rapidly changing markets, the increasing deregulation, unprecedented rise of emerging technologies (internet, e-commerce, e-services, etc.) and more demanding customers (Lovelock et al. 2001). Hence the need to explore different approaches enabling a greater involvement of users throughout the development process of a product/service.

The innovation capability was discussed in chapter 1. Here, it is worth paying more attention to the transfer of knowledge and technology from the outside.

2.4. Transfer of Knowledge and Technology in the Open Innovation Environment of High-Tech and Knowledge-Intensive SMEs

Knowledge and technology transfer processes have been and are still widely interpreted in the literature. Technology transfer can be defined as the process of transferring skills, knowledge, technology, product manufacturing methods or design services between academic centres, government agencies and other institutions to ensure that developed solutions (scientific and technological) will become available to a wide range of users who will further transform them into new products, processes, applications or services. According to Wojtachnik (2003), the transfer of knowledge and technology consists in the transfer of a set of information enabling the proper implementation in practice and improvement of business activity (Prystrom 2012: 88).

The mere purchase of technology does not guarantee obtaining various benefits resulting from it. This means that an entity using technologies that have been produced elsewhere should adapt them to the conditions specific to its own organisation. Umiński (2000) also emphasises that the technology transfer process involves the creation of various feedback loops between providers and recipients of technological solutions, and their goal is further assimilation and their dissemination throughout the economy. The entities that may actively participate in technology transfer include, i.a. enterprises, business support institutions, universities and other scientific and research centres. Technology transfer can be horizontal (between interested companies) or vertical (knowledge is transferred from research units to the enterprise sector).

Transfer of Knowledge and Technology: Collaboration with Other Firms

In a broader sense, knowledge sharing is defined as activities of transferring or disseminating knowledge from one person, group or organisation to another (Ipe 2003, Lee 2001). In this process, social networks, and individuals within them, make important facilitators and receptors of interorganisational knowledge sharing (Okyere-Kwakye and Nor 2011). Knowledge sharing represents a key concept within the knowledge management process. Direct contact among employees from different organisations should lead to a more efficient transfer of knowledge and subsequently higher absorptive capacity (Schmidt 2010). The study by Minbaeva et al. (2003) concludes that the key factor in knowledge transfer is not the owner organisation's original knowledge, but rather the extent to which the receiving organisation acquires that knowledge and uses it in its operations. Nevertheless, as Harrison and Leitch (2005) put it, organisations must acquire and internalise only potentially useful knowledge. In addition, organisations must possess so-called 'absorptive capacity', i.e. the ability to use prior knowledge to recognise the value of new information and create new knowledge from that information (Cohen and Levinthal 1990). Potential barriers that may infringe the process of knowledge transfer from managerial and organisational perspectives include: insufficient resources and uncertain market, unrealistic expectations, organisational and administrative barriers, division of rights and management of IP, poor bottom-up management, insufficient support from top management (Piller et al. 2012).

If the technology provider has not deployed the right resources, including not enough personnel who have the ability and willingness to teach, the diffusion will not take place, even if the recipient organisation is willing and able to adopt. Similarly, however much the technology provider has the willingness and the ability to teach, if there is no pulling effect from the recipient organisation, the effort will not succeed. The insufficient resources may result from the lack of internal commitment or simply the lack of interest of the R&D department. The departments dealing with IP-related issues related to open innovation may be too concerned about the terms of conditions and the IP structure. The major barriers in knowledge transfer may also result from an unrealistic set of expectations on the level of some managers towards the effort that is needed for knowledge transfer on both sides of partners. Equally organisational and administrative barriers may just include frequent organisational (work) and administrative (budgetary planning) routines that lead to significant delays in knowledge transfer. Last but not least, insufficient top management support – which means that there is a lack of support for the project by company leadership – frequently results in the lack of sufficient resources.

Transfer of Knowledge and Technology: Collaboration with Universities

Knowledge and technology transfer can take place between an academic institution or research institution and the enterprise. By partnering with university research labs, companies gain the opportunity to experiment with the latest technologies without committing to hiring permanently the expertise needed to develop these technologies. Universities have specialised facilities and staff that cannot readily be obtained elsewhere. Nevertheless, the effectiveness of this knowledge and technology flow depends on a number of conditions (Marszałek 2014). First, an institution offering knowledge or technology must constantly adapt its 'product' and resources to the requirements of the recipients (relating to the quality and international competitiveness of the 'product'). Secondly, enterprises using such services should also be characterised by a relatively high level of the technological absorption and be ready to receive specialised solutions. Thirdly, companies can access university innovation via a number of formal and informal channels, i.e. seeking academic experts' technical advice, hiring students, licensing university-owned patents. In the course of the evolution of the knowledge transfer process, such instruments as, for instance, initiating joint R&D projects, establishing spin-offs (originating from academic centres), offering internships for students or doctoral students in selected departments of enterprises, offering joint postgraduate studies, establishing the centres of excellence or launching tailored training for specific companies (Marszałek 2014). Moreover, the transfer of knowledge and technology does not just happen from academia or research to industry. We can also encounter the opposite relationship. Scientists doing internships in enterprises and thus learning about the technology-related practical problems are able to offer the business-specific solutions.

The commercialisation of technology is an inherent and necessary stage of the innovation process. This process includes a number of complex and, at the same time, difficult activities, which cooperation and partnership. The commercialisation process based on R&D resources of universities is serviced by internal organisational units, i.e. innovation centres, technology transfer, IT units and patent information departments, academic business incubators or specialised centres of research laboratories and centres of excellence. They deal with the commercialisation of scientific research results, IP rights management, support for cooperation between business and science, education for entrepreneurship, popularisation of issues related to innovation, as well as obtaining funds for university investments. It is commonly assumed that the commercialisation of technology covers all activities related to the transfer of a given technical or organisational knowledge and related know-how to economic practice (all kinds of the diffusion of innovation and technical education). This transfer is usually based on a selected concept of a commercialisation strategy, e.g. sale of property rights, licensing, strategic alliance, joint venture, independent implementation (spin-off, spin-out) (Glodek 2005). The various studies on the major barriers in the technology and knowledge sharing between the university and enterprises point to such problems as: stiff administrational and organisational structure; different values (in terms of relevance of projects, power of empirical evidence, risk involved); insufficient incentives or motivation, lack of trust, cognitive distance and different communication channels; division of rights and management of IP (Runiewicz-Wardyn 2020, Kozierkiewicz 2020, Eckl 2012, Mahdad et al. 2020). University employees, doctoral students and students are faced with how to protect their IP, as well as when to do it and what should be the subject of protection. It may delay or limit the knowledge transfer process.

In Poland, as in many European public universities, problems related to the protection of IP cover many issues, i.e. low awareness of the importance and ignorance of procedures for the protection of IP; too little attention and time devoted to this subject in university curricula; lack of prepared staff at universities; high costs of patent protection related to registration fees, fees for subsequent protection periods, services of patent attorneys that inventors – employees, doctoral students and students – cannot afford; a long time of obtaining a patent, which is associated with complex and time-consuming procedures, e.g. patentability assessment; lack of contacts with specialists who can assess the maturity of the solution for implementation; too few implementations, so no use of the patents already held; no possibility of industrial use of the patent; the conflict of goals between the scientific development of the inventor related to the frequent and quick publication of research results and limitations resulting from the procedure of obtaining a patent (prohibition of publishing before the patent application) (Buczarek 2018).

Intellectual property is a multidimensional good, hence its management must take into account not only various aspects of IP but also the fact that different groups of people with different goals participate in the management process: employees of R&D units, universities, scientific institutes – creating IP, managers organisations (universities, research institutes, laboratories), lawyers – protecting IP; authors (rights owners) of inventions, managers of organisations, entrepreneurs – using IP. Each of these groups of people has its own evaluation criteria and priorities (Santarek 2008).

American universities are frequently mentioned as a model of effective cooperation with industry in the field of technology transfer. Stanford University is a good example of such cooperation. A particularly preferred form of such cooperation is the development of spin-off companies based on the technological and human resources of universities and cooperation with large companies. The main mechanisms of technology transfer from universities to business at Stanford University include: university graduates, publications, conferences, institutionalised consultancy, i.e. officially endorsed by the university, research financed (commissioned) by the industry, research conducted jointly by the university and industry, licensing to use various forms of IP. In accordance with US law, a university may retain the right to discoveries and inventions created as part of federally funded research programmes (Pluta-Olearnik 2009, Runiewicz-Wardyn 2020b). The university grants a free and non-exclusive licence to use the research results. Any company that has obtained the exclusive right to the results of federally funded research programmes must manufacture the products in the United States. The university is obliged to give preferences to SMEs in terms of access to licences and to share with inventors – university employees – all revenues obtained from the sale of licences. Even though the university is an active party in the technology transfer, it also owns all discoveries that have been made with the participation of the university's resources (Pluta-Olearnik 2009).

Transfer of Knowledge: Collaboration with Users

Customer and users' domains usually provide large bases of information about needs, applications and solution technologies that reside in the domain basically limited to the ideas search phase, in order to achieve key benefits associated with the open innovation model, classified as the enlarged information base to be utilised for the innovation process (Piller and Ihl 2009), the ability to leverage new product development on external sources (Docherty 2006), faster action on ideas and technology, the development of innovative culture from the 'outside in' through continued exposure and relationships with external innovators. Wecht and Baloh's 2006 work has proved that thoroughly executed customer integration into a new product development can be beneficial for a company's innovation performance. The same is also claimed by Thomke and von Hippel (2002), who defined users as a common source of innovations. User innovation is considered as one of open innovation's part fields (Gassmann et al. 2010). The main contribution of the customer is perceived as an enlargement and enrichment of information bases that can be utilised for the innovation process, especially the information on needs and solutions, applications that resides in the domain of the customers and users of a product or service (Piller and Ihl 2009).

Yet, in terms of customer-driven open innovation, the specific challenge is related to how we could involve customers knowledge into the innovation processes at much more intense levels than traditionally.

Customers (can be defined as lead users, co-designers and decision makers) can be invited to contribute their creativity and problem solving skills by generating and evaluating new product ideas, elaborating, evaluating or challenging a detailed product concept, discussing and improving optional solution details, selecting or individualising the preferred virtual prototype, testing and experiencing the new product features by running simulations, getting information about the new product or consuming practices (Fuller and Matzler 2007, Piller et al. 2010). The concept of user-driven innovation is defining a result of collaborative co-creation process – innovation initiated, created and/or developed by the user. (Petraite 2011). Reviewing the scientific literature on the innovation process as well as innovation stages and the activities of innovation partners, it can be stated that user-provider collaboration can take different forms along all the three generic steps of the innovation process. During the idea generation phase, the user may help in the identification of innovation possibilities (collecting user data), evaluating new product ideas, elaborating, evaluating or challenging a detailed product concept as well as discussing and improving optional solution details (Fuller and Matzler 2007). During the development phase, the user may take part in the co-development and co-creation of the project or the product, contributing with their creativity in problem solving or individualising the preferred prototype, testing and experiencing the new product features by running simulations, getting information about the new product or consuming practices. Finally, the commercialisation phase takes place by transforming ideas into products (commercialisation). The user may express valuable opinions about the new product or technology. Concepts like open innovation and lead-user innovation have provided methods for leveraging this potential for companies. The concept of 'responsible innovation' is particularly important to mention here. The users' involvement must be beneficial not only for the innovators but also for the diverse stakeholders, by helping to overcome innovation barriers and increase the societal acceptance, desirability and accessibility of innovation outcomes. The concept of 'responsible innovation' encourages innovators to take both user needs and concerns seriously. It also obliges the firms to be transparent and accountable about how innovations are created, implemented and scaled. The latter builds trust and limits the risk of the rejection of innovations at a later stage of the product or project development and commercialisation. Nevertheless, users' involvement may also be related to some challenges to the whole innovation process. Involving users in the early development phases may have difficulty in transcending users' limited powers of imagination. Without having a fully developed project or product at the users' disposal, the users do not have a clear-cut idea of what they want or need (Limonard and de Koning 2005: 176). The second challenge results from the increasingly interdisciplinary character of the innovation process, which requires a consolidation of knowledge and tools from various disciplines. This creates an additional problem of the integration of complex and multidisciplinary knowledge, acquired by teams, into the innovation development process. It also requires a greater synergy between users (the adequate translation and transformation of their generated insights) and technology (Wout et al. 2010, Veryzer and Borja De Mozota 2005).

Summary and Conclusion

Innovation processes in the high-tech and knowledge-intensive SMEs are different than in large enterprises. The subject literature does not deliver clear evidence to the negative or positive relationship between the R&D intensity and firm's size. The R&D intensity and innovative performance may also depend of the firm's management motivations. In general, smaller firms may have lower internal innovation capacity than large enterprises, which may affect firms' absorption of technical knowledge from the environment (especially from the universities). On the other hand, their simple organisational structure, flexibility, easier social relationship, and informal relationships with customers allow to learn and introduce innovations faster (external innovation capacity). The latter capacity is related to the much bigger opportunities for the SMEs (than large firms) to involve in creating networks with market partners in the field of innovation, i.e. academia, customers, public authorities. Involvement of various partners in the co-creation of innovations enable to build trust and smoothens the technology transfer and commercialisation processes, on the other hand, may also relate to some challenges, as it requires greater synergy (values and sources) between various partners.

Chapter 3

Open Innovation in the Context of Selected High-Tech and Knowledge-Intensive Industries

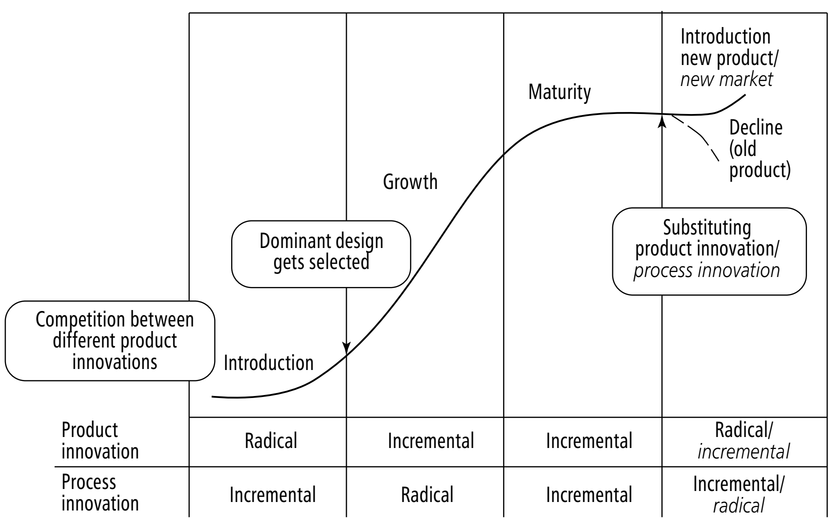
Introduction

Assessing the role of open innovation in the innovation process may not be straightforward. Every sector and every company is characterised by a complex network of relationships which serve different purposes in different phases of their technological life cycle. Some knowledge and R&D intensive industries are characterised by rapid change and the presence of radical innovations, others by smaller, incremental changes. The prevalence of the specific type of innovations is partly due to the nature of technological progress in these industries as well as their technological life cycles. Hence, the question arises: for which stages of the innovation process is the open innovation ecosystem approach (and its modes) the most suitable? Moreover, the innovation process has very different characteristics across different technology sectors, which should be examined here because those sectoral characteristics will affect the industry/sector-specific open innovation strategies. Differences notably arise in the types and process of innovations, technological maturity and the pace of technological change, actors involved and the relevance of regulatory environments and IPRs. The present chapter discusses the characteristics of selected high-tech and knowledge-intensive sectors, and attempts to link them to the concept of open innovation.

3.1. Open Innovation Collaboration, Social Networks and Innovative Product Life Cycle

In the early R&D phase of an innovative high-tech product life cycle, social networks allow researchers, entrepreneurs and other related stakeholders to engage in discussions, share information and connect with others in order to expand their professional network and raise funds. They also build trust, which might be very important when deciding whether to exploit research output as a business idea or not. At the beginning of the introductory stage, only a small group of 'innovators' are interested in the product, once 'early adopters' come on board, the adoption accelerates and the product reaches early and late majority groups, and finally laggards (see Figure 5). During the beginning or early stage, it might not be clear yet to the developers which target customers the product fits best, and they may not even know what problem it solves. Therefore, the technological and market uncertainty in the early or beginning phase of an industry life cycle is usually accompanied by increased knowledge exchange between firms, in which experts develop a common language which is not yet codified (Rosenkopf and Tushman 1998, Rowley et al. 2000). Open innovation collaboration with the lead users gradually results in a collective evaluation of the new product. Embracing 'collective creativity to innovate together' is not only beneficial for new innovative products but may also be a good customer strategy (see 'collective customer commitment' in Ogawa and Piller 2006 and Antikainen et al. 2010).

Figure 5. Innovative product life cycle, types of innovation and innovation collaboration



Source: Smeds (1994).

Moreover, at this stage, one of the incentives behind open innovation is exploring potentially important technical expertise which the firm may not be yet endowed with. It is also important to interact with a wide variety of external actors in the industry (customers, other firms, suppliers, research institutes, etc.) early on, in order to strengthen the installed base of the firm's technology (Rowley et al. 2000).

During growth, innovators try to make their products more appealing to larger audiences within the market, to capture bigger slices of the demand that the new technology is creating. The companies start to recover the costs and expenses that have been incurred. At the decline stage, open innovation collaboration may help to integrate technology (by adding new features) and market opportunities (finding new uses).

3.2. Technology Life Cycle, Open Innovation and Firms' Competitive Advantage

Competitive advantage is what makes organisation products or services superior to all of a customer's other choices. Porter (2008) defined two ways in which an organisation can achieve competitive advantage over its rivals: cost advantage and differentiation advantage. Differentiation means that companies deliver better benefits than anyone else, by providing a unique or high-quality product, while cost advantage means that it provides the same products and services as its competitors at a lesser cost. Open innovation is about the broadening and exploitation of a firm's technology base and thus enable one to sustain and/or gain new competitive advantage for one's products and services with the aid of outside parties. Particularly as a company grows, the obstacles of launching successful new products become even more difficult to overcome. The open innovation approach may allow one to simultaneously balance the needs of new and existing customers as well as to discover new business lines (Ries 2011).

In general, Pavitt (1984) distinguishes industries by their source of innovation: supplier-dominated industries (traditional manufacturing), production-intensive (capital-intensive, large-scale industries) and science-based industries. For supplier-dominated sectors, the sources of innovation are the suppliers; for production-intensive industries, these are the customers or lead users, and for science-based industries the sources of innovation are universities and other non-commercial research institutes (Pavitt 1984, De Jong and Marsili 2006, Teece 1986). The first type of industry is usually associated with low to mid-tech, while the other two can be labelled high-tech industries. Following Pavitt's (1984) taxonomy, one could claim that a focus on firms only in a sector will not provide enough insight to understand the dynamic nature of a sector as a whole. Especially for understanding the role of open innovation in firm's competitive advantage, one should also take wide range of relations of non-sector firms into account. In line with Pavitt (1984), several authors have elaborated on this new field in innovation studies (Palmberg 2006, De Jong and Marsili 2006). Industries with complex systems as their final product have relations with other industries by definition (Pavitt 1984). The first phase of the technology life cycle concept consists of the introduction of new products with the breakthrough technology, followed by new products of competitors with partially different technological designs (Schilling 2005). However, if a dominant design is preferred, all remaining firms follow this design and further innovations rather concentrate on its improvements and on process or modular innovations (Henderson and Clark 1990). In the light of the open innovation concept, it is important to note that initially firms in an industry explore and apply various technological options (product designs). Yet, once a dominant design emerges, many of those options may not be applicable any more in this particular sector. So, even in the simple situation where an industry has a single dominant technology, the stages where multiple technologies exist and the stages where only a single dominant technology exists differ from the perspective of open innovation. According to Beije and Dittrich (2008), at the early stages, many technologies are potentially applicable on other markets, while at the later stages, especially when a dominant design has been already established, only one technology is available (unless a firm decides to further develop a particular technology, even if it cannot be applied any more on its original market). Hence, the dominant technology and the similar technologies that are available in the industry can be applied in other markets and industries as long as their competence is still available. Moreover, Beije and Dittrich (2008) concluded that the pressure 'to do more' may have been greater for the firms, whose developed technology did not become the dominant design. The authors use the example of the textile industry which has witnessed the development of new machines and new synthetic materials which were made by specialised machine manufacturers in the chemical industry. The new synthetic material can be seen as the potentially new dominant design technology in the textile industry. In the same way, ICT is the basis for many innovations in the other services and industries. One example includes the media industry – newspapers, recorded music, films and television – for which new modern ICT solutions allowed one to raise and develop new products. In other words, these developed technologies act as 'enabling technologies' to foster and create enhancements in the capabilities of the other technologies. Marion and Friar (2019) provide another example of a jet-powered commercial aircraft and, more specifically, De Havilland Comet and Boeing 707 first passenger jets brought to market in the 1950s. The enabling technology for this innovation was a turbo-jet engine, advances in metallurgy (strong aluminium alloy airframes), turbo compressors for pressurised cabins and reliable hydraulics for control surfaces. Enabling technologies are different from converging technologies, as the change of a new technology is not just an improvement of a single technology. Following Marion and Friar's 2019 example, one can conclude that the industries with a developed supply network have a greater access to other technologies than 'stand-alone' industries. These newly developed technologies may be applied to different markets, each with their core products and components. The distinction between core technology and component technologies is not always easy to make, especially in complex technology industries, in which one or more of generic technologies is the core of the product range (e.g. nanotechnology, biotechnology or microelectronics). A good example is nanotechnology which can be applied in many different sectors and in which the combination of generic technologies gives additional application options (Meijer 2006, Beije and Dittrich 2008). In sum, linking the technological dynamics with open innovation, allows for extending the technological life cycle of specific technologies (both struggling to become the dominant design on the market or being already the dominant design) to find applications on different markets.

3.3. Technology Dynamics and Polish Market Trends of Selected High-Tech and Knowledge-Intensive Industries

One of the generally adopted approaches to studying the technological maturity of industries is tracking the intensity of patent applications (Haupt et al. 2007, Watts and Porter (1997, Andersen 1999). The information contained in patents embodies the necessary information about technological development itself since the patents contain the technological know-how. Patents inform one about research intensity and innovativeness and therefore the technological state of the art in the relevant field. The number of patent applications can vary at different stages of the technology life cycle. At the emerging and growth stages, the indicator of the number of patent applications is typically higher (once the basic technological and market uncertainties vanish, innovations become less radical, the R&D risk decreases and the number of patent applications increases). In the phase of maturity, the number of patent applications (typically incremental innovations) remains constant. Yet, when the potential for new product innovations decreases the technology and, consequently, the number of annual patent applications decreases constantly, the technology's decline stage begins (Runiewicz-Wardyn 2013). However, patents can only affect industry dynamics if the market adopts them. The major weakness of the patent adopted approach to study technological dynamics is the fact that the real technological dynamics in the industry can only take place if the new technology is widely diffused and used. In other words, when individuals or organisations select and adopt the new technology. This refers to the diffusion stage at which the technology spreads to general use and application.

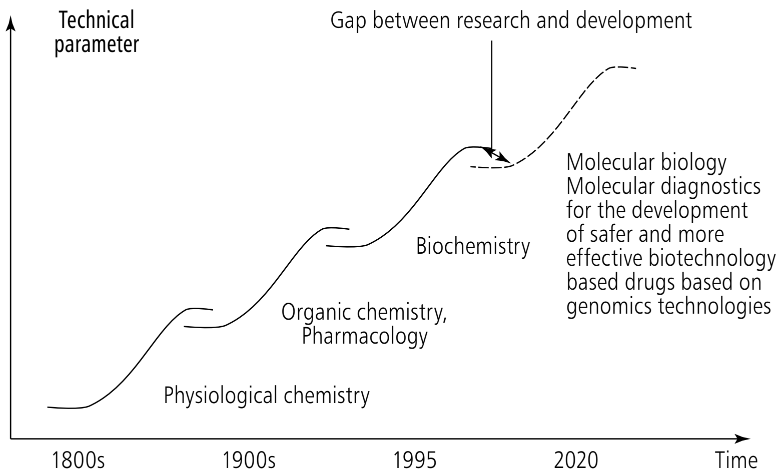
The following section discusses the maturity of technology and its relationship to technology diffusion based on the studies by Wunderlich and Khalil (2002), Utterback and Abernathy (1975) and Fisher and Pry (1971). The measure of technology diffusion may be expressed as a percentage and can be characterised over time by applying the Fisher–Pry equation. Two characteristics of the Fisher–Pry equation are that by measuring technology maturity through technology diffusion,

–L/(1+e**(–b (t – a))) firstly, it reveals the midpoint in time (identified as 'a') at which the market achieves 50% adoption and secondly, it provides a relative quantification of the rate (known as 'b') at which the technology was adopted (Runiewicz-Wardyn 2013). Based on data from the US National Academy of Engineering (NAE), Wunderlich and Khalil (2002) have grouped the 20 most notable technological engineering achievements into industrial sectors. The timelines of these technologies enable at least a rough estimate to be made for the start of the rapid growth of each technology. The scores ranged from 0% to 100%, based on the Fisher–Pry equation for technology diffusion. A score of zero would indicate that the technology had not yet been conceived, and a score of 15% would be the rise of mass production. The significance of the 15% milestone for technology diffusion is that it indicates that rapid market growth has been initiated and will carry on until it reaches another significant point of 85%, which indicates the end of rapid market growth (Runiewicz-Wardyn 2013). At this point of time, the technology is judged to have achieved widespread diffusion in a way that nearly everyone who had wanted to obtain it had done so (according to Wunderlich and Khalil 2002). A score of 100 would indicate that a specific technology had reached complete diffusion or maturity. The results of Wunderlich and Khalil (2002) and Utterback and Abernathy (1975) for the biotechnology and pharmaceuticals and computer and electronic industries are presented below.

Bio-/Pharmaceutical Industry

The biotechnology and pharmaceuticals industries belong to a broader family of the life-sciences sector, which is one of the fastest-growing high-tech sectors worldwide. Both industries produce medicines, but the medicines made by biotechnology companies are derived from living organisms, while those made by pharmaceutical companies have more generally a chemical basis. Modern biotechnology is a relatively young branch of bioscience, developed by the biopharmaceutical industry in the late 2000s. According to the literature, the biotechnology industry started to form its shape in the early 1980s, when it improved the regulatory and patenting and licensing systems and launched government-lead research initiatives, especially in the United States. The innovation processes within the biotechnology industry are not just one life cycle curve. It consists of waves from organic chemistry/pharmacology to biochemistry, molecular biology, etc. (Figure 6). Molecular biology overlaps the waves of biochemistry and they are about to leap upward. Based on the theory of the innovation life cycle, the process of technological change in the life sciences industry represents technological evolution in the biopharmaceutical industry as a whole. Scientists and researchers are exploiting basic molecular research to identify new drugs and further advance the genomics technology (Runiewicz-Wardyn 2020). Scientific breakthroughs, such as genetic engineering, the ability to create monoclonal antibodies, and the mapping of the human genome, have opened up new areas of research and the pace of discovery in basic biomedical science.

Figure 6. Technological change and technological convergence in the life-sciences industry



Source: own elaboration based on Utterback and Abernathy (1975), Fisher and Pry (1971) and Barrell (2005).

The new fields in the life sciences have one common scientific path of development. Mainly, they result from convergence and collaboration between different disciplines (Zhang 2005). The present and future development in the life sciences is based on the confluence of different technologies, including communications (telemedicine), information technology, genomics, biochemistry and others. For instance, the convergence of chemistry, biology and semiconductor technologies, enabled researchers to develop biochips which, when used for the blood test, could detect the elevated risk of Alzheimer's disease. New types of plastics from the chemical industry may support the use of synthetic materials in resurfacing bone joints and cartilage repair (Runiewicz-Wardyn 2020b). Moreover, rapid advances in technological convergence and its applications in life sciences also induce changes in the market conditions, forcing the transformation of current business models, research networks models and public innovation and R&D support policies. This trend, along with the increasing global biopharmaceutical competition, drives specialisation and increases the role of business alliances and partnerships in research and innovation. Close collaboration is also important in the development of genomics technologies that requires massive amounts of information to be collected and analysed. In turn, the characterisation of genes requires a means to manage, store and process enormous databases of biological information (bioinformatics).

In fact, the biopharmaceutical industry and biotechnology have been some of the first pioneering industries in applying open innovation practices (Gassmann et al. 2010). For instance, in 2003, biopharma and biotechnology companies filed over 13% of the European Patent Office's (EPO) applications with multiple applicants. In comparison, researchers in the chemical industry filed only around 8% of such applications (Backer 2008, Pigott et al. 2014). According to a more recent survey study by the Deloitte company (https://www2.deloitte.com/2014) conducted among 281 biopharma companies in 1988–2012, there is a three-fold probability of later-phase clinical success when drugs are sourced with the open innovation model. The new open innovation models allow for establishing across multidisciplinary biopharma consortia, covering multiple therapy areas and comprising a wide range of expertise and capabilities (Pigott et al. 2014).

The pharmaceuticals market in Central and Eastern Europe (CEE) has grown significantly for the last two decades. The Polish market is the sixth largest market in the European Union. According to McKinsey, the value-added breakdown in pharmaceuticals ranges from 70% to 90% in pharmaceutical manufacturing, with up to 15% in retail and wholesale, and 3% up to 5% in logistics. Poland's main assets include, among others, generic prescription drugs, and over-the-counter (OTC) drugs.

According to statistics from the Central Statistical Office (2018), there are over 100 companies involved in the production of pharmaceutical substances, various drugs and medical devices in Poland. About 60% of them are enterprises employing over 49 employees. The rest of them are smaller companies, employing from 10 to 49 people. Polish pharmaceutical companies rely mainly on the production of generic drugs. Only several smaller pharmaceutical companies are working on innovative drugs (including in the field of oncology). The latter is mainly due to the fact that they do not have such sufficient investment funds as the multinationals. The presence of big-scale international companies (such as: Gedeon Richter, Servier, Roche, AstraZeneca, KRKA, Baxter, Sanofi, Valeant, Teva/Pliva, GlaxoSmithKline, Novartis and Takeda) represents opportunities for the Polish biopharma market. The greatest number of biotechnology and biopharmaceutical companies is located in the capital – Warsaw – followed by other bigger cities like Krakow, Lodz, Tri-City, Cracow, Wroclaw and Poznan. According to *Biotechnology Sector in Poland* (2021), around 30% of the companies combine R&D activities with biotechnological manufacturing, while 70% of the companies focus only on R&D. Around half of the total expenditure spent on R&D comes from the SMEs. Companies have broad access to highly qualified researchers from 38 Polish universities offering educational programmes in biotechnology, medical biotechnology, molecular biotechnology, environmental biotechnology and other biology-related studies (among them 30 at the PhD level) (*Biotechnology Sector in Poland*, 2021).

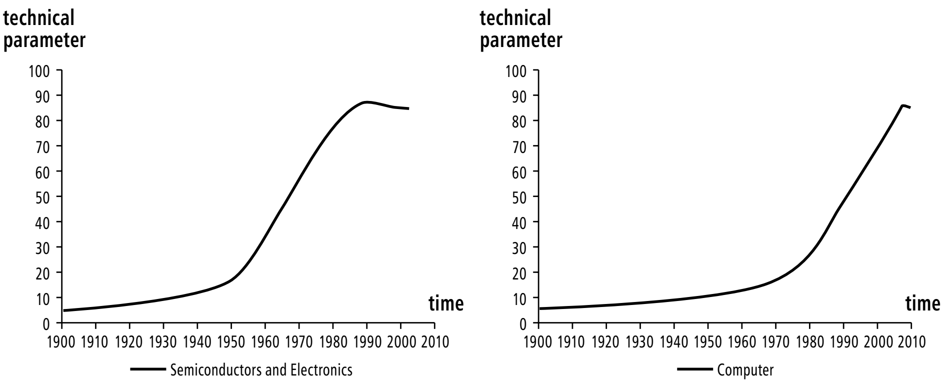
In sum, in terms of biotechnology dynamics, the Polish biotechnology industry lags behind the trends observed in the advanced economies. In fact, it could be placed at the emerging phase. Yet, when it comes to the pharmaceutical market, the analyses from 2020 signalled the strengthening and growth of the pharmaceutical market in Poland. According to the latest PMR (healthcaremarketexperts.com) report, since 2019 the drug production market in Poland has grown at an average of 4.5% per year in terms of value. The most common barriers in the biopharmaceutical sector include: a low level of organisational, social and cultural proximity between the scientists and business, little motivation and no mechanisms stimulating research cooperation, patenting and commercialisation, legislative gaps and excessive bureaucracy in the scope of clinical trials, the lack of intermediary institutions, brokering university-industry collaboration, as well as supporting innovations via giving scientific advice at early stages of research works, a high level of individualism and lack of interdisciplinary cooperation, especially at the university level, and little competition over the European research funds (Kozierkiewicz, 2020). In the drugs production, the challenge is also unfair competition and unethical behaviour as well as the gaps in the legal provisions allowing for a great freedom of interpretation, which leads to the so-called reverse drug distribution chain and worsens the availability of reimbursed drugs in pharmacies.

Electronics and Computers Industries

From the technological and scientific perspectives, both the electronic and computer industries deal with the physical hardware components of systems. There are many technological and R&D overlaps that occur in the two fields, which means that professionals in both areas share many common skills for designing and understanding the hardware that goes into computers, household items or other machines. While electronic engineers work on such technological solutions as electrical equipment and microwaves, computer engineers work on digital media players, artificial intelligence (AI), laptops and desktop computers. The development of both industries illustrates the traditional industry life cycle by first experiencing product innovation, then processes and services innovations. For instance, in the past days, when mainframe computers dominated the industry, researchers and engineers paid more attention to product or system design issues than to the process of constructing a particular piece of software or an operating system. Figure 6 shows that both industries accelerated in the mid-1980s and reported constant growth through the 1990s. In the mid-2000s, computer technology was at its highest growth rate (with the PC industry as its driving force). It retained its high growth rate for over two decades, mainly due to upgrades in hardware, services and add-on products and features (Figure 7).

Since its beginning, the semiconductor and electronics industry has continually introduced innovative products. Gruber (1994) points out that the declines in the price/performance ratio of semiconductor components have propelled their adoption in an ever-expanding array of applications (in electronics industries; telecommunications, automobiles, military systems, consumer electronics, personal communications and home appliances) (Macher et al. 1999). Thus, the industry maximised its profits through the entire growth and maturity stages.

Figure 7. Technology maturity of the semiconductor and electronics (a) and computer industries (b)



Source: own elaboration based on Fisher and Pry (1971) and Barrell (2005).

By the end of 2000, the market became very competitive and the industry entered its early period of the maturity stage. This trend could be supported by observing the present market, with many manufacturers introducing rather incremental innovations by introducing a range of models (from desktop computers to notebooks) and continuing the product differentiation process which began at the growth stage.

In sum, the computer industry shows slowing dynamics or greater stability over the past decade, but because of the diffusion of computing technology and its adoption in advanced countries, the effects of local industrial structure on industry growth may differ from country to country.

Similarly, the electronics industry (based on a Fisher–Pry score for technology diffusion) has entered the high maturing process and early decline stage. The decline of the electronics industry is explained, firstly, by the fact that there are no immediate substitutes for semiconductor chips. Therefore, current substitution is extremely low. Secondly, by the competitive nature of the marketplace and the need to acquire production experience and move down the learning curve (Gruber 1994). In fact, innovations in the electronics industry highly depend on the stock of existing knowledge of productive units, specialised human capital (scientists, engineers, developers, etc.) and the learning-by-doing spillovers, which could generate new string of incremental innovations. Traditional segments of the electronics sector include telecommunications, data processing, audio-video and household appliances or consumer electronics.

The computer sector and the IT technology are at the high growth stage in Poland. The sector is responsible for generating 8% of the country's GDP and employs 430 thousand people (*IT/ICT Sector in Poland*, 2019). In 2018, the domestic IT/ICT market grew by 7.2%, which generated EUR 16 billion in revenue. Poland has access to qualified work force in the field, trained by local technical universities and is a location of R&D centres of such global brands as Samsung and Intel. The domestic market includes around 60,000 companies, both Polish and foreign. The domestic IT services market is driven primarily by the digitisation of public administration, the enterprise sector and services. In 2017, expenditures in the cloud technologies in Poland amounted to nearly EUR 200 million, while a year later it reached almost EUR 300 million (the cloud technology market is developing five times faster than the entire Polish IT services sector, and by 2022 it will reach a value of approximately EUR 450 million (*IT/ICT Sector in Poland*, 2019). The potential for growth is high, because, statistically, one in ten companies uses this type of services, and the demand increases. Based on the pre-COVID-19 data, for 2017, the share of Polish households which own selected electronic goods makes 76%, whereas the same share of households with a personal computer in developed countries was closer to 80% (GUS 2020). The COVID-19 pandemic has accelerated trends even further.

The gross domestic expenditure on R&D is rising too, reaching EUR 5.1 billion (2017), which is an increase by 15% compared to the previous year. Many companies have benefited from the EU cohesion funds and used them for financing their R&D as well as for production facilities modernisation. Poland has created successful and internationally acknowledged start-ups, such as Big Data and the Internet of Things. The fintech (IT solutions for the financial sector) recently attracts the largest group of investors (*IT/ICT Sector in Poland*, 2019). The Polish consumer electronics industry represents an annual growth rate of 7% between 2016 and 2020 (which includes manufacturing of TV and audio equipment). Poland is the largest producer of electronics equipment in Europe, next to Germany, Italy and the UK. This market continues to have large potential for development. According to a forecast by BMI, the sector grows at around 4% per annum (2019). Poland hosts 65,000 students (2014) at its electronic engineering faculties with 4,500 graduates annually (*Electronic Sector in Poland*, 2017). In past years, and especially following the COVID-19 pandemic crisis, the consumer electronics industry demonstrated some lower dynamics. The latter is related to the overall economic situation and slowing demand for the household appliances, audio and video equipment and electronic equipment (https://electronicswatch.org, Poland, 2021).

Chemical Industry

The development of the chemical industry arose largely from the early 18th century to the mid-1920s. By the mid-1930s, most of the features of the modern chemical industry have been established, including continuous processes, catalytic processes, industrial electrochemistry, high pressure chemical technology and chemical engineering. The further growth of the chemical industry was accelerated by the industrialisation and increasing role of the coal chemistry (Chemistry 1.0), the emergence of petrochemistry (Chemistry 2.0), the rise of globalisation and specialisation (Chemistry 3.0) and the latest phase with Chemistry 4.0, in which digitalisation, circular economy, and sustainability play key roles. The transformation of chemical industry from the globalisation and specialisation field (Chemistry 3.0) to the phase of digitalisation and the rise of circular economy (Chemistry 4.0) has started around 1970 (Table 4) (*Chemistry 4.0: Growth Through Innovation in a Transforming World*, 2017). The modern chemical industry involves the use of chemical processes, such as chemical reactions and refining methods to produce a wide variety of solid, liquid and gaseous materials. Most of the chemical products serve to manufacture other items with some of them going directly to consumers (e.g. pesticides, lye, washing soda, etc.). Though chemical products are of extreme importance and can be found in almost every aspect of our lives, the chemical industry has been accused of overexploitation of natural resources, as well as pollution of the environmental media (air, water and soil). This category of chemical products includes chemicals mainly sold within the chemical industry and to other industries where they are used to manufacture other products sold to the public. For this reason, they are usually produced on a very large scale.

The modern chemical industry finds itself in a phase of change and development under the digital processes and data-based operating models. The customers are often actively involved in this process, by sharing their specific individual requirements. The examples of current developments in this area include: the digitalisation of agriculture, in additive manufacturing (3D printing) or in e-health concepts in the health sector.

The Polish chemical industry has a strong position in the region. According to data from the Central Statistical Office, the chemical sector in Poland creates about 300,000 jobs, which accounts for 11% of total employment in industry. In 2010–2016, the growth rate of chemical production that was sold was 5.7% (over 2% more than in manufacturing in general and greater than in more advanced economies, such as the USA, Germany or France) (*Przemysł chemiczny w Polsce*, 2021). According to the report by the Polish Chamber of Chemical Industry (PIPC) (*Przemysł chemiczny w Polsce*, 2021), despite the recent positive trends, the chemical industry in Poland currently has an insufficient range. Compensation for these shortcomings is the too low budget allocated to Polish industry every year. The low investment in this sector results in outdated technologies, consuming a lot of energy, poor condition of devices used for environmental protection, low efficiency and low competitiveness of production on world markets (*Przemysł chemiczny w Polsce*, 2021). One of the important challenges is the environment and the overall social assumption about the threat of the production of chemicals for the environment. Both for Poland and the entire EU, innovative solutions in the chemical industry are essential to deliver a low-carbon and circular economy. The European Commission has recognised the chemical industry for its 'indispensable' role to help society achieve the new European Green Deal objectives.

Table 4. Drivers of transformation of chemical industry – from Chemistry 3.0 to Chemistry 4.0

Chemical industry	Globalisation and specialisation	Digitalisation and circular economy
	Globalisation, the European internal market, growing competition and the influence of financial markets on corporate strategies, commodification	Digital revolution, sustainability, climate protection, closing material cycles
Raw materials	Increasing use of renewable raw materials and natural gas	Intensive use of data, recycling of carbon-containing waste, H2 from renewable energies in combination with CO2 used to produce base chemicals
Technology	New synthesis and production processes through biotechnology and gene technology, enlargement of individual processes	Digitalisation of manufacturing processes
Research	Close cooperation between basic research in universities and application-oriented research in companies	Decentralisation of R&D in customer markets, utilisation of Big Data, joint development with customers
Corporate structure	Internationalisation of trade and on-site production abroad, specialisation and growth in SMEs, consolidation through M&A, creation of chemical parks	More flexible cooperation as part of economic networks, digital business models and consolidation
Products	Expanding product range, specialty chemicals oriented to specific customer requirements, new drugs, replacement of traditional materials with chemical products	Expanding the spectrum of value creation: chemical sector becomes a supplier of extensive and sustainable solutions for customers and the environment

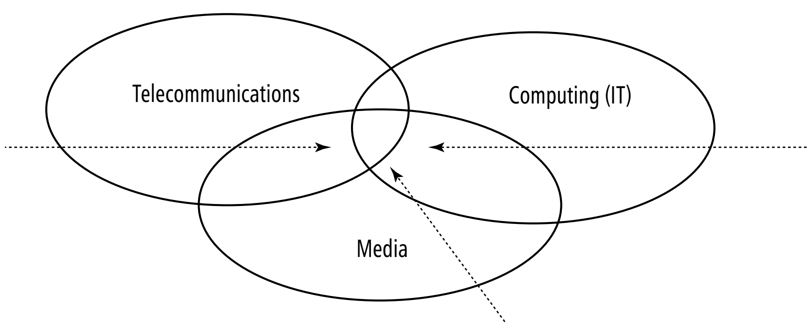
Source: *Chemistry 4.0: Growth Through Innovation in a Transforming World* (2017).

In sum, the Polish chemical industry seems to approach its growth stage. The described features of the chemical industry show that its innovations are of great importance for many customer industries (e.g. automotive, construction, packaging, etc.). The focused incremental innovation products and processes, offered by customer-oriented SMEs, may offer further growth opportunities for the Polish chemical industry, whereas the intensifying competitive pressures offer the chemical sector opportunities for collaboration. Thus, open innovation collaboration, especially in developing the ecological strategy and pro-environmental image of the Polish chemical industry may enable further innovations and technological dynamics in the industry. The challenges facing the Polish chemical industry include the lack of investments in the outdated chemical facilities and labs, low capital attractiveness and adjustment of the production of chemical products to the current market demand, little cooperation between chemical industry, research institutes, public and non-public organisations as well as further implementation of EU regulations in the area of process safety and environmental policy

Media, Publishing and Printing Industry

The history of printed newspaper goes back to the 17th century and the history of radio dates back to the late 19th century. The real technological breakthrough that influenced the media and publishing industry was the widespread installation of television sets in the late 1940s, followed by satellite television (1962) and the internet technology in 1990. The digitalisation has enabled the convergence of different technological solutions into a single whole. The process of technological convergence (combining different media, telecommunications operators and the computer industries) affected the media and publishing industry by introducing new tools and equipment used to produce and distribute news and entertainment programmes (Figure 8) (Jenkins and Deuze 2011, Kolodzy 2006, Baron 2015). The process of convergence, by its basic definition, is essentially permanent and continuous. Thus, the media industry is evolving under the continuous technological innovation and the convergence of technological solutions.

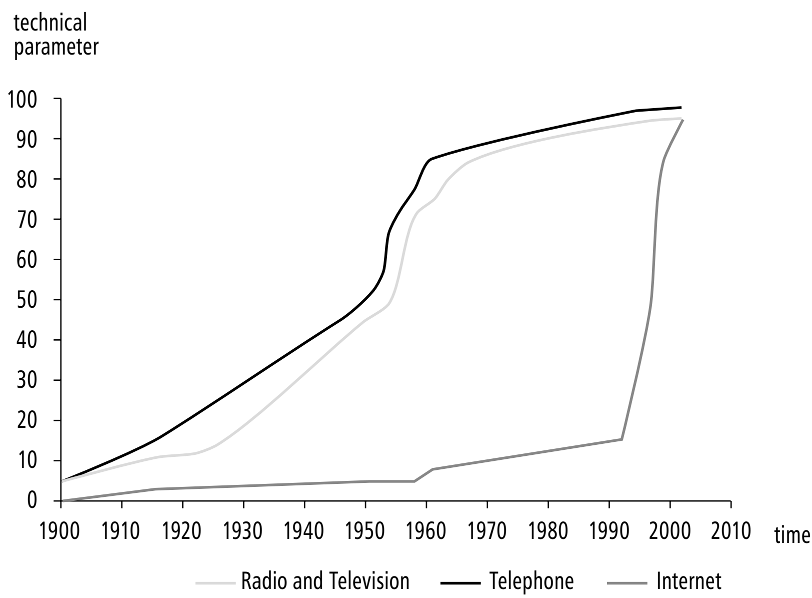
Figure 8. Model of convergence between IT, telecommunication and media industries



Source: Nystrom (2007).

The 'media and publishing industries', which can also be defined as 'creative industries', rely on the knowledge and creativity, skills and talents of people. The industry has potential for wealth and job creation through the generation and exploitation of IP (*Advanced Technologies for Industry – Technological Trends in the Creative Industries*, 2021). Yet, creative activities are based on cultural values, or other artistic individual or collective creative expressions. Therefore, the IP is a powerful tool in the creative industries. Not only does it protect the integrity of original works, it also creates an ongoing revenue stream to invest in future projects. The EC considers the following fields as a sector of creative industries: new media, publishing, video games, gaming, music, film, museums, architecture, visual art, performing arts and design. The important feature of the creative industries is that they provide not only direct inputs to the rest of the productive system, but also generate important spillover effects on the other sectors of the economy and society via the flows of new ideas, skills and knowledge.

Figure 9. Technology maturity of the media and internet industry



Source: own elaboration based on Fisher and Pry (1971) and Barrell (2005).

The digitisation of creative industries has lowered the costs and, consequently, the barriers to production for artists and creators. This has led to an increase in artistic production and more creative works are produced, distributed and published than before. The media and publishing industries were among the first creative industries to be impacted by the spread of digital technologies. Moreover, in the last decades, the creative industries have been mostly influenced by the emergence of the following advanced technologies: augmented and virtual reality (AR/VR), artificial intelligence (AI), cloud and blockchain technologies (Figure 9). Other nondigital technologies, such as advanced materials, nanotechnology and micro- and nanoelectronics, have also affected various creative segments, such as visual arts or gaming hardware.

Nevertheless, the adoption of advanced technologies is raising critical questions about ethical design, privacy protection, monopolisation and the economic impacts, the value of copyright and the boundaries of human-machine interaction within the creative process itself.

The digitisation of creative works has lowered the costs and, consequently, the barriers to production for artists and creators. This has led to an increase in artistic production and more creative works are produced, distributed and published than before. Consequently, this makes the media and publishing industry very competitive and fast-growing (Figure 9). This trend has accelerated even more by the COVID-19 pandemic. The lockdowns have boosted user engagement, for instance, with video games and e-sports.

The consumer experience became the next level of focus in the creative industries. So, the challenge then becomes: how to retain those customers before they seek other streaming options? How do I attract you with original content, but then keep you by knowing more about you as a customer? In addition, customers want tailored options in terms of content and pricing. Therefore, while the availability of original content is typically critical for attracting customers, a broad content library and tiered pricing (including free, ad-supported offerings) are increasingly essential for keeping them. Increasingly, customer retention will depend upon having a single platform capable of satisfying a wide range of entertainment desires. So, rather than focusing solely on streaming video, providers should explore potentially adding games, music and podcasts to their suite of offerings or partnering with other providers: video gaming, music or podcast-based advertising providers. The digitalisation of the media industry has been driven by changing consumer behaviour and expectations, especially among younger generations who demand instant access to content, anytime, anywhere. Thus, many companies which possess better and more actionable customer data can offer personalised video content, music, games and podcasts as well, exploring the new open innovation business models and technologies that foster a deeper understanding of consumer behaviour and better consumer engagement.

According to the European Commission (*EU Cultural Statistics*, 2021), the sector of culture and creative industries in Poland produces on average 2% of the GDP growth. As after Mackiewicz and Namyślak (2021), creative clusters in Poland were established between 2006 and 2015, with the biggest number established in 2011–2012. The authors have identified 17 clusters related to creative industries. Out of 434 entities, almost half of them are based in the same locality as the cluster headquarters (with especially high concentration of clusters in two southern regions – Silesia and Małopolska). The overall digitalisation process has increased the growth of industry related companies in Poland. In 2020, 90% of households in Poland had access to the internet. This was an increase by 3% in comparison to the previous year. The overall share of households in Poland with internet access was only 1% lower than the average of the European Union (EU-27) in 2020. The study by Mackiewicz and Namyślak (2021) identified several key factors hindering the development of creative clusters in Poland. These include insufficient financing from both private and public sources as well as the weak cooperation of entrepreneurs with universities, caused by institutional and cultural distances between the universities, including the bureaucratic and institutional barriers of universities. Moreover, further development of the Polish media, publishing and printing sector depends on the ability of Polish companies to gradually shift in global supply chains, stimulate innovative activity, as well as to develop legal and regulatory mechanisms that would effectively protect media pluralism.

Scientific R&D, Professional and Technical Activities

This sector comprises establishments primarily engaged in activities related to the human capital, its expertise and training. The professional, scientific and technical services sector comprises public and non-public organisations that specialise in performing professional, scientific, and technical services for others. A number of open innovation-influenced researchers have explored the relationship between dynamics of this sector and the open science as well as other forms of companies` innovations beyond simple technology transfers (Beck et al. 2020, Guinan, Boudreau and Lakhani 2013, Chesbrough 2020). However, understanding the synergy between open science and open innovation remains very fragmented and limited, as the sector covers multiple fields of research and practice. Open Innovation makes it possible to examine specific exchange relationships and translation services between science and other sectors of society. The process of open innovation in the context of the scientific R&D sector is related to purposive permission, initiation, and management of inbound, outbound, and coupled knowledge flows and inter-/transdisciplinary collaboration between organisations along all stages of the scientific research process (i.e. from the conceptualisation to the collection, processing and analyses of data, as well as dissemination of results through writing and translation into innovation. The outcomes of the open innovation in the scientific R&D sector may have scientific and societal impacts, such as faster response to novel diseases (Beck et al. 2020). The latter, while the commercialisation of scientific knowledge may be done by academic scientists themselves, the market-oriented knowledge transfer requires partnership with industry. The successful university-industry collaborations can cover the entire spectrum from contributory to co-creative interactions and result in an increase in the number of patents received commonly by academic scientists and research organisations (Perkmann et al.

2013, Lissoni et al. 2008). As mentioned in earlier sections, long-term innovative collaborations between universities and industry are usually built on strong personal and informal relations between individuals. The open science and open innovation in research may also create potential tensions and conflicts, e.g. greater openness with respect to research data and outputs may undermine efforts at technology commercialisation (Beck et al. 2020).

As for 2018, the scientific R&D, professional and technical activity sector accounted for 8.9% of the total number of persons employed in the EU and 19.4% of the total number of enterprises in the EU. The most specialised EU countries in the share of the employment in the sector were Sweden, Ireland, Belgium, the Netherlands, Cyprus, Malta and Luxembourg; each contributed to more than 10% of their non-financial business economy employment in these activities. Poland is one of the lowest performers, along with Romania and two Baltic States – Lithuania and Latvia – in the percentage share of this sector in the value added and employment (in the non-financial business economy in total). In Poland, only 7% of all enterprises are engaged in professional, scientific and technical activities. However, following the GUS (2021) database, it is also one of the sectors with an increasing number of employees. For instance, in 2020, as in previous years, the sector of professional, scientific and technical activities attracted most of new companies (10.9%). The three administrative regions with the largest number of active entities in this sector are Mazowieckie, Małopolskie and Wielkopolskie. A major share of companies active in this sector employ up to 10 employees (over 85% of entities). Examples of larger entities in this industry are: the Maria Sklodowska-Curie National Research Institute of Oncology, the Military Institute of Medicine or the Cardinal Stefan Wyszyński Institute of Cardiology.

Summary and Conclusion

The global biopharma and pharmaceutical industries are currently both in the growth and thus highly competition-intensive stage, pressured by the increasing marketing and R&D costs, more sophisticated buyers, greater competition and decreasing profits. In general, the new medicine development requires substantial upfront investments in R&D and having long product development cycles leads to a long product innovation process additionally burdened with the public authorisation procedures. Many companies relocate production facilities to countries with lower operation and R&D costs. The Polish biopharma and pharmaceutical industries lag behind these global trends and may be positioned in the emerging phase in the biotechnology and at the early growth stage of the pharmaceutical industry. The electronics and computers industry has generally demonstrated greater stability and maturity over the past decade. However, because of the price decline and the diffusion of computing technology and its adoption in an ever-expanding array of applications in various fields and sectors, many manufacturers introduce incremental innovations and continue the product differentiation process, which in many cases further extends the growth stage of the industry. In the case of the chemical industry, Poland is slowly reviving the industry growth through the increase of the investments into incremental customer-oriented innovation products and processes and intensifying competition. The further dynamics of the industry will also depend on its ability to adapt its strategy to the green transition and the pro-environmental image. The Polish media, publishing and printing industry has been rapidly evolving under the continuous technological innovation, convergence of technological solutions and the digitisation of creative industries. The share of the creative economy in the added value created in Poland has increased significantly in the last decade. The industry has reached its early growth stage. Finally, Polish scientific R&D, professional and technical activities sector is at the emerging stage of its development. Introducing the open and collaborative practices may allow one to produce more novel and impactful scientific knowledge, solve real life industry/business challenges and further accelerate its evolution.

Chapter 4

Open Innovations From the Perspective of Polish Knowledge and Technology Intensive SMEs

Introduction

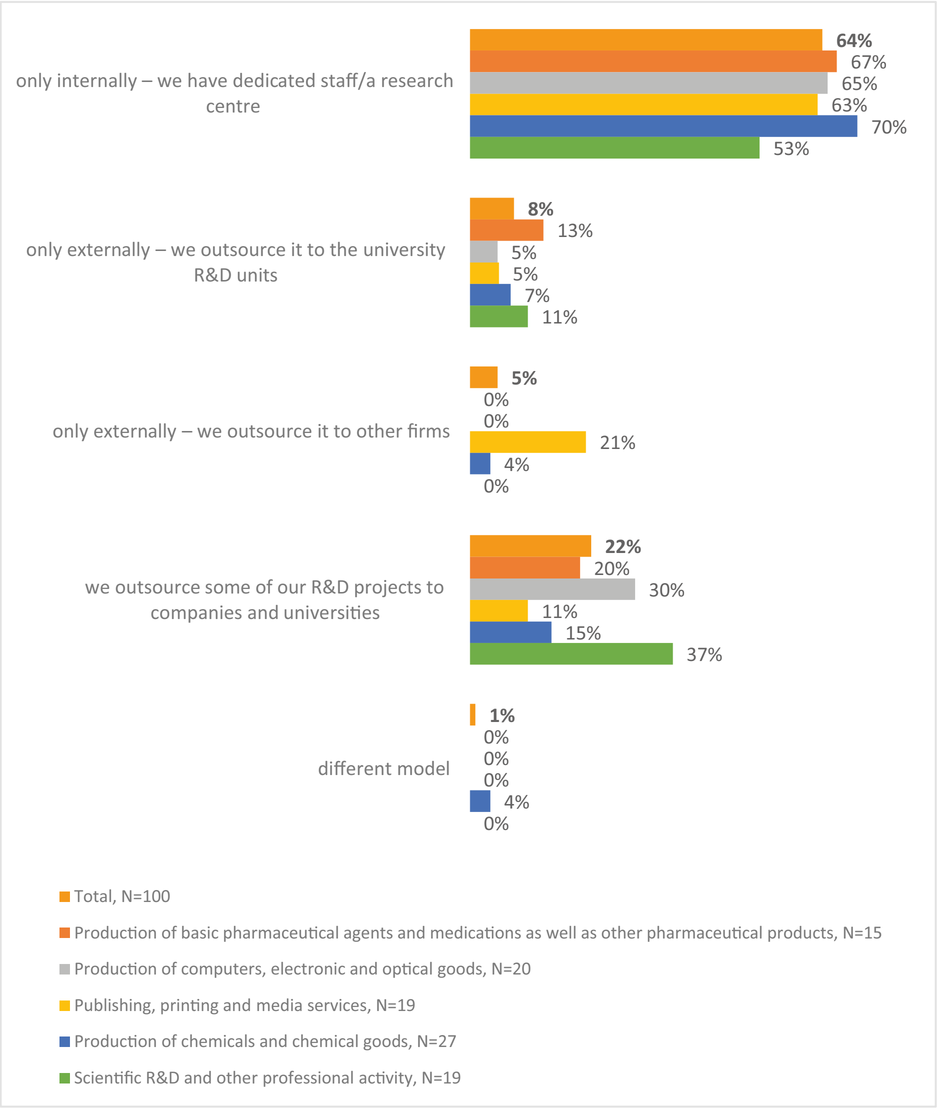
The study applies qualitative survey research method, which allowed the author to better understand the complex nature of innovation relationship and the open innovation environment as well as the major drivers and barriers behind open innovation processes in the Polish SMEs. The qualitative research survey was conducted with the cooperation with ARC Rynek i Opinia company (from January to April 2021). The study was conducted using the CATI (computer-assisted telephone interview) method. The survey implementation process was longer than planned due to COVID-19 pandemic. The respondents in the study were representatives of small and medium-sized enterprises (SMSEs), people from middle to high management level, most competent in this field. The survey questionnaire preceded with the pretesting and piloting with the five interviews (N = 5). As a result of the pilot study, it was decided to remove selected open questions from the questionnaire (due to the interview time being too long, longer than originally assumed). Due to the remote work model introduced in the surveyed companies, access to the target respondents was difficult and frequently required multiple contacts. Additionally, the small number of companies meeting the survey criterion (selected CACs from the high technology industry), and therefore a limited number of potential respondents, additionally hindered the survey implementation process. The survey covered 100 companies located as belonging to the PKD – Polish Classification of Business Activity (GUS 2021); advanced technologies industries: (21) Manufacture of basic pharmaceutical substances and other pharmaceutical products; (26) Manufacture of computers, electronic and optical products; (27) Manufacture of electric motors, generators and transformers; (20) chemical industry and production of chemical products; (18) Publishing, printing and media services; (62) Computer programming activities, computer consultancy and other activity; (72) Scientific research and development; (74) Other professional, scientific and technical activities. The main objective of the study was to identify inbound and outbound open innovative practices as well as to identify major drivers and barriers in engaging into the open innovation collaboration, including the role of psychological and individual factors such as ‘trust’, perceived on the inter-organisational level. The questionnaire contained mixed (open and closed) 25 questions structured in five parts: (1) the general structure R&D and participation in open innovation collaboration, (2) factors influencing open innovation collaboration; (3) advantages and drivers in engaging into open innovation collaboration process, with firms and academia; (4) the disadvantage and barriers in engaging into open innovation collaboration process with other firms and academia; (5) future plans regarding the open or closed innovation collaboration. Due to the rounding to full values, the data in the charts for single-choice questions may not add up to 100% (they may add up to 99% or 101%). The data may not add up to 100% also due to the possibility of selecting multiple answers by the respondent. The section below presents the a synthesized findings of the above survey. Additional graphs as well as the complete structure of survey can be found in the Annex 1 and 2.

4.1. Innovation Openness of the Polish High-Tech and Knowledge-Intensive SMEs

Most of the knowledge and R&D intensive companies surveyed conduct R&D activities exclusively internally. It is most popular in chemical companies (70%), followed by companies involved with the p**harmaceutical industry** (67%) and the c**omputers, electronic and optical industries** (65%). The popularity of the only external model is low. It is most frequently adopted by companies dealing with p**ublishing, printing and media services**, while the mixed model is preferred by a large percentage of companies producing c**omputers, electronic and optical products** (compared to other industries). The size of the company – small or medium – does not significantly affect the model used. Although there is a slight tendency to outsource innovation to larger companies.

Representatives of the majority of companies carrying out at least some of their research and development work internally declared that internal R&D activities largely satisfied their innovative needs (Figure 10). Internal R&D activities to the greatest extent satisfied the innovative needs of companies from the pharmaceutical industry and computer, electronics and optical industries products industries, and to the least extent – those companies that were involved in the production of chemical products. At the level of the entire surveyed group, the size of the company does not affect the degree of meeting innovative needs by internal activities.

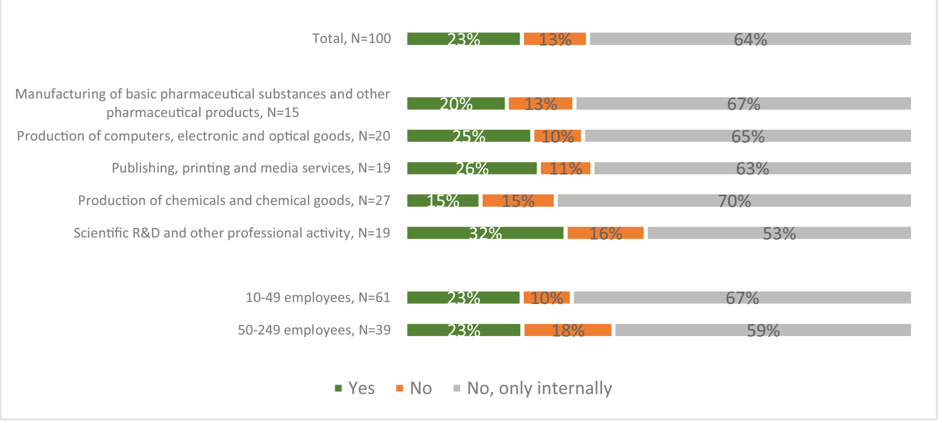
Figure 10. The way of conducting R&D activity in Polish knowledge- and R&D-intensive SMEs



Source: own survey conducted with the assistance of ARC RInek i Opinia in January–March 2021.

When asked about open innovative cooperation, i.e. cooperation consisting in mutual exchange of knowledge, technical solutions and licences (i.e. not only creating one's own solutions but also the effective use of external solutions), 64% of companies declared they 'do' conduct such activity (Annex 1). The percentage of companies conducting open innovations is similar in individual industries. The highest percentage was observed in the scientific R&D and other professional activity sector, followed by the production of computers, electronic and optical goods, and the lowest was observed in the chemical industry. The latter is not surprising, as its representatives declared to conduct 70% of R&D activity internally (see Figure 11). Also, the size of the company does not significantly affect the use of open innovation. Both in the case of small and medium-sized companies, 23% of the representatives declared to conduct open innovation activity.

Figure 11. Open innovations as percentage to the full sample



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

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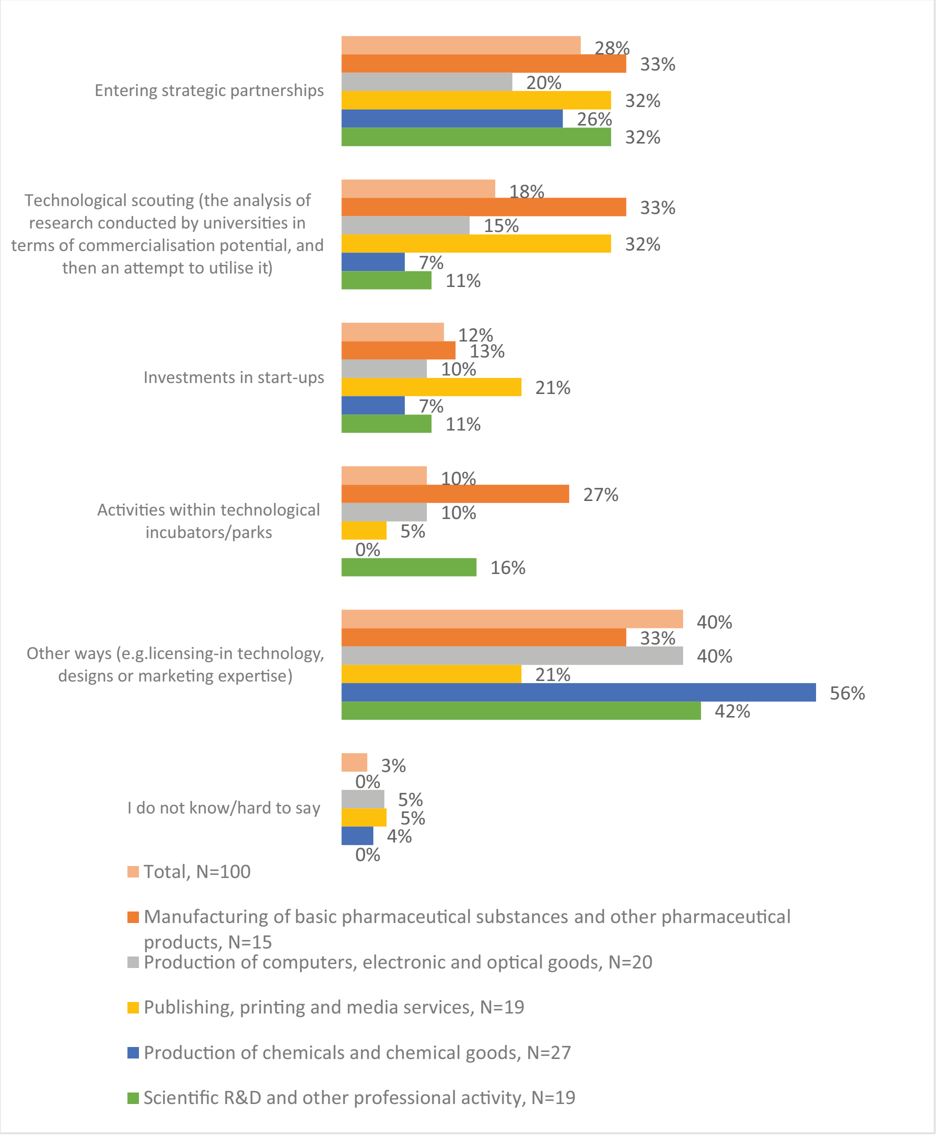
Representatives of the surveyed companies most frequently declared that no activities were undertaken in their companies to obtain external knowledge (they responded spontaneously, 'None.'). Upon reflection, they provided more detailed answers. For instance, in the pharmaceutical industry, entering strategic partnerships, technological scouting, activities within technological incubators/parks and licensing new technologies were equally important.

Representatives of the chemical and computer, electronic and optical industries chose other traditional methods of licensing knowledge and technologies. Investments in start-ups were the least popular way of external knowledge sourcing, with some exception of the publishing, printing and media industries, for which start-ups, especially in the field of social media, open new opportunities for business.

Figure 12. Actions taken to acquire external knowledge

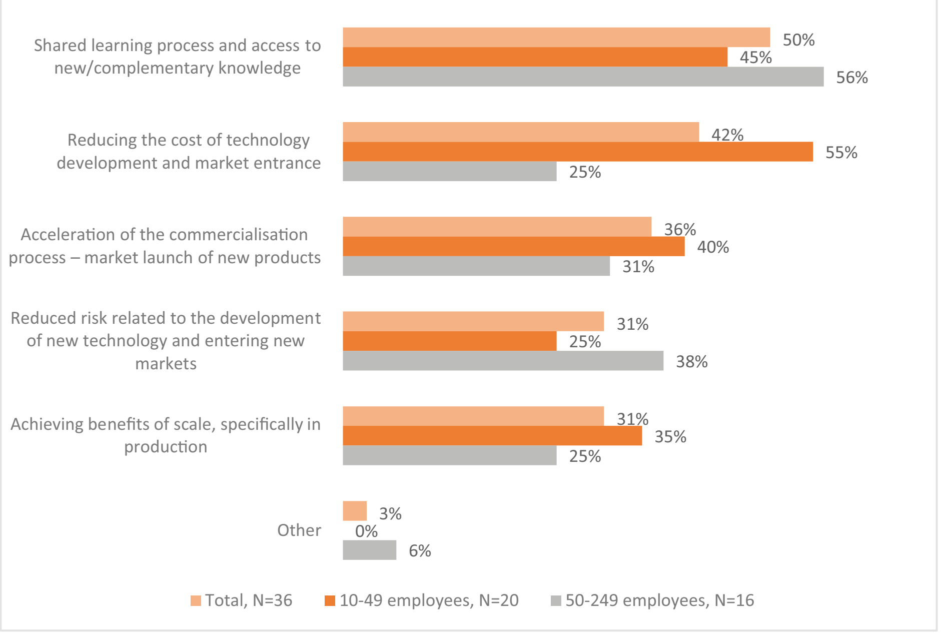


Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

In general, activities within technological incubators/parks were not popular among Polish R&D and knowledge-intensive SMEs (Figure 12). The latter means that technological incubators/parks are not the most effective channels of technology transfer (with some exception of the pharmaceutical industry), which is also an important conclusion for the relevant public policies.

When asked about the main benefits of engaging in open innovation processes (the question only concerned companies that conduct open innovation cooperation, i.e. the basis for paying off – the company performs at least some of its research and development work externally, i.e. N = 36), the companies indicated a common learning process (more frequently in large companies) and a reduction in the costs of technology development or market entry (more often in small companies) as the main benefit of engaging in innovative cooperation (Figure 13).

Figure 13. Key benefits of engaging in open innovative processes

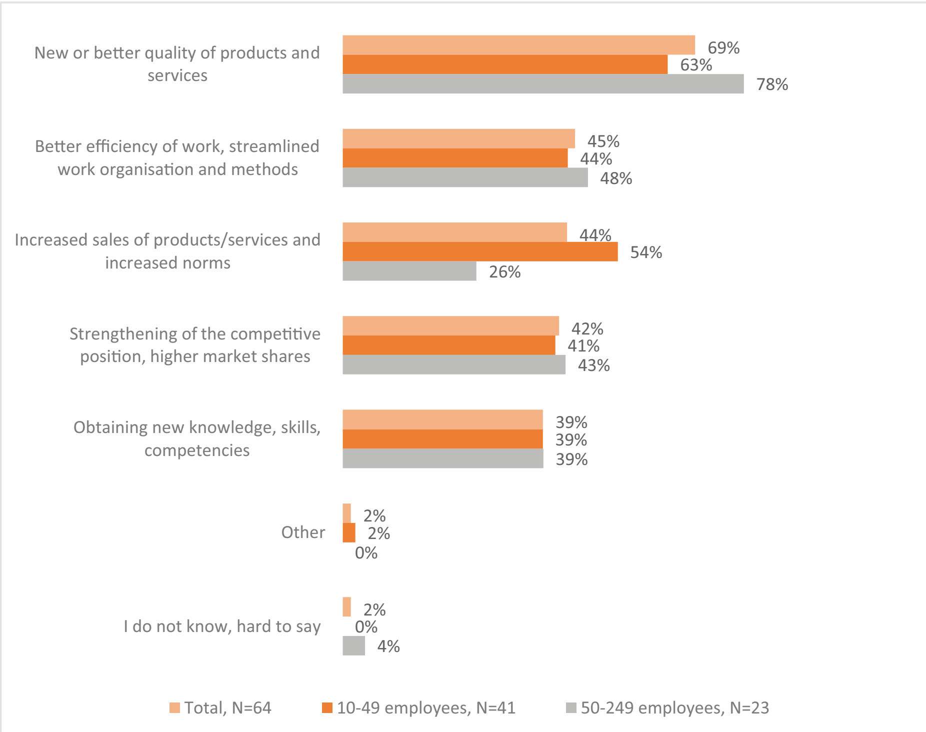


Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

Due to the small size of the sample, it is not possible to conduct an analysis by industry. The companies that did not engage presently in the open innovation activity (basis for percentage – the company carries out research and development work internally only, N = 64) were asked a similar question – about potential benefits of engaging in open innovation processes. In the eyes of companies, the potential benefits of open innovative cooperation are primarily the new or better quality of products and services (especially in the eyes of large companies and the pharmaceutical and publishing sectors) (Figure 14).

Companies from the publishing, printing and media industry more often than the representatives of other industries indicated that the benefit of introducing open innovation is the improvement of work efficiency (work productivity). In turn, representatives of the pharmaceuticals industry paid special attention to the increase in the company's market share, while the companies involved in the production of computers, electronics and optical products to the overall increase in sales.

Figure 14. Potential benefits of engaging in open innovation processes



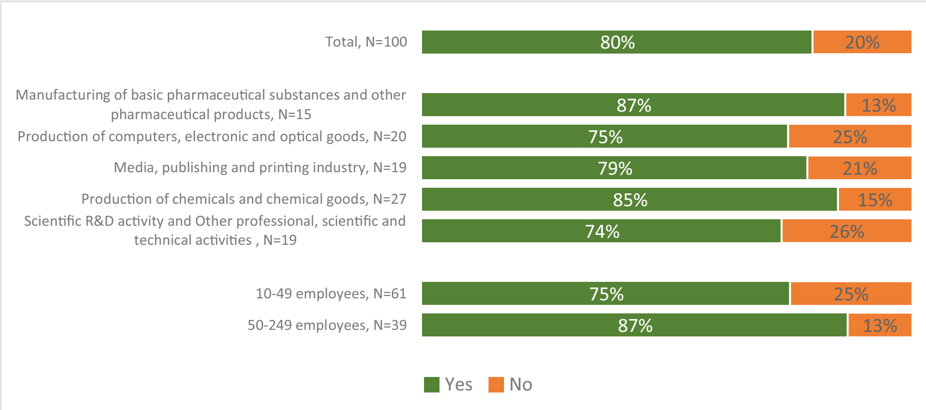
Source: author's survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

4.2. Open Innovative Environment and the Role of Proximity in Open Innovation Networks

The author's research findings have shown that 80% of respondents favoured physical proximity in the initiation of the innovative interactions. The representatives of pharmaceutical sector shared especially strong views on the greatness of physical proximity in the innovation process. Around 87% of enterprises in this sector declared a significant impact of physical proximity on the initiation of their innovative interactions. Somewhat similar answers were provided by representatives of the chemical industry – 85% (Chapter 3).

Representatives of companies from other knowledge-intensive industries agree with the statement that physical proximity has a positive effect on initiating inno-

Figure 15. Impact of physical proximity on initiating innovative interactions in knowledge-intensive SMEs in Poland



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

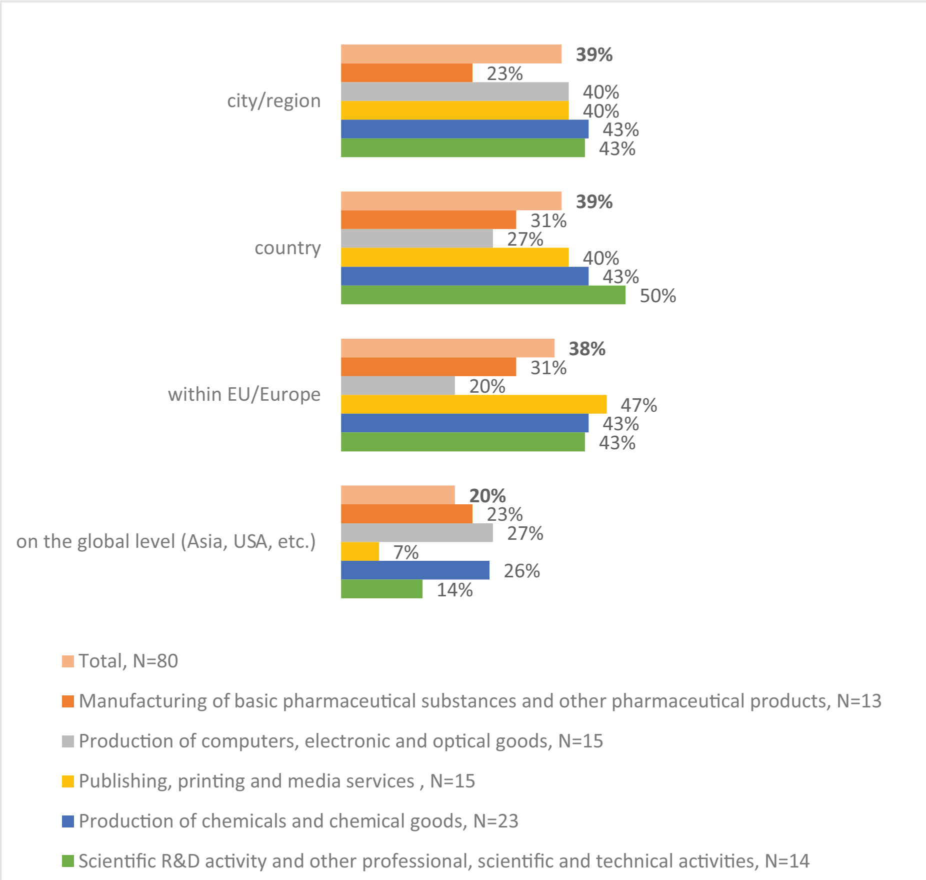
vative interactions, yet their views somewhat differ across each sector (Figure 15). For instance, in the view of respondents belonging to the computers, electronic and optical industry, innovation performance depends on 'global-local' innovation interlinkages and R&D collaboration, whereas in the case of pharmaceutical substances and other pharmaceutical products on the EU and national interlinkages (Figure 16).

The size of the company does not significantly change the perception at what level physical proximity is the most beneficial for initiating innovative interactions.

Furthermore, in the case of scientific R&D activity and professional activities, both city-region, national and EU-level R&D interlinkages matter most, whereas in the case of the **chemical industry**, geographical proximity did not play any role at all (in the view of the respondents, they have innovation and R&D partnerships anywhere). The latter should constitute an important context for regional innovation, technological and growth processes.

When asked about the other types of proximities that have the largest impact on the selection of partners for innovative cooperation, the equally important factor influencing the selection of partners for innovative cooperation was technological proximity (understood as a technological profile). On average, 79% of respondents declared that technological proximity between partners influenced their decision of innovative collaborative activity. In other words, the capacity to take productive advantage of firms' R&D capacities and stocks of knowledge depended heavily on the extent of the technological similarity of their innovation partners. The second important factor mentioned was individual-social proximity

Figure 16. The geographical level of physical proximity most favourable for initiating innovative interactions in knowledge-intensive SMEs in Poland

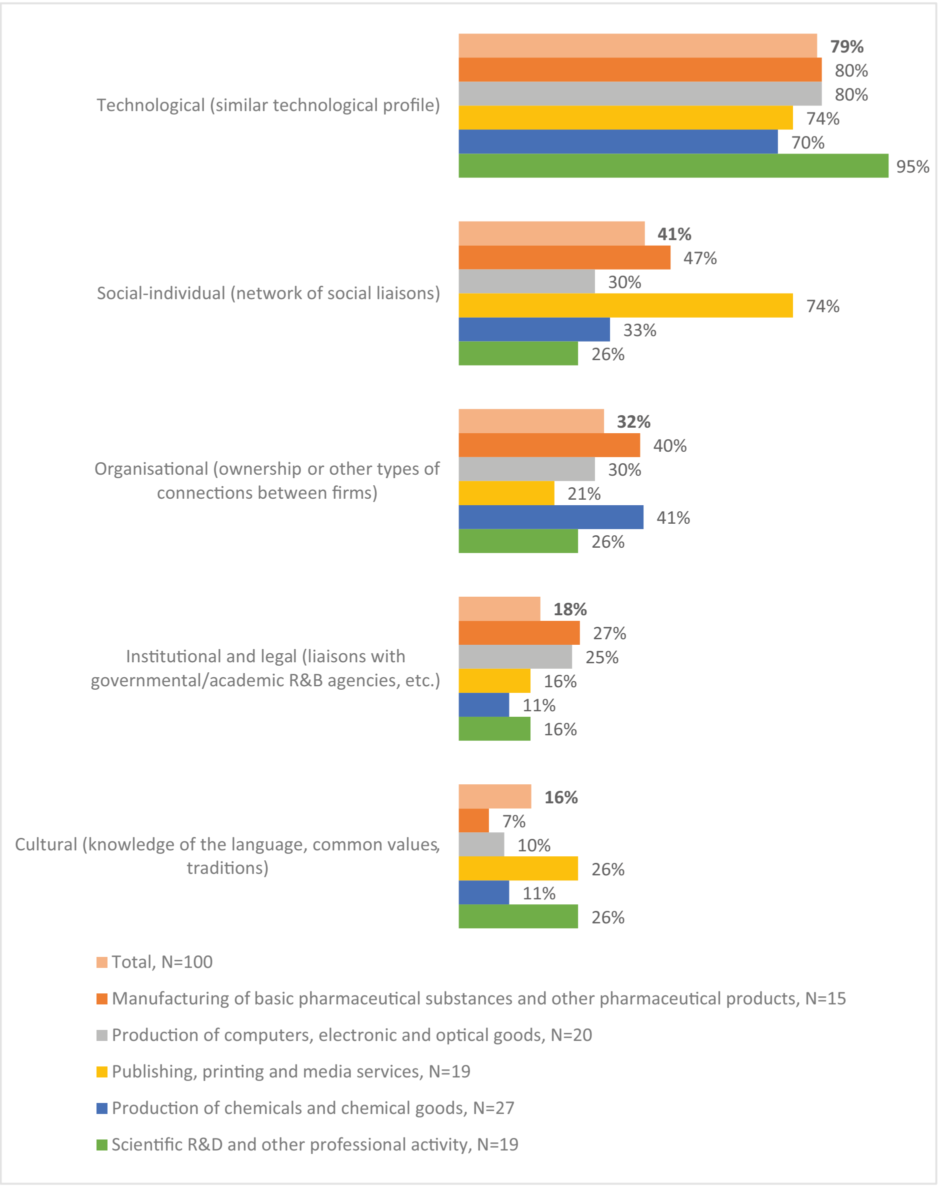


Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

(related to professional, formal and non-formal networks) (41%), followed by the organisational proximity (related to ownership and connections between firms) (32%), institutional proximity (liaisons with academic R&D units and government authorities) (18%) and finally cultural proximity (common values and language of communication) (16%). The exceptions are the companies belonging to the publishing, printing and media services industries, where socio-individual proximity is just as important as technological proximity (see Figure 17). In this sector, one could also observe a more important role of cultural proximity (74%) than in most other industries.

The cultural proximity had the least important role in the selection of innovation partners in the pharmaceutical, computer, electronic and optical industry and chemical industries, whereas the highest role in the case of scientific R&D and other professional activities and publishing, printing and media services industries (26% for each group). Moreover, taking into account the size of entities, the role of socio-individual factors decreases with the size of the company, while the importance of organisational links between companies increases.

Figure 17. Factors affecting the choice of innovative partners



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

It indicates that social and cultural connection between the enterprises and similar knowledge are equally important (and in some cases more important, e.g. scientific R&D and other professional activities; publishing, printing and media services) for the innovation collaboration as the co-location.

The significance of social proximity was observed in the case of 41% of SMEs on average. Furthermore, the study revealed that networks of social liaison were especially important for innovation and R&D relationships in the local publishing, printing and media services, followed by basic manufacturing of the pharmaceutical industry. On the contrary, for the study representatives of scientific R&D and other professional activities the social network liaison presented some challenges. The largely stigmatised social trust in the Polish post-socialist reality hinders the openness and trust in social relations and thus motivation in cooperation between scientists and business representatives in the R&D collaboration networks.

In the eyes of the representatives of the surveyed companies, the key factor influencing the selection of partners for innovative cooperation is the technological factor (understood as the technological profile). The exception is the printing industry, where social and individual issues are just as important as technological issues. In this industry, we also observe a more important role of cultural factors than in most other industries.

Taking into account the size of entities, the role of social and individual factors decreases with the size of the company, while the importance of organisational links between companies increases.

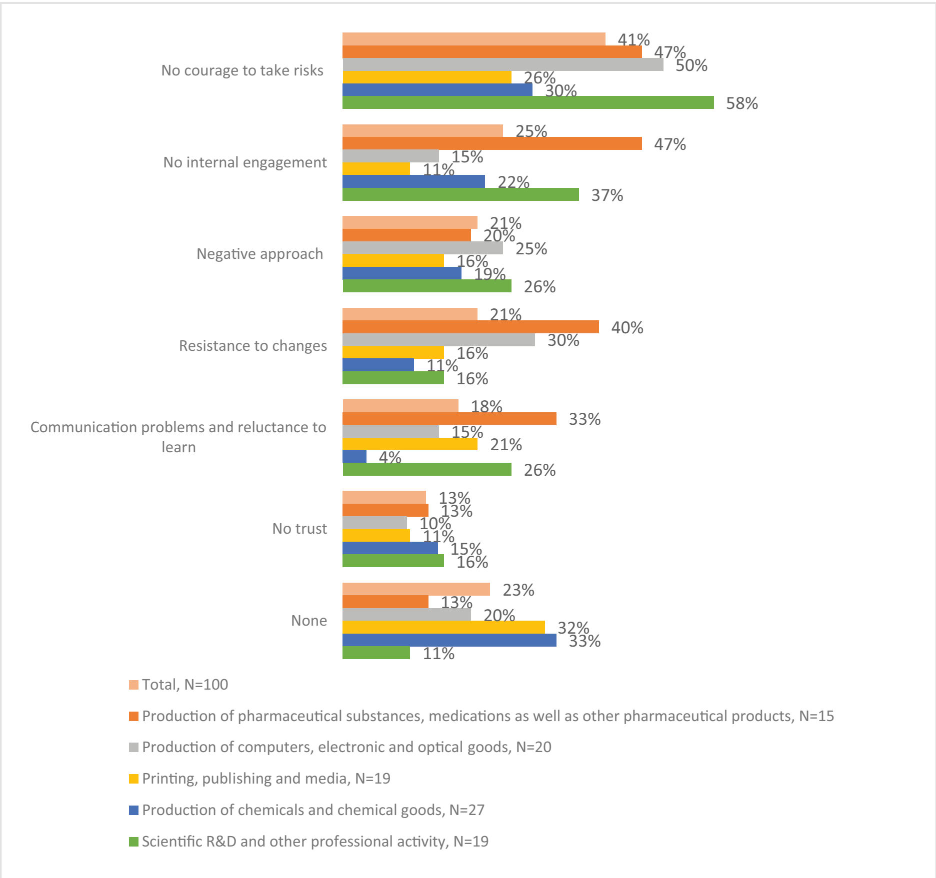
In sum, the study shows that however, physical proximity is important for the innovation collaboration of the Polish SMEs, the role of geographical dimension for initiating innovative interactions may vary for each industry and its firms. Moreover, the further levels of proximities, especially technological, institutional, organisational and social ones, are also relevant.

4.3. Socio-Behavioural Characteristics and Open Innovation Environment

The open innovation collaboration is above all affected by peoples' the individual-level resources, such as cognitive ability, personality, behaviour and motivation. Supportive individual-level sources encourage innovation whereas behaviour characterised by resistance to changes, risk aversion, no internal engagement, distrust or a negative approach to sharing knowledge inhibit the implementation of open innovation model. The study allowed for identifying which traits and personal characteristics hinder group innovation or open innovation environment in specific R&D and knowledge-intensive sectors (see Figure 18).

According to the surveyed company representatives, the lack of courage in taking risks is a personality trait that inhibits the process of innovative cooperation to the greatest extent. A negative attitude and resistance to changes are more frequently indicated by larger companies, the lack of internal involvement and resistance to changes apply particularly to the pharmaceutical industry.

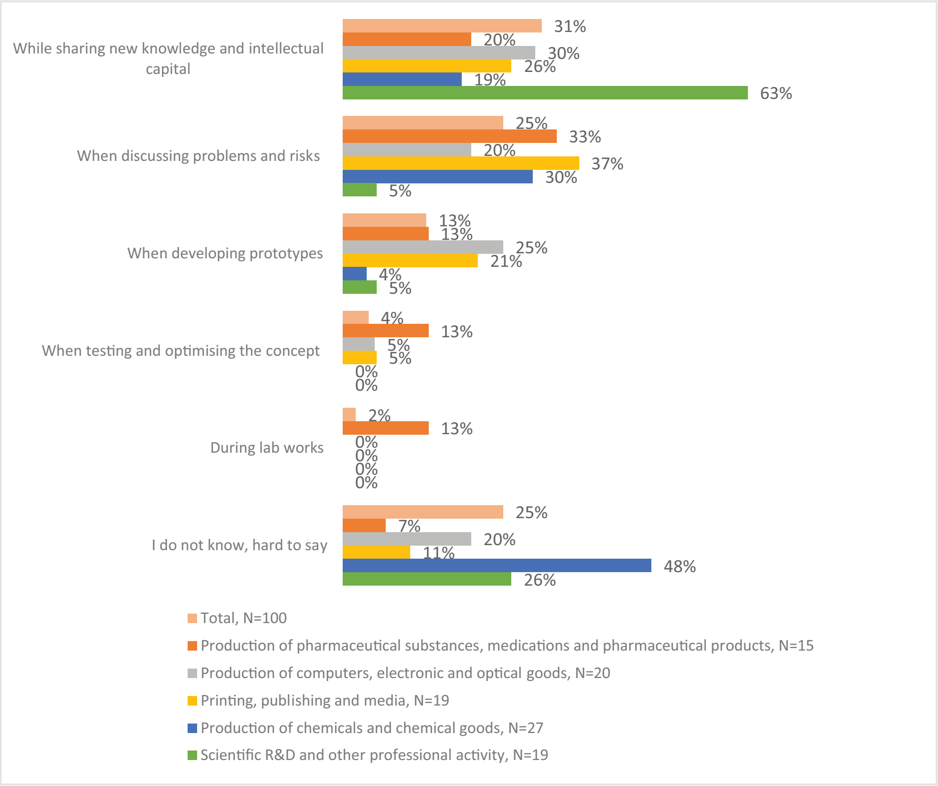
Figure 18. Personality traits hindering innovative cooperation (split according to sector)



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

Activities in which it is most difficult to trust partners include, sharing new knowledge and intellectual capital (31%), discussing problems and risks (25%), developing prototypes (13%) or testing and optimising the concept (4%) in this particular order. The problem of trust in sharing knowledge is equally relevant for small as well as medium enterprises, while trust in discussing risks and problems and lab works is more significant for bigger companies.

Figure 19. Activities in which it is most difficult to trust partners (split according to sector)



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

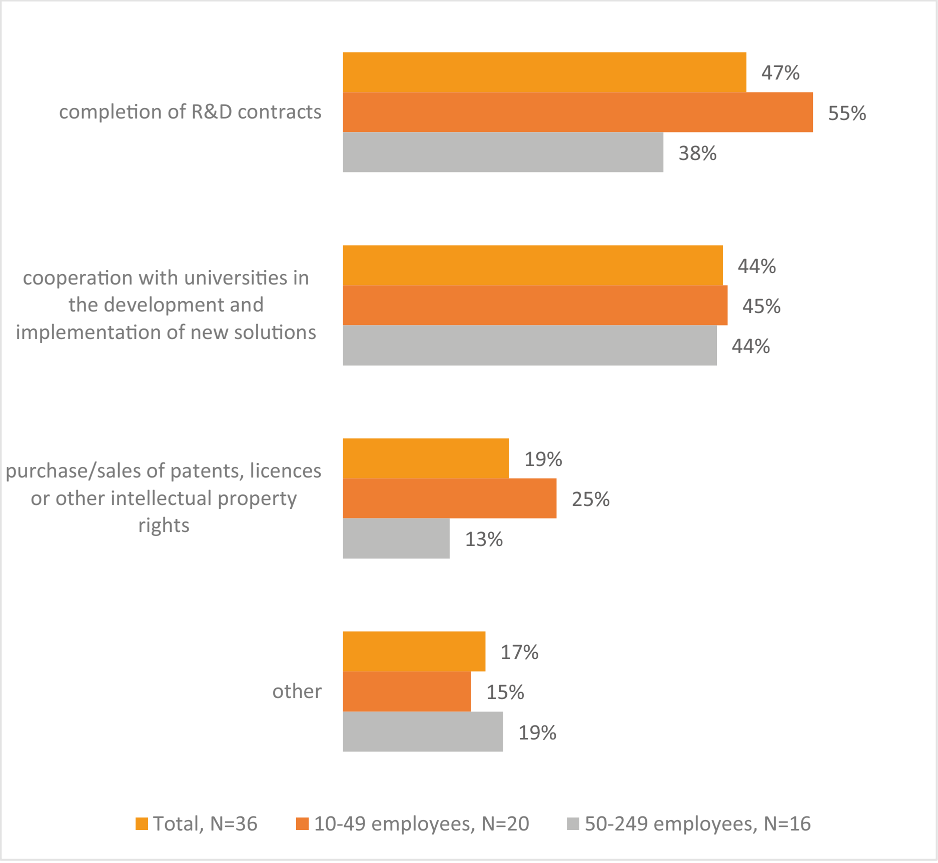
According to the representatives of the surveyed companies, it is most difficult to trust partners when sharing new knowledge and intellectual capital. This was confirmed by 63% of SMEs belonging to the scientific R&D and other professional activity sectors. For the representatives of the printing, publishing and media industries and producers of pharmaceuticals, the issue was discussing problems and risks – 37% and 33%, while for the producers of computers, electronic and optical goods, when developing prototypes, it was 25%.

4.4. Institutional and Managerial Aspects of Open Innovation Collaboration

Companies that carry out at least some of their R&D work externally indicated that the most common ways of conducting this cooperation is the implementation of R&D contracts with other business entities (more often in smaller companies:

55%, relative to bigger companies: 38%) and cooperation with universities (nearly equal numbers for smaller companies and bigger companies). The answer ‘purchase of university spin-offs’ was not indicated. Purchase of patents, licences or other IP rights was more popular among the smaller companies. Due to the small sample size (N = 36), it is not possible to make inferences by industry (Figure 20).

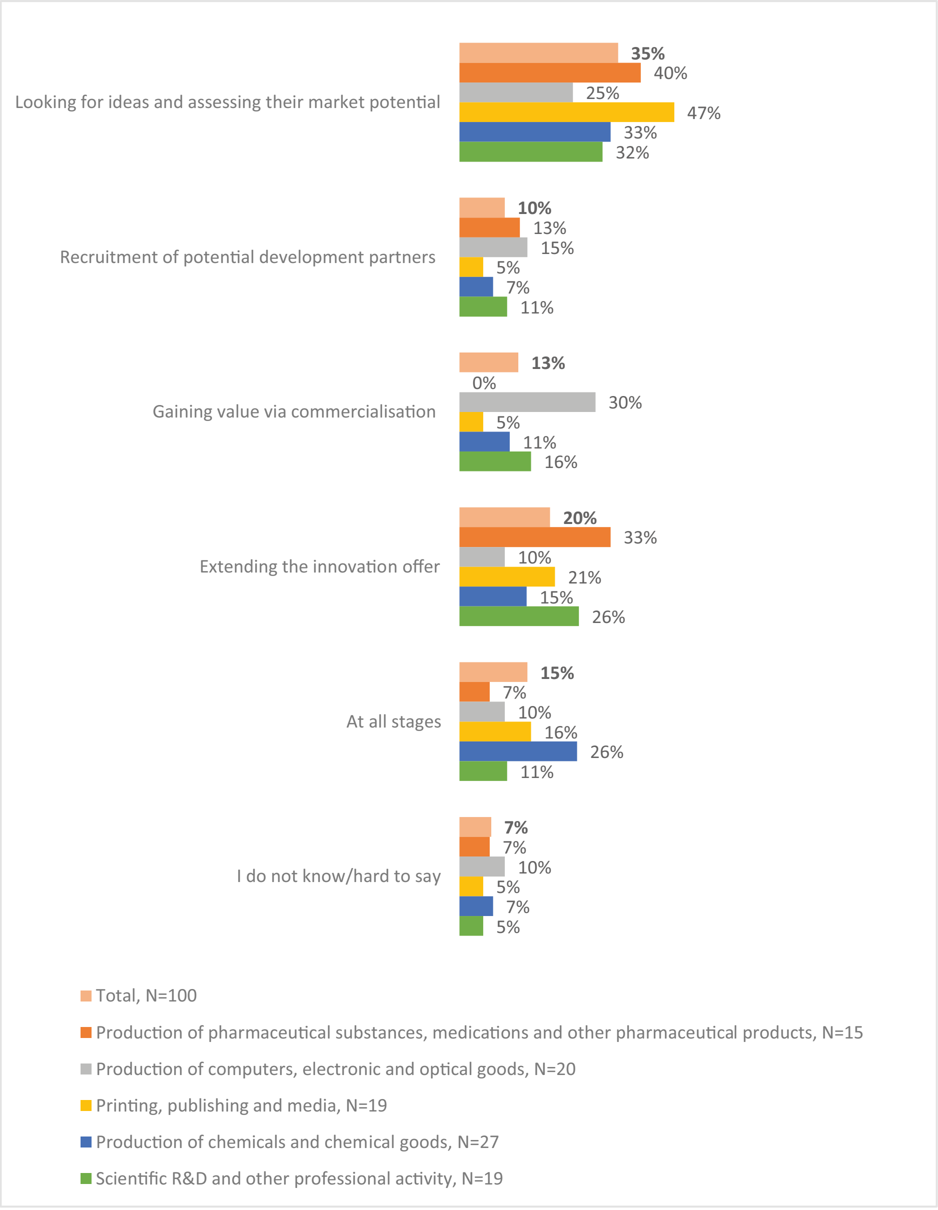
Figure 20. Innovative cooperation model



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

Representatives of the surveyed companies declare that the stage of the innovative process, during which cooperation with partners is most needed, is primarily the initial stage – looking for solutions and assessing their potential. This is especially indicated by the representatives of the printing, publishing and media industries (Figure 21). The representatives of the pharmaceutical industry, apart from the initial stage, also pay attention to the expansion of the innovative offer, while the representatives of the computer, electronics and optical manufacturing industry pay attention to gaining value through commercialisation.

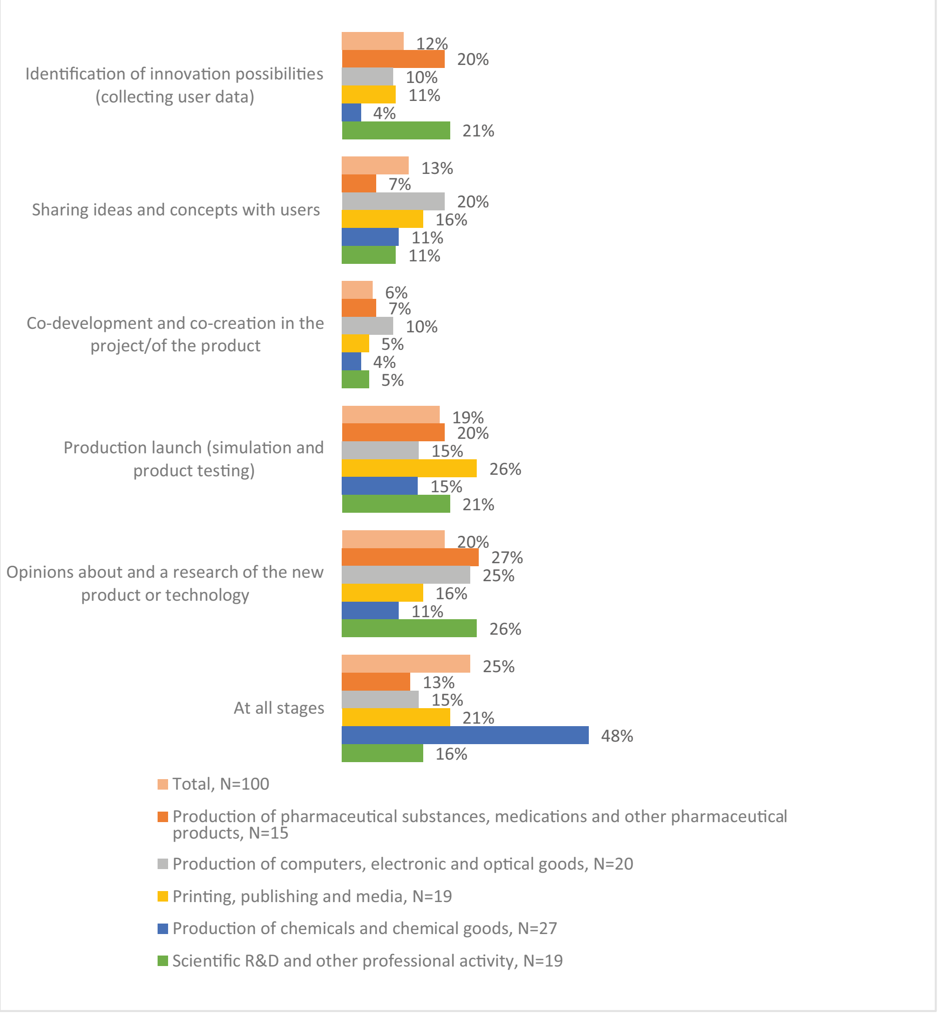
Figure 21. Stages of the innovative process at which cooperation with partners is most necessary



Source: own survey conducted with the assistance of ARC Rynek i Opinia during January–March 2021.

The size of the company differentiates the approach to searching for partners, especially at the stage of searching for ideas and assessing their market potential as well as recruitment of potential development partners. More than 38% and 18%, according to companies, pay attention to this stage. On the other hand, innovative cooperation with partners at the stage of gaining value via commercialisation is more important for smaller companies (16%).

Figure 22. Stage of the innovation process at which the end users' opinions matter the most

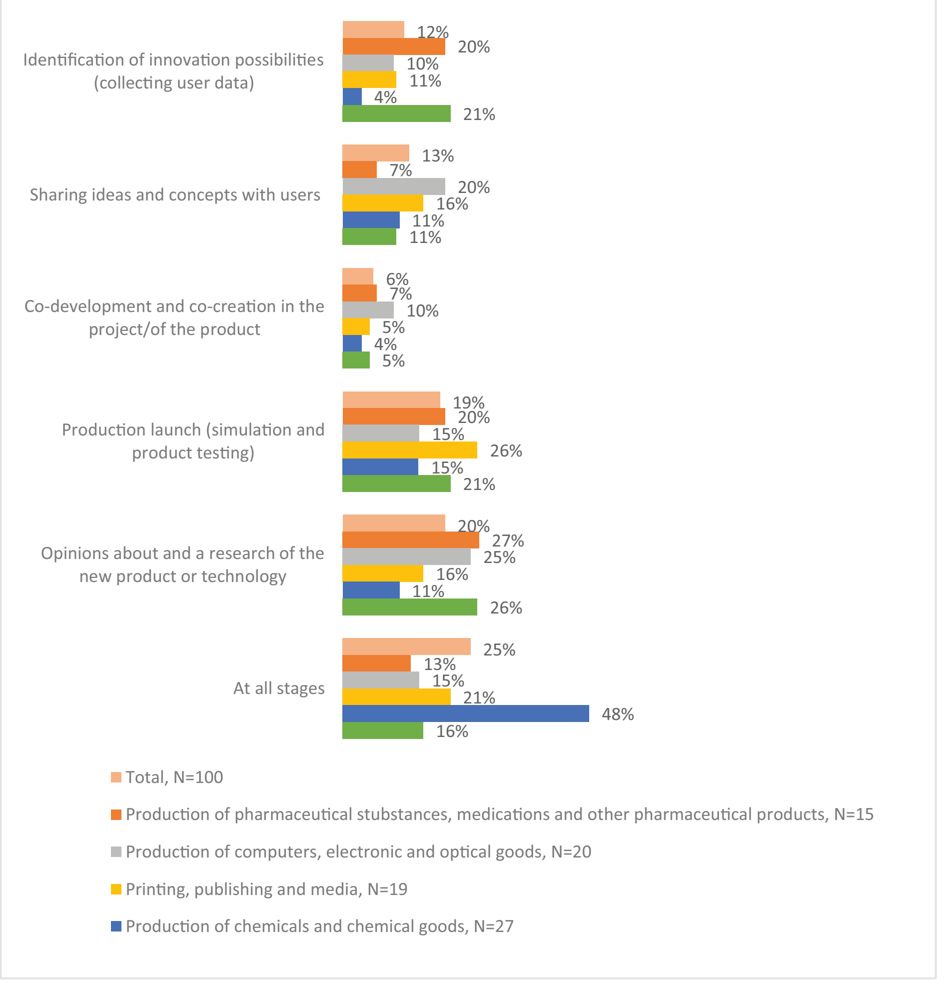


Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

Regardless of the size of the company, representatives of the surveyed companies declare that the importance of the end user's opinion is of key importance in all phases of the innovation process (Figure 22). It is worth emphasising that this answer was not indicated to the respondents as one of the options to choose from – it was selected only when the respondent indicated it spontaneously.

The chemical industry stands out in particular, for which as many as 48% of the representatives declared the importance of the end user (see Figure 23). The opinion of end user is equally important for the Scientific R&D and other professional activity, especially where the user's opinion is relevant both in opinions about research of the new product or technology (26%), followed by the identification of innovation possibilities (collecting user data) – 21% and by production launch (simulation and product testing) – 21%.

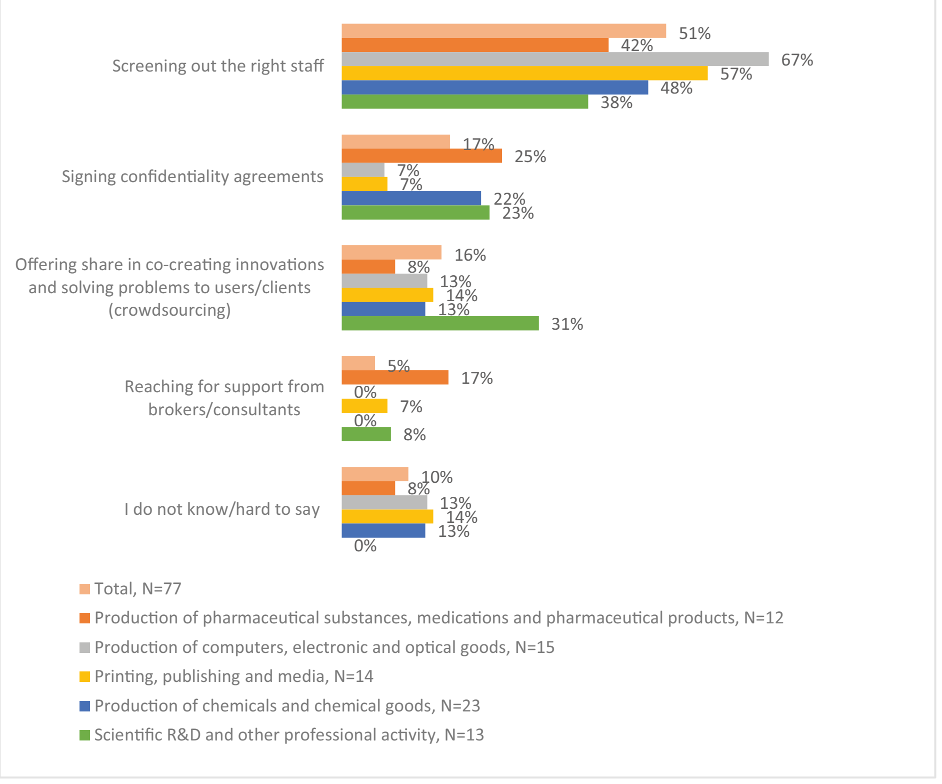
Figure 23. Stage of the innovation process at which the end users' opinions matter the most



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

For the pharmaceutical companies, the end user's opinion was very important when starting the research on a new product or technology (27%), then followed by the production or launch (simulation and product testing) stage (20%), and finally, the during the identification of innovation possibilities (collecting user data) – 20%. The co-creation and co-development of new *value* in the project/of the product (concepts, solutions, products and services) together with end users seem to be the least important stage in the innovation collaboration model.

Figure 24. Approaches to managing cooperation in the innovation process according to companies that do not engage in open innovations



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

The differences between the indications within the remaining industries are insignificant, taking into account the size of the surveyed groups. In general, the opinions of the end users mattered the most during the product launch stage for the big companies and during the early pre-R&D stage of sharing ideas and concepts for smaller companies.

Companies most frequently use their own IT tools to manage cooperation in the innovation process (39%). Some 26% of SMEs were using innovation platforms (e.g. life labs) – engaging all shareholders and some 17% were using of open innovation programmes. Due to the small number of such companies, it is not possible to analyse it by industry or company size.

When asked about the most frequently used approach to managing cooperation in the innovation process according to companies that do not engage in open innovations: 67% of computer, electronics and optical, 57% of printing, publishing and media and 48% of chemical industries representatives declared screening out the right staff (see Figure 24).

The second most popular tool in the case of the pharmaceutical industry (25%), the scientific R&D and professional activity industry (23%) and the chemical industry (22%) was signing confidentiality agreements. Crowdsourcing was only mentioned by the representatives of scientific R&D and professional activity (31%). Reaching for support from brokers and consultants was the least popular tool to manage the innovation cooperation process (with some exception to the pharmaceutical industry amounting to 17%).

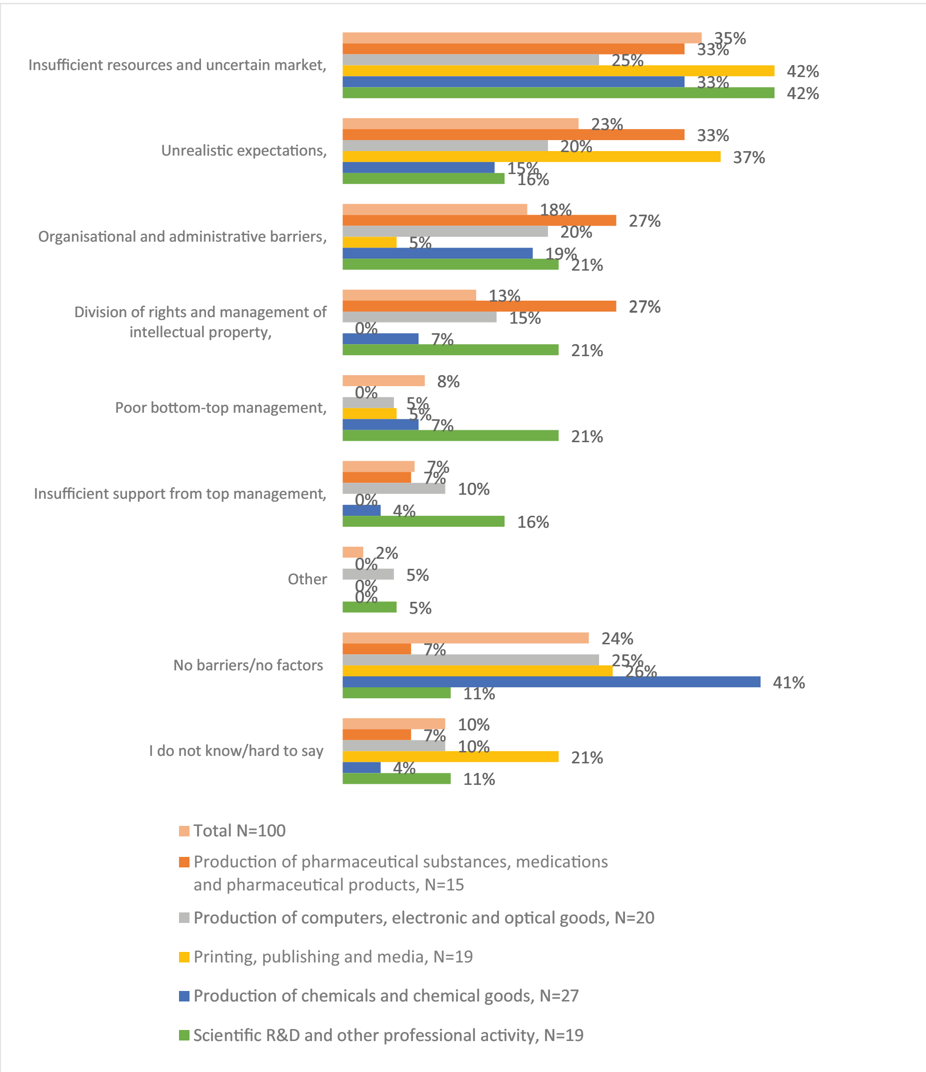
According to companies that do not use open innovation, the most common approach to managing cooperation in the innovation process is thus selecting the right staff. This element is most frequently indicated by large companies (57% compared to 47%). Small companies, in turn, expressed a greater importance of signing of confidentiality agreements.

When asked about potential or current barriers to cooperation with other enterprises, the most frequently indicated factors in case of Production of pharmaceutical substances, medications and pharmaceutical products are insufficient resource and uncertain market (35%), unrealistic expectations (23%) and organisational and administrative barriers (18%). The least significant barrier is the management process in the open innovation collaboration model (see more on specific R&D and knowledge intensive industries in Figure 25). Nearly every fourth representative did not find any difficulty in such collaboration. Compared to smaller companies, the larger ones more often have difficulties resulting from organisational and administrative barriers as well as from the division of rights and IP management.

Spread into specific sectors, representatives of the surveyed companies indicate that the biggest obstacle in the implementation of the open innovation model are, or potentially may be, burdensome bureaucratic procedures. This was especially declared by the representatives of larger companies (50–249 employees), as well as those operating in the pharmaceutical industry and in the scientific R&D and other professional activity sectors. For the pharmaceutical industry, the unrealistic expectation of business partners, division of rights and management of IP as well as organisational and administrative barriers were also significant – 33%, 27% and 27%, accordingly.

Similarly, in the case of scientific R&D and other professional activity, the same categories were notified as real and potential barriers in the (open) innovation co-operation with business partners – 21% in every category. Other obstacles were mentioned much less frequently. On the other hand, no difficulties were mentioned by representatives of the chemical industry more often than by the representatives of other industries.

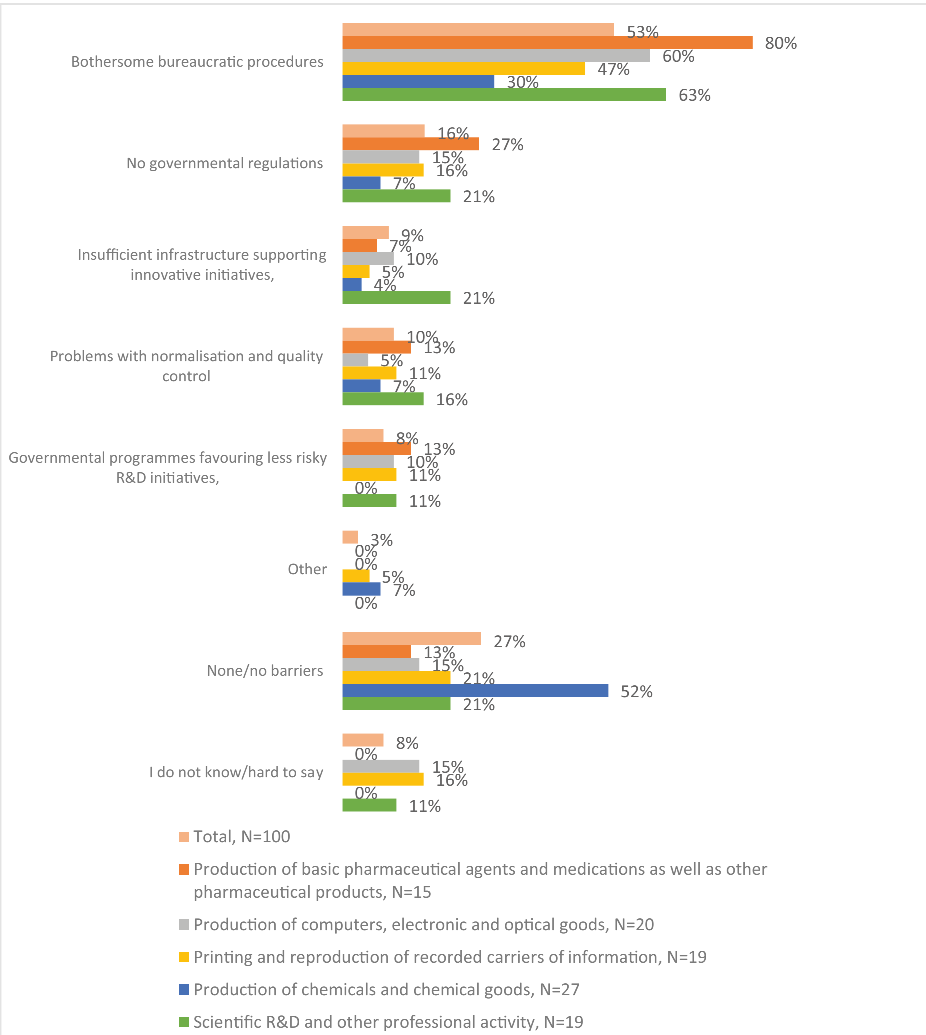
Figure 25. Potential or current barriers to cooperation with other enterprises (split according to sectors)



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

When asked about the institutional and legal barriers to the implementation of open innovations 80% of the pharmaceutical industry, 63% of scientific R&D and other professional activity and 60% of the computer, electronics and optical industry representatives pointed out to the bothersome bureaucratic procedures (Figure 26). Also, 27% of the pharmaceutical industry actors complained about the lack of proper government regulations, where 21% of scientific R&D and other professional activity actors found insufficient infrastructure supporting innovative initiatives.

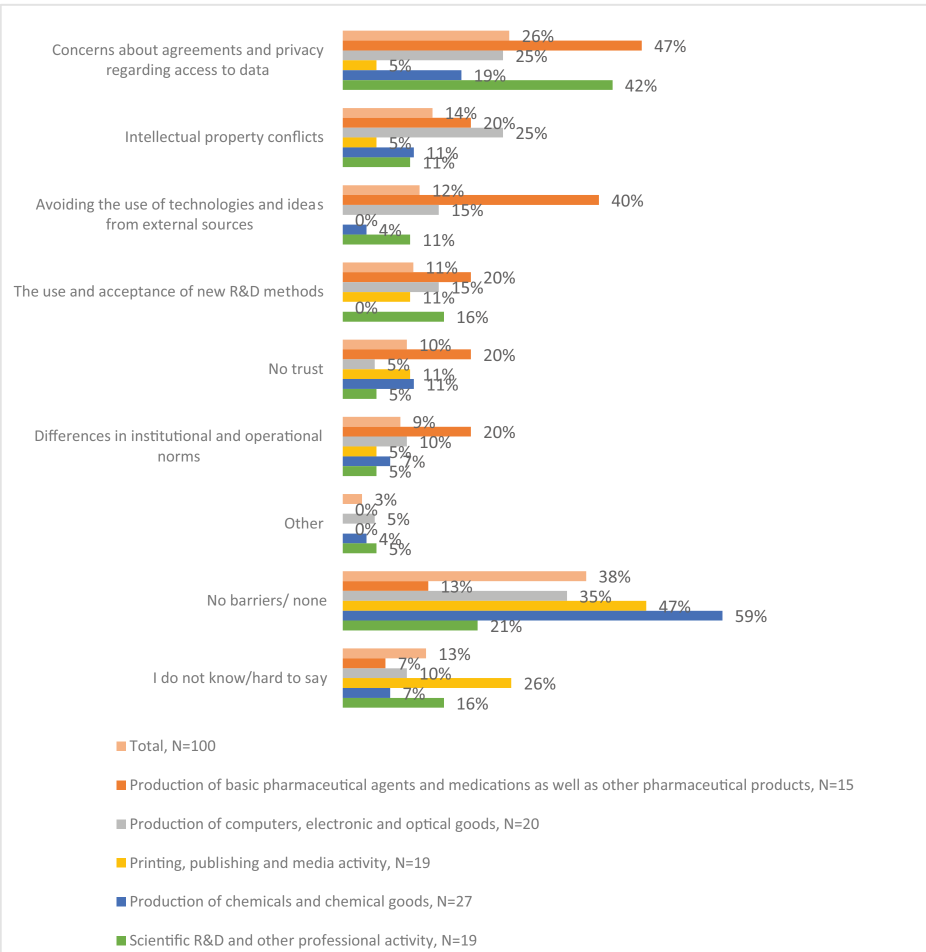
Figure 26. Institutional and legal barriers to the implementation of open innovations



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

When asked about the potential and current barriers in R&D collaboration process with universities, 38% of SMEs did not find any particular barriers (usually smaller companies), while 26% expressed their concerns about agreements and privacy regarding access to data (usually bigger companies), 12% displayed their general sentiment about of the avoidance of using technologies and ideas from external sources (usually bigger companies), 11% indicated general problems in accepting new R&D methods (usually bigger companies), 10% pointed to problems of mutual trust (usually bigger companies) and 9% pointed to differences in institutional and operational norms (Figure 27).

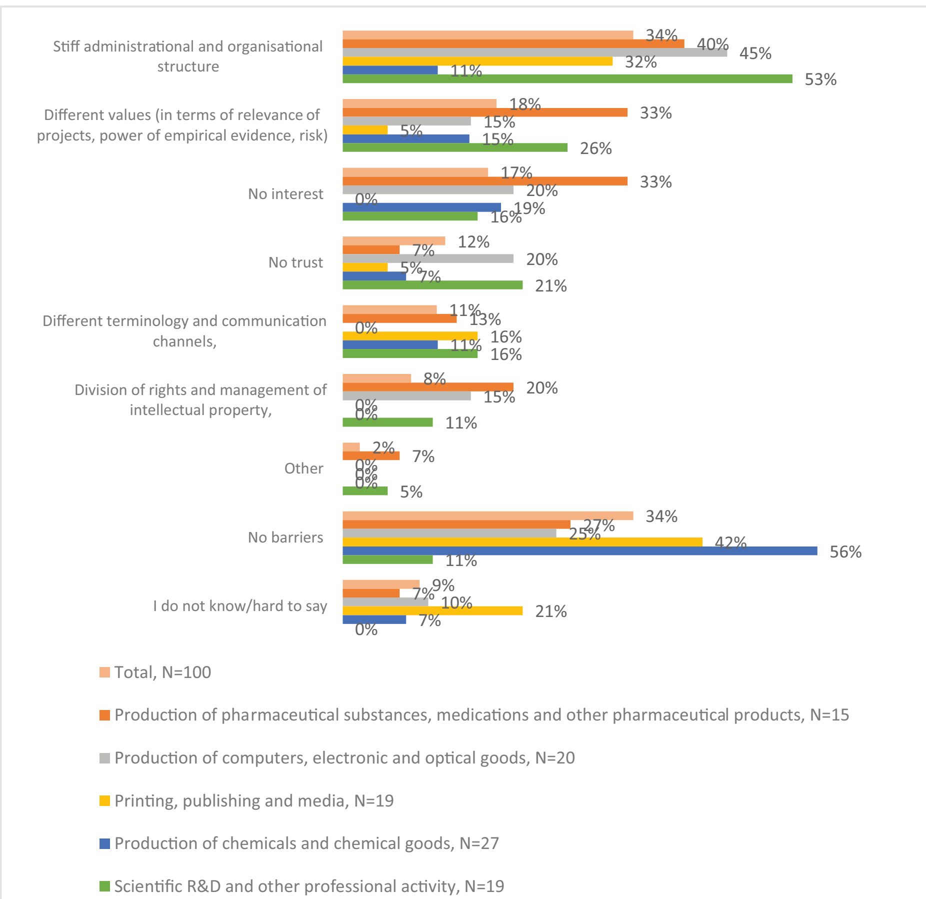
Figure 27. Potential and current barriers to cooperation with universities on the R&D process and testing (split according to sector)



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

Concerns regarding contracts and privacy constitute an obstacle in innovative cooperation with universities at the level of research and development processes and testing (47%), were indicated by representatives of companies belonging to the production of basic pharmaceutical substances as well as drugs and other pharmaceutical products (Figure 27). Another significant barrier for them are concerns about avoiding the use of technology and ideas from external sources (40%), use and acceptance of new R&D methods by university partners (20%), IP conflicts (20%), no trust (20%) and differences in institutional and operational norms (20%). Only in the case of chemicals and computer, electronics and optical industries representatives mentioned no real or potential institutional and legal barriers in the collaborative R&D process with universities (59% and 47% respectively).

Figure 28. Potential and current institutional and legal barriers to cooperation with universities (split according to sector)



Source: own survey conducted with the assistance of ARC Rynek i Opinia in January–March 2021.

When asked what factors hinder innovative cooperation with universities on the R&D or innovation project management level 34% of all respondents mentioned the stiff administrative and organisational structure of universities (more often in bigger companies: 41%), 18% emphasised different values in terms of relevance of projects (more often in bigger companies: 26%), risk or the power of empirical evidence), whereas 17% found no general interest on the universities' part. Only 12% of the respondents considered trust as a barrier in the efficient R&D and innovation project management (more often in bigger companies: 21%) (Figure 28).

Representatives of the surveyed companies indicate that the greatest difficulty (or potentially difficulty) in innovative cooperation with universities at the project management level is a rigid administrative and organisational structure. All of the above-mentioned difficulties affect larger companies to a greater extent.

Summary and Conclusion

The dominant model of conducting innovative activities in the Polish high-tech and knowledge-intensive SMEs were internal activities (about 2/3 of the surveyed companies), most frequently carried out as the only form of this type of activity. About 1/5 of the surveyed companies decide to use the mixed model, combining internal and external activities, and only external activities are rare. At the same time, internal activities moderately meet the needs of companies – the average rating of the level to which they meet the needs oscillates (depending on the sector) within 5–7 points on a 10-point scale. Due to the lower popularity of externally conducting innovative works, the idea of open innovations is also not popular – though in the group of companies that innovate in the at least partially external model, a slight advantage of companies using open innovations over those rejecting this model can be observed. It is worth noting that the concept of open innovations is attractive – half of the surveyed companies plan to implement them in the future. The dominant view is that physical proximity has a positive effect on the development of innovative interactions. Among companies that conduct innovative cooperation, the basic form of cooperation is the implementation of R&D contracts, although cooperation with universities is also popular. The key stage of the innovation process, during which cooperation with partners is needed, is primarily its beginning – looking for ideas and assessing their market potential. The opinion of the product user is key and, according to the representatives of the surveyed forms, should be taken into account at the final stage or at all stages of the process. In the innovation process, companies most frequently use their own IT tools – the use of open-source programmes or innovation platforms is less popular. The key and most frequently used approach to managing cooperation in the process of open innovation is selecting the appropriate staff. According to the companies that use it, the main perceived benefits of innovative cooperation are collaborative learning and lower costs of the entire process. Companies that do not engage in such processes mention the improvement in the quality of products and services as the main benefit.

Final conclusions and implications

Poland has high innovative and technological potential, with its rich human capital and long-term scientific traditions, sound macroeconomic framework and the effective absorption of EU funds. Nonetheless there are some important changes that must be introduced to strengthen the excellence of its R&D and innovation efforts. The current and the past innovation policies stem from the logic of a closed innovation mindset. Yet, the rise of interdisciplinary nature of science, and technological convergence, driven by i.e. IT technologies, artificial intelligence and automation, as well as the growing importance of innovation as a factor of competitiveness, and more recent complex socio-economic changes caused by global socio-demographic turbulences, such as the Covid-19 pandemic, indicate that the current innovation model is no longer appropriate to meet the needs of the knowledge and innovation-driven economy in the 21st century. 'Open innovation model' can make it possible for SMEs to adapt and thrive in the current competitive and turbulent environment. It also allows to overcome the limitations relative to their high technological dynamics (especially in such industries as Pharmaceutics, Media or IT). By applying open innovation model, SMEs will be able to compensate for their lack of limited internal R&D resources and competencies, by using external resources to develop new technologies and take advantage of market opportunities. External knowledge sourcing can allow SMEs to accelerate their internal innovation process and fill technology gaps existing internally. This approach can benefit the innovative performance of SMEs by allowing to increase their innovativeness and competitiveness, through development and increase of the effectiveness of their new and complex products.

Using the innovative potential of the Polish high-tech and knowledge-intensive sector requires parallel actions – breaking the awareness barriers clearly visible in SMEs, i.e. underestimating or misunderstanding the role and importance of open innovations in their business activities, including their impact on the competitiveness and further development of the enterprise; perception of "open innovation" not as a threat, but as an opportunity and possibilities to improve structures that increase the effectiveness of resource management processes – knowledge and technology. This requires convincing SMEs that broadly understood "open" innovative cooperation is an important condition for their functioning and competing in a complex environment. Seemingly everyone understands and accepts it. However, economic practice proves that SMEs are dominated by a "closed" innovation strategy for the development of companies. Therefore, the first important recommendation is to support the **breaking the "barrier" of knowledge on open innovation models.** The study also proved that the level of knowledge of the issue of 'open innovation' among SMEs executives is insufficient. Therefore, specific support is needed, in the form of appropriate guides or the organization of consultancy activities, in terms of open innovative cooperation, in particular with the academic sector, non-profit organizations, users, etc.

Furthermore, the study has revealed companies that implemented the open innovation model in collaboration with universities, the biggest obstacle in its implementation were burdensome bureaucratic procedures and cultural distance. In turn, for companies that do not used this model, it has been the most important obstacle of the potential implementation of such model. Polish higher education has changed fundamentally since early transition period. These changes have been noticeable in the both higher students participation rate, quality of teaching and research, institutional autonomy and academic freedom, new competitive research funding regimes as well as in its full integration with EU economies. Yet, many public universities system is still bureaucratic and controlled from the top down, making system less flexible and responsive to companies demand. The problem of rigid administrative and organizational structure, insufficient resources of universities as well as the concerns about privacy and IP protection hinder innovative cooperation between the companies and universities. **The clear IP patterns (considering the needs of all parties), well-established procedures and mutual benefit assessment tools of open innovation collaboration** would help all the partners – university and business – perceive 'open innovation' as a 'win-win' game.

The study showed that Polish larger SMEs companies were more involved in open innovation activities, and therefore expressed more often general attitude towards opening up the innovation process. Smaller companies were in particularly concerned about the risks of collaboration in open innovation model. They expressed more often fears of losing their core skills, experience, and knowledge that consist the basis of their competitiveness. These companies are at their early growth stage in the highly competitive and fast growing high-tech and knowledge-intensive fields. Their major challenge relates to the needs of a large amount of capital investments in supplying the latest technology, equipment, as well as other fixed costs. No wonder, over half of them (mostly small companies) indicated the reduction in the costs of technology development or market entry are the main benefits of engaging in innovative cooperation for the smaller SMEs. Thus, government support should **focus on the early stages of the innovation networks formation**

and operation in order to raise awareness about opportunities and benefits of open innovation and facilitate the search for partners.

The study also showed that Polish SMEs have greater difficulty in developing mechanisms capable of effectively implementing open innovation due to lack of resources and skills to develop a culture of open innovation. It also revealed the cultural barriers that emerged from the collaborative participation of a large number of diversified players, especially from various institutions – academia and business. Therefore, in order to develop open innovation environment in Polish SMEs **trust build on effective communication is crucial**.

The study`s findings somewhat differ from the results of past studies on a broader group of companies in the high-tech industries, which assumed that the geographical neighbourhood (proximity) strongly influences the innovation and R&D activity. Rather, it supports the idea that the innovative interlinkages in the knowledge intensive SMEs has more individual character and may be determined by their specific subject fields, and their technological profiles. Thus, in case of the Polish high-tech and knowledge-intensive SMEs knowledge intensive SMEs geographical proximity and the development of cluster initiatives are not the prerequisites for the innovation collaboration. This is also shown in the assessment of strengths and weaknesses of the Polish clusters in the Report on *Benchmarking of clusters in Poland* (PARP 2020). It means that in order to increase the efficiency of public innovation (territorial) policies, in moderating the nature and dynamics of interactions within the Polish high-tech sector, **cluster initiatives must consider other than just geographical proximities, i.e. social, organizational, institutional proximities.**

Moreover, the innovation policy has to consider the nature, dynamics, specific needs and challenges of each industry, and its SMEs environment. Public and other non-profit institutions **should be more active in brokering, encouraging and reinforcing such innovation collaboration at local, regional and global levels**.

Last but not least, innovation policies should focus on eliminating more general barriers to collaborative environment, investing into building social capital, social trust and open innovative culture. **Innovation policies should be built on long-term vision and draw its origin back at the stage of secondary education**. Building a knowledge-based economy requires the activation of society's openness to the creation, adoption and diffusion of innovations, as well as an educational system enabling to strengthen 'social trust' and 'creativity'.

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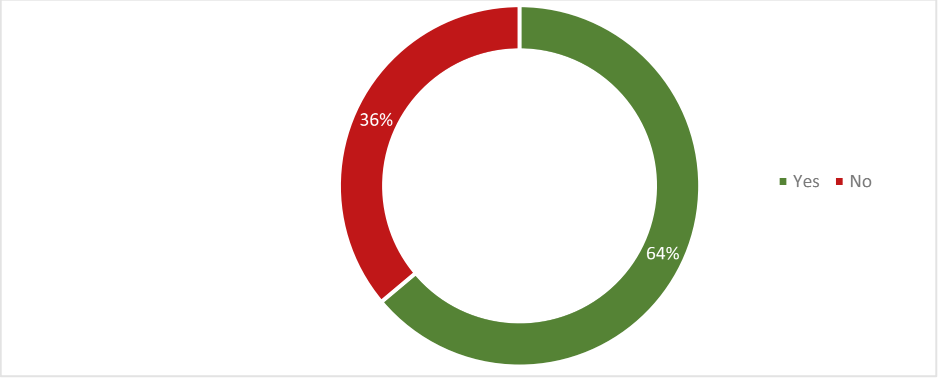
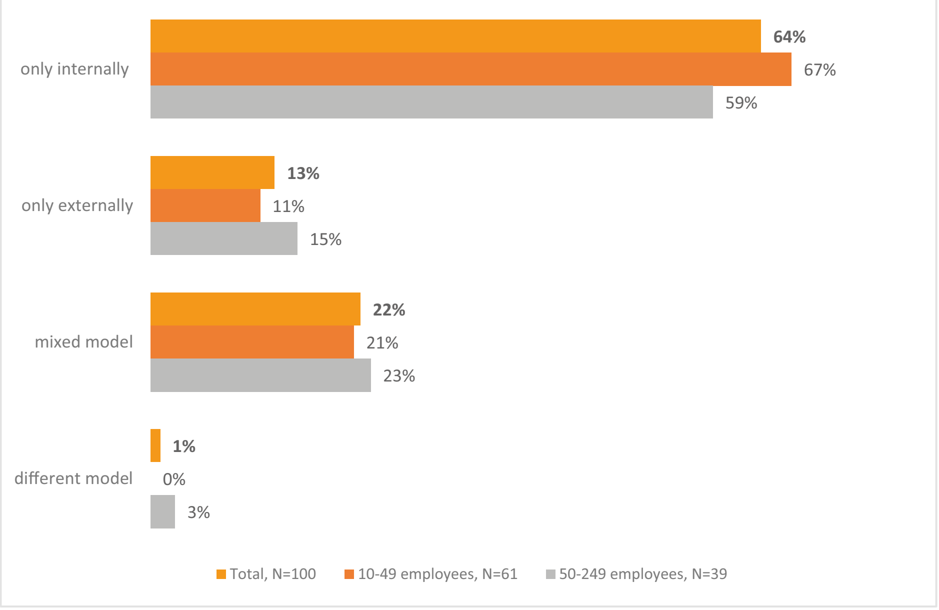
Annex 1.

Figure 1. Open innovation in Polish knowledge and R&D intensive SMEs



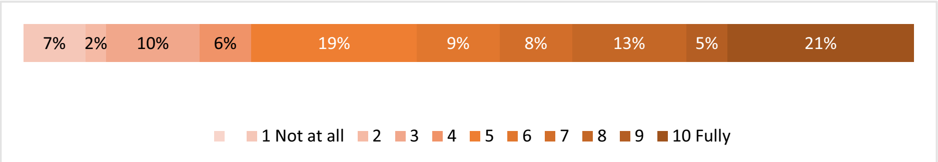
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 2. Method of conducting research and development activity (division according to the size of the company)



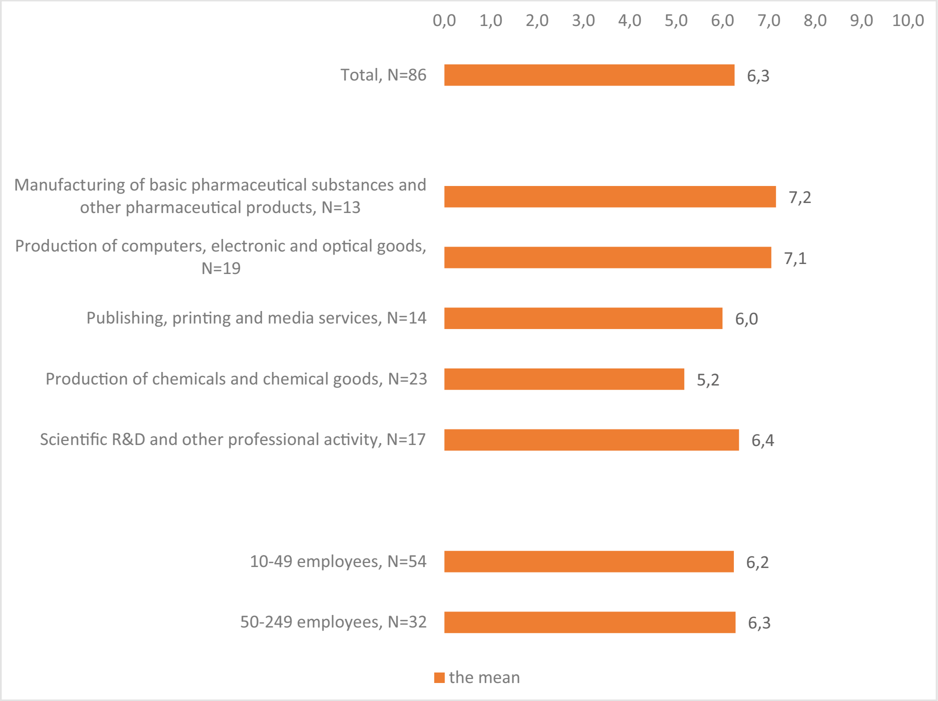
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 3. Extent to which needs for innovations are satisfied by internal activities



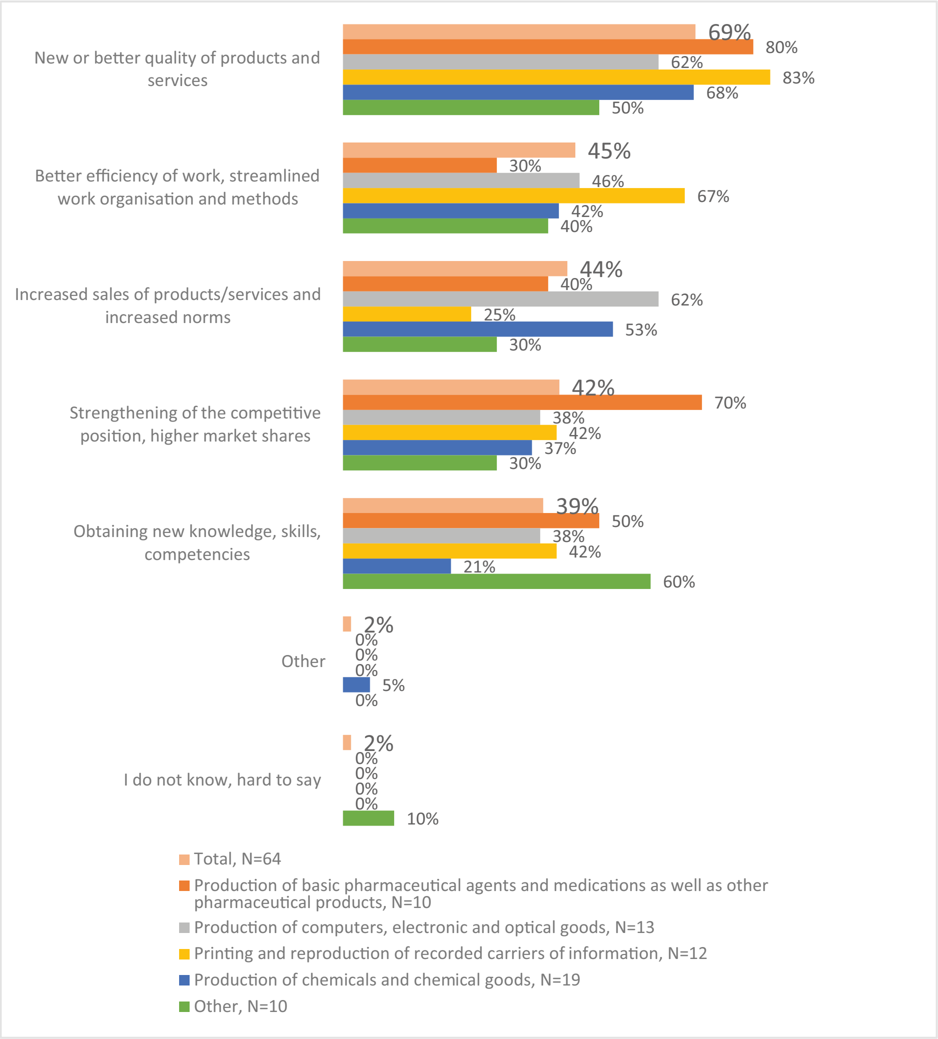
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 4. Extent to which needs for innovations are satisfied by internal activities – the means



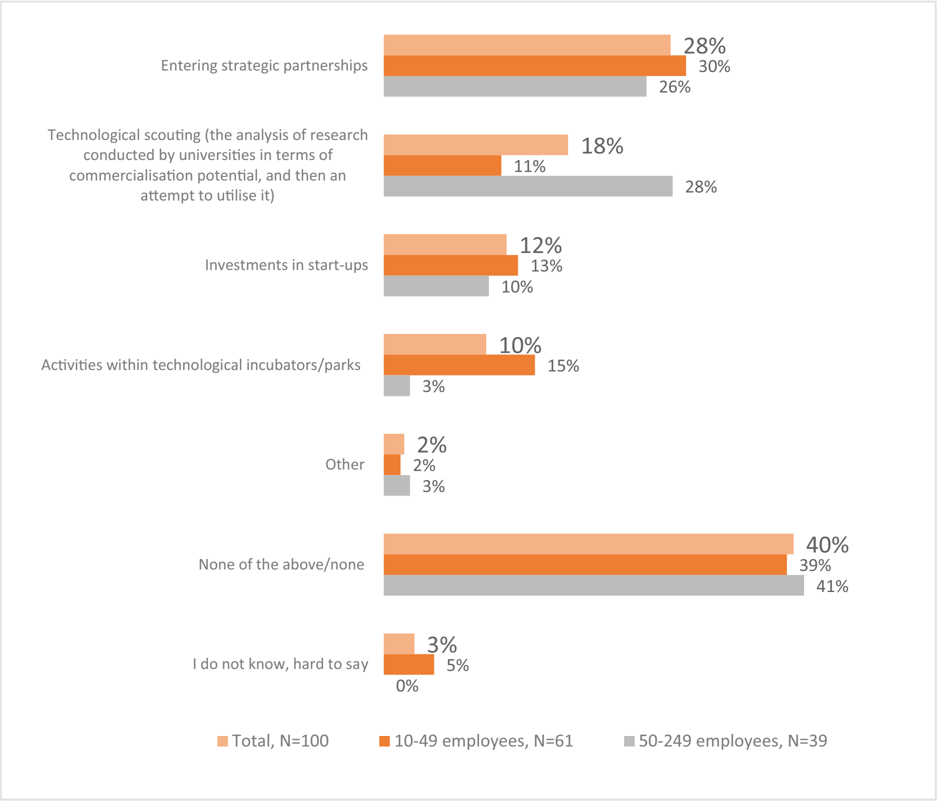
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 5. Potential benefits of engaging in open innovation processes by companies not presently involved in open innovation activity



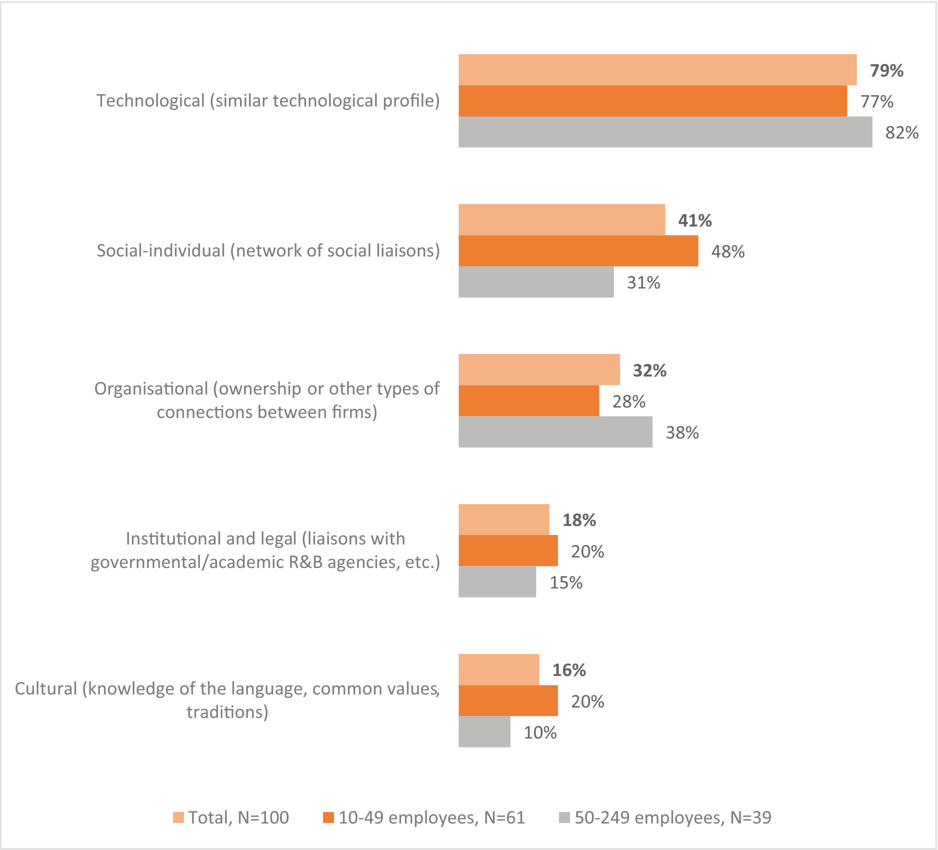
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 6. Activities taken up to obtain external knowledge



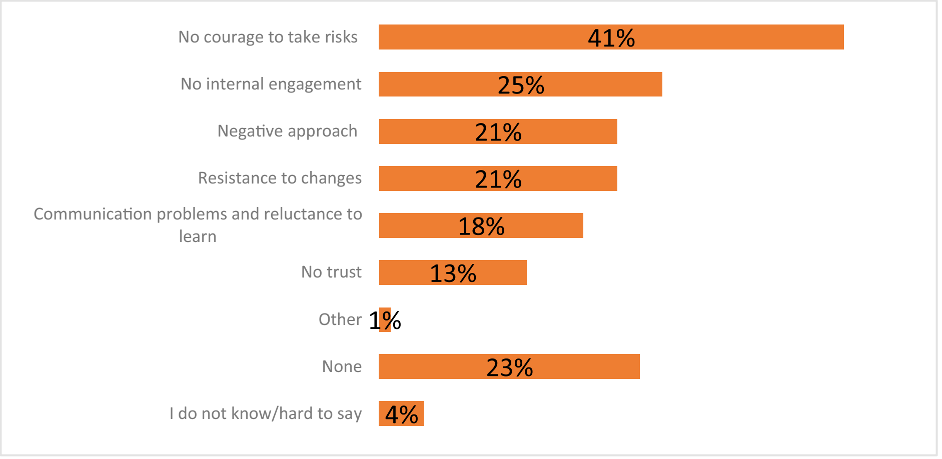
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 7. Factors affecting the choice of innovative partners



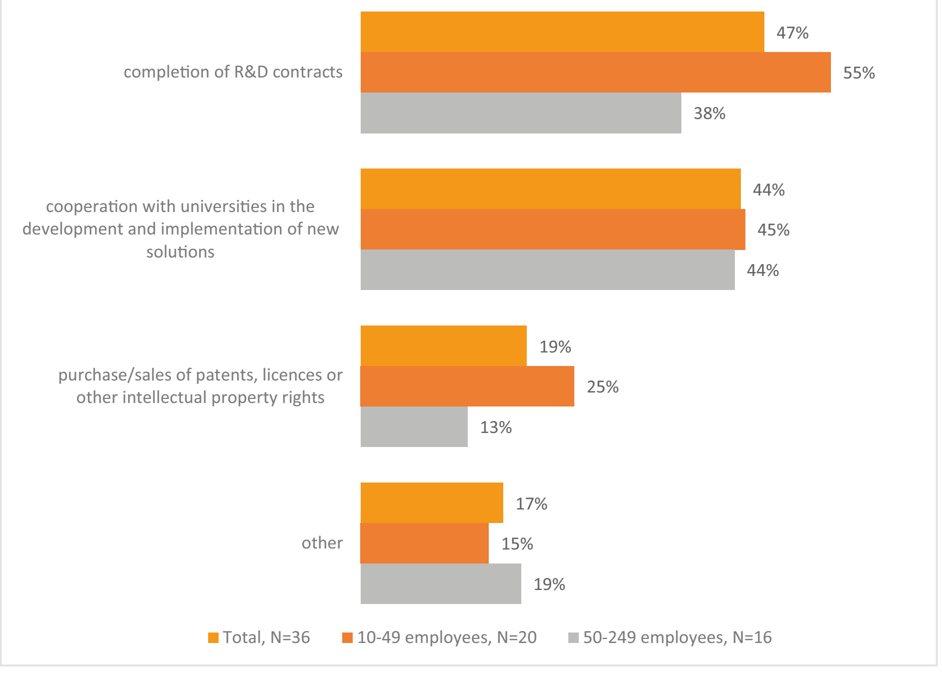
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 8. Personality traits hindering innovative cooperation



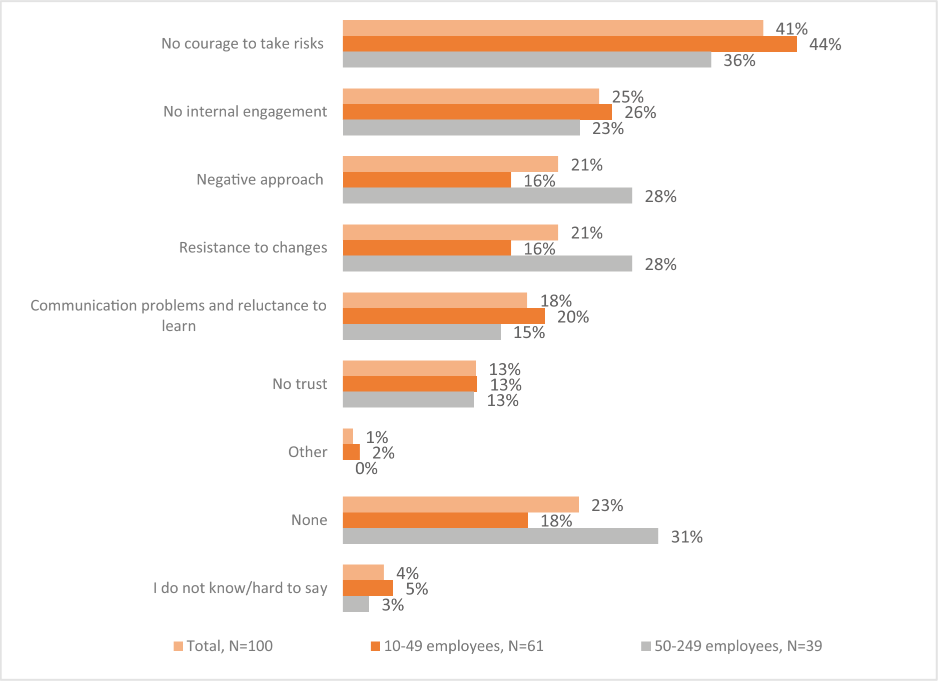
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January-March, 2021.

Figure 9. Innovative cooperation model



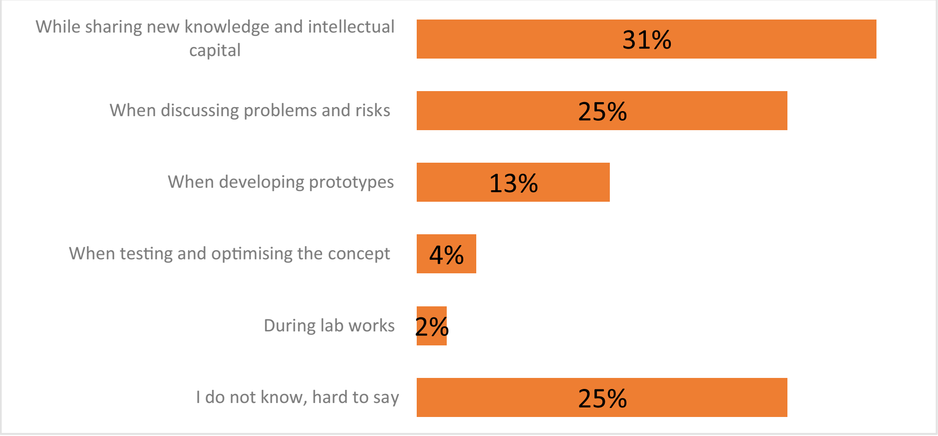
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January-March, 2021.

Figure 10. Personality traits hindering innovative cooperation (split according to company size)



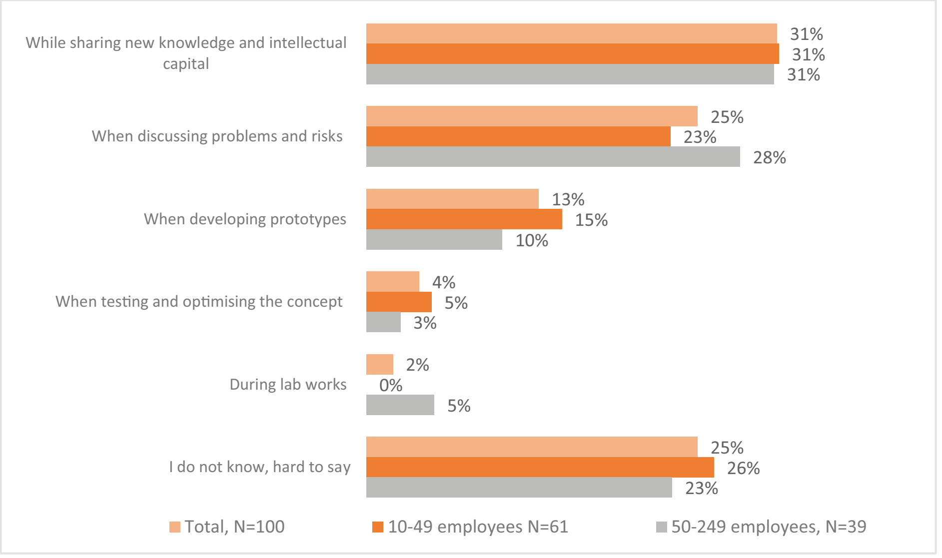
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 11. Activities in which it is most difficult to trust partners



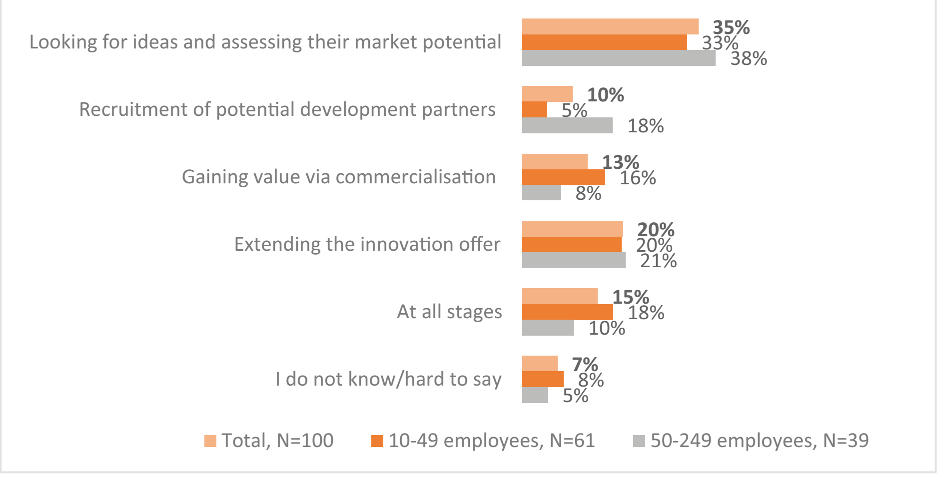
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 12. Activities in which it is most difficult to trust partners (split acc. to company size)



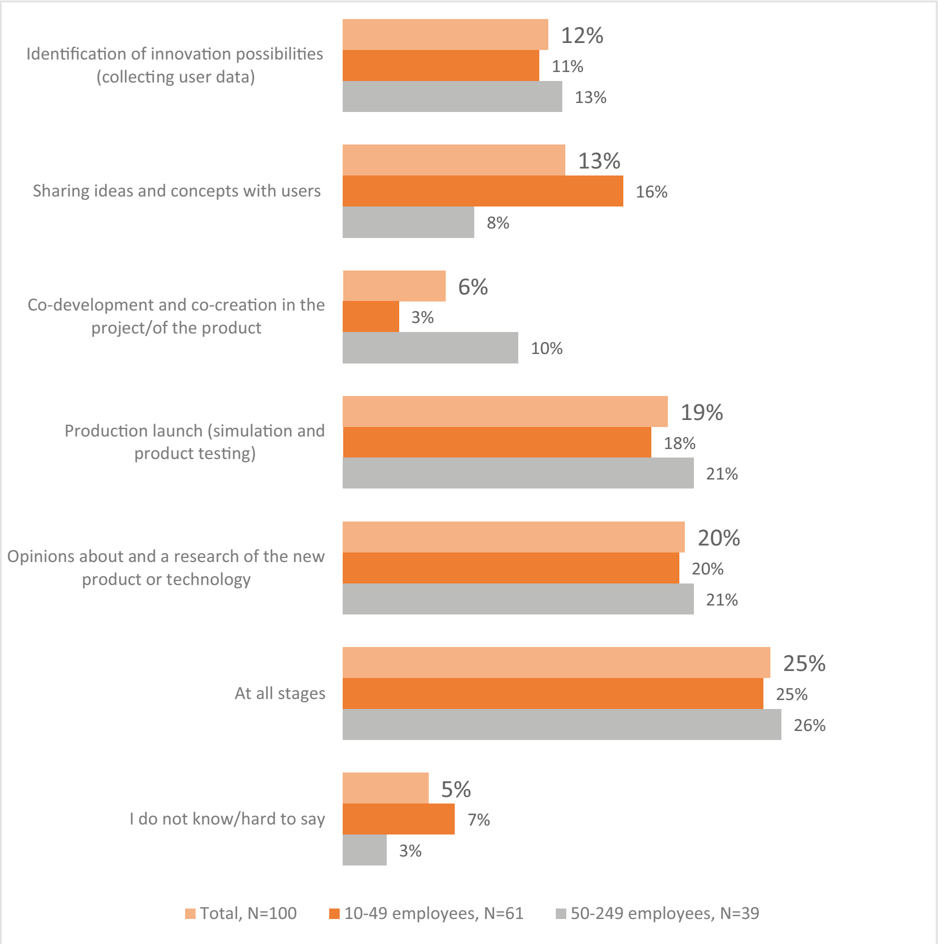
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 13. Stages of the innovative process at which cooperation with partners is most needed



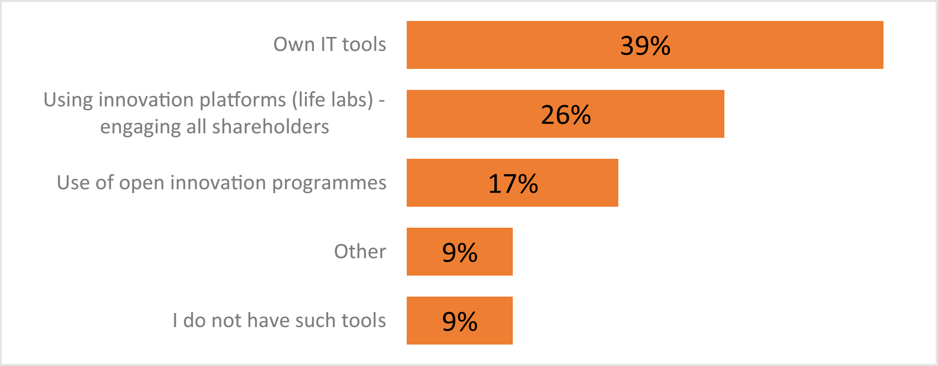
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 14. Stage of the innovation process at which the end-users' opinion matters the most



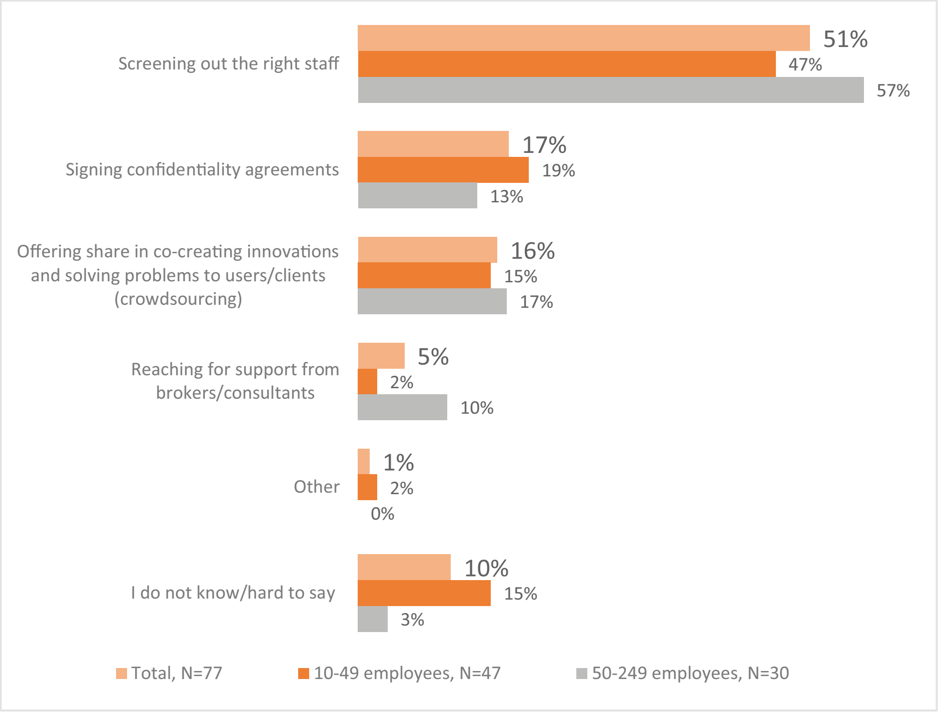
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 15. Tools to manage cooperation in the innovation process



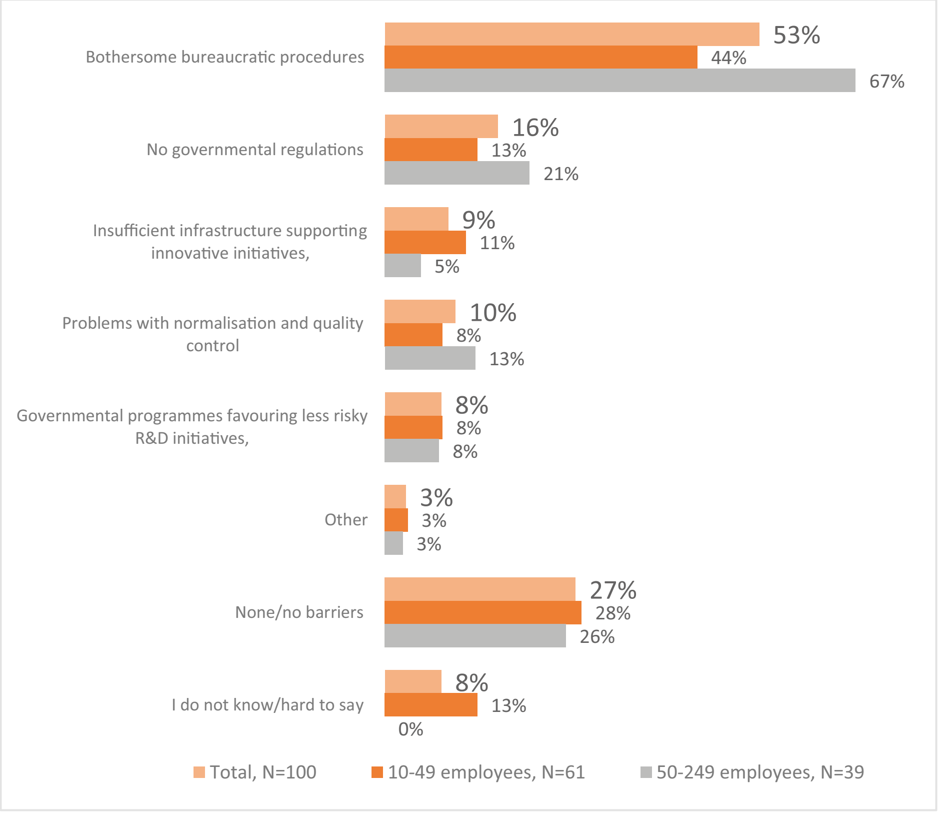
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 16. Approaches to managing cooperation in the innovation process according to companies that do not engage in open innovations



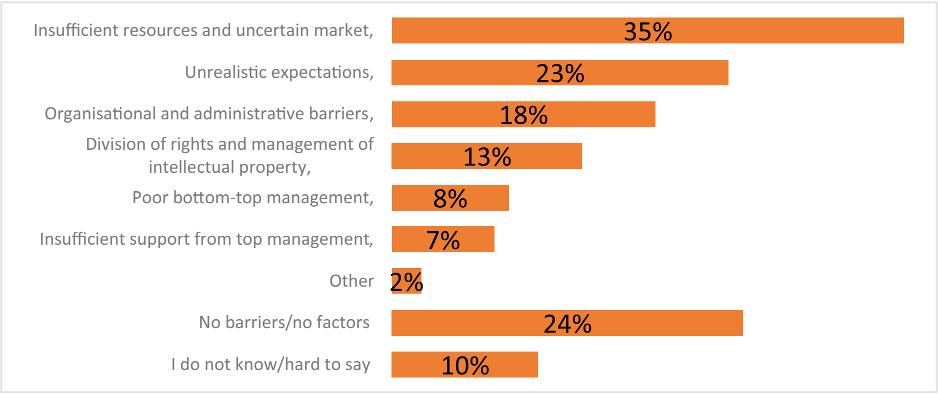
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 17. Institutional and legal barriers to the implementation of open innovations



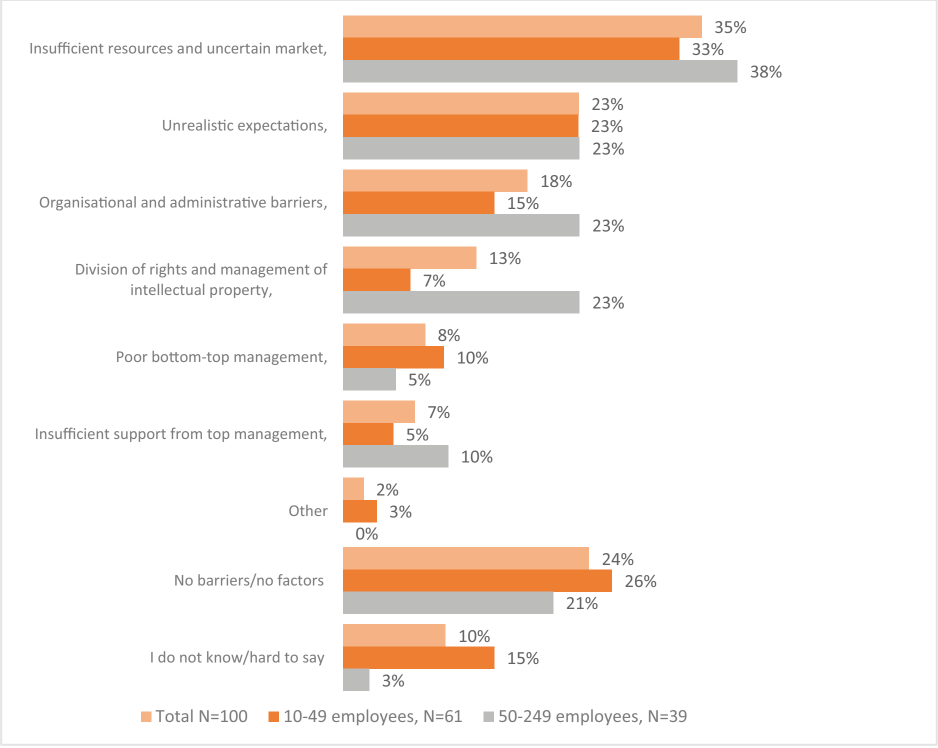
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 18. Potential or current barriers to cooperation with other enterprises



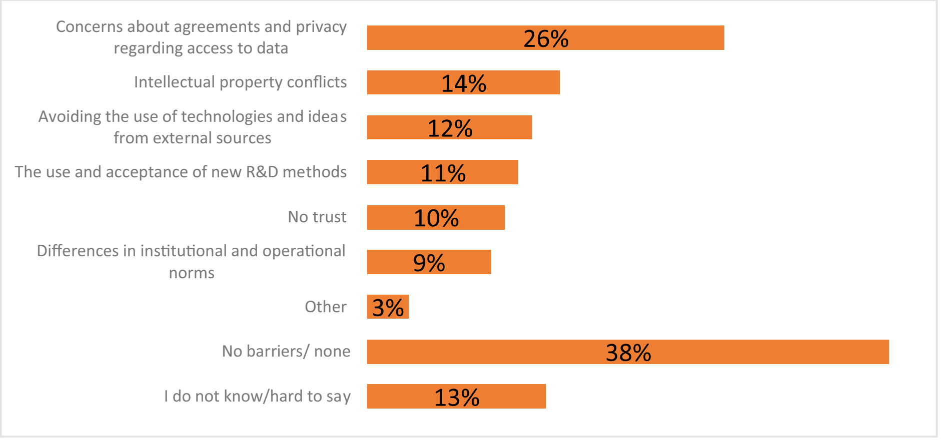
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 19. Potential or current barriers to cooperation with other enterprises (split acc. to company size)



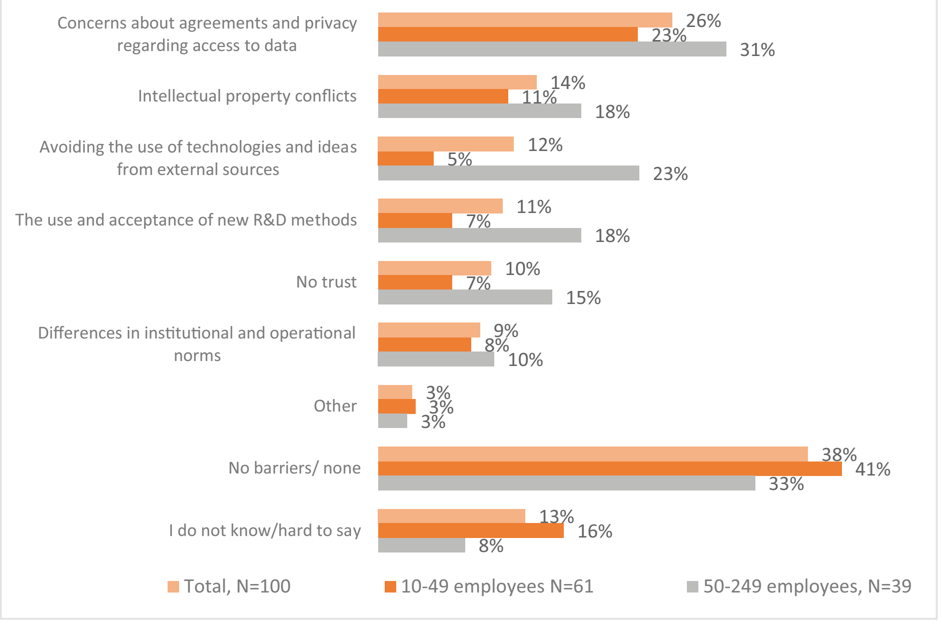
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 20. Potential and current barriers to cooperation with universities on the process level



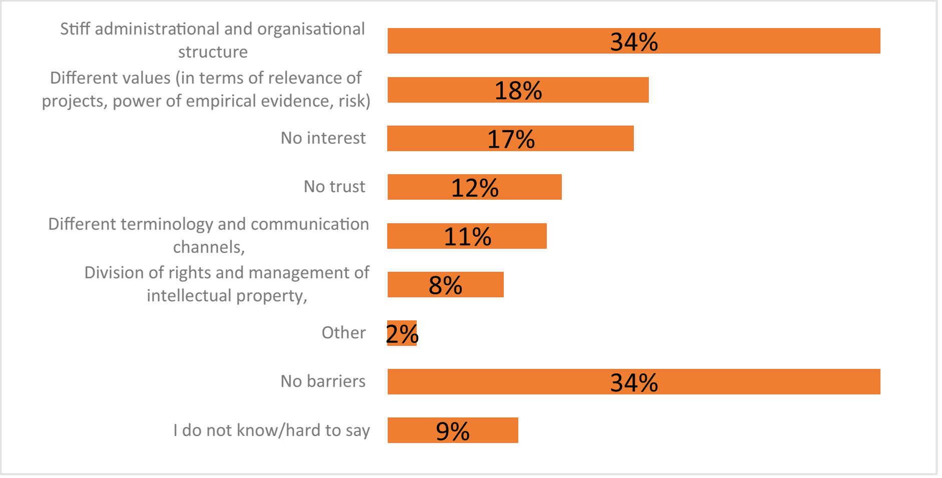
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 21. Potential and current barriers to cooperation with universities on the process level (split according to company size)



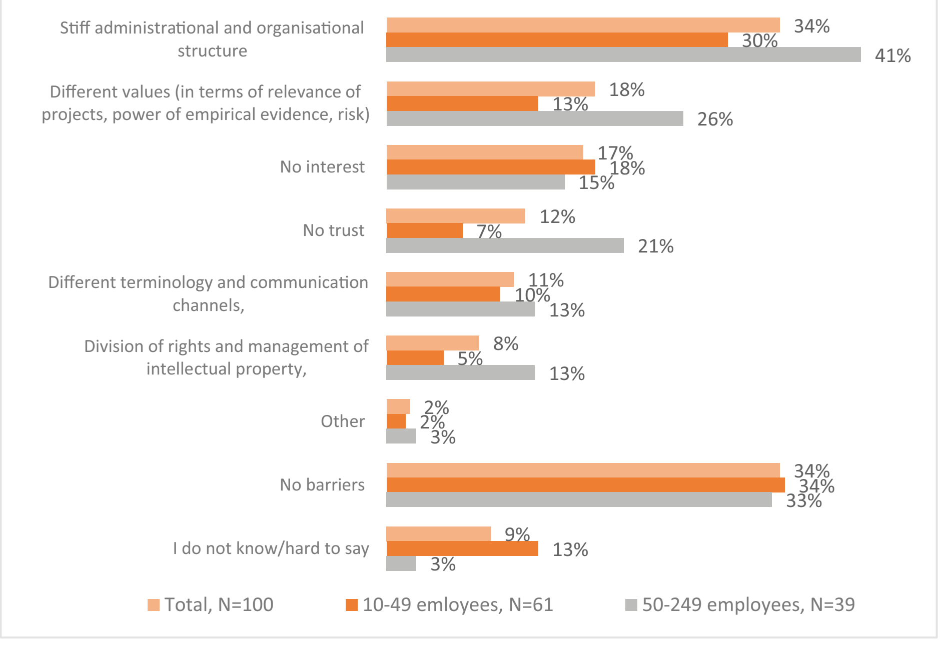
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 22. Potential and current institutional and legal barriers to cooperation with universities



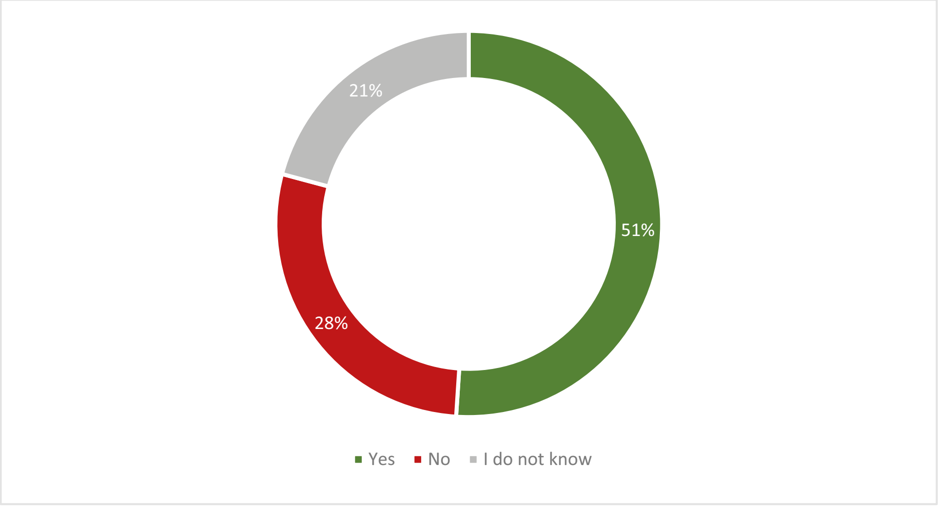
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 23. Potential and current institutional and legal barriers to cooperation with universities (split according to company size)



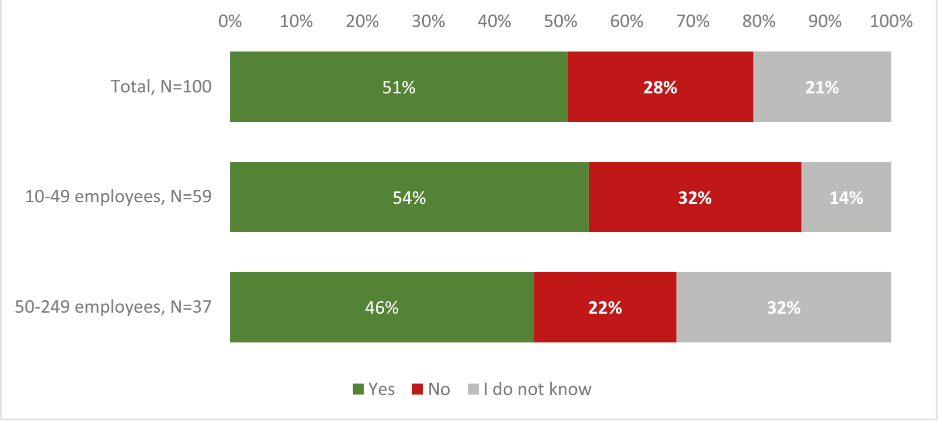
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 24. Plans on open innovative activities



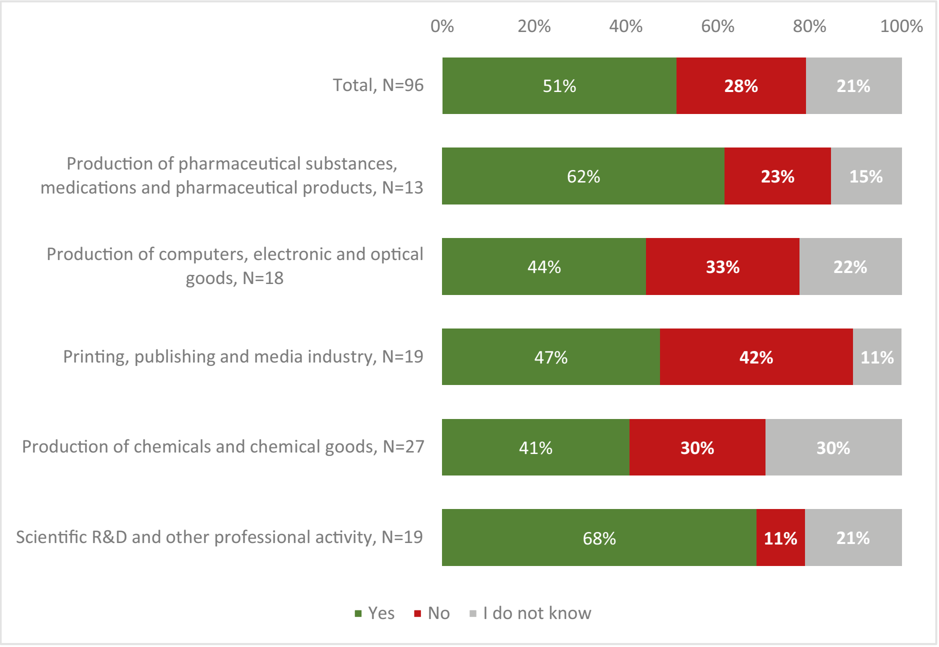
Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 25. Plans on open innovative activities (split according to company size)



Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Figure 26. Plans on open innovative activities (split according to sector)



Source: author`s survey conducted with the assistance of ARC Rynek i Opinia during January--March, 2021.

Annex 2.

Survey questions:

1) How do you conduct R&D activities?
   a. Only internally (we have dedicated staff/research center for this)
   b. Only externally (we outsource subcontracting to R&D units of the university)
   c. We subcontract only externally to other companies
   d. We outsource part of our R&D to companies and universities.
2) Extent to which needs for innovations are satisfied by internal activities, scale 1–10?
3) What is the best level of physical proximity initiating innovative interactions?
   a. province/city
   b. country
   c. within EU/Europe
   d. on the global level (Asia, USA, etc.)
3) What factors are important when selecting partners for innovative cooperation (from the most important ones)?
   a. Geographical (geographical proximity)
   b. Organizational (ownership or other ties between companies)
   c. Technological (similar technological profile)
   d. Socio-individual (network of friendly contacts)
   e. Cultural (knowledge of the language, common values, traditions)
   f. Institutional and legal (links with government R&D/academic/etc. agencies)
4) How do you conduct open innovation cooperation?
   a. purchase/acquisition of patents, licenses or other intellectual property rights,
   b. granting/selling patents, licenses or other intellectual property rights,
   c. implementation of R&D contracts,
   d. cooperation with universities in introducing and implementing new solutions,
   e. purchase of university spin-offs,
   f. we do not conduct open innovative cooperation.
5) At what stage of the innovation process cooperation with partners is most needed?
   a. Looking for ideas and assessing their market potential
   b. Recruitment of potential development partners
   c. Gaining value via commercialization
   d. Extending the innovation offer
   e. At all stages

6) At what stage does user feedback play a role in the innovation process?
   a. Identification of innovation possibilities (collecting user data)
   b. Sharing ideas and concepts with users
   c. Co-development and co-creation in the project/of the product
   d. Production launch (simulation and product testing)
   e. Opinions about and a research of the new product or technology
   f. At all stages
7) What is the approach used to manage cooperation in the (open) innovation process?
   a. Screening out the right staff
   b. Signing confidentiality agreements
   c. Offering share in co-creating innovations and solving problems to users/clients (crowdsourcing)
   d. Reaching for support from brokers/consultants
   e. Other
8) What are the tools to manage cooperation in the innovation process?
   a. Own IT tools
   b. Using innovation platforms (life labs) – engaging all shareholders
   c. Use of open innovation programs
   d. Other
   e. Do not have such tools
9) what are the key benefits of engaging in open or closed innovative processes?
   a. Shared learning process and access to new/complementary knowledge
   b. Reducing the cost of technology development and market entrance
   c. Acceleration of the commercialization process – market launch of new products
   d. Reduced risk related to the development of new technology and entering new markets
   e. Achieving benefits of scale, specifically in production
   f. Other
10) What are the potential benefits of engagement in innovative processes?
   a. New or better quality of products and services
   b. Better efficiency of work, streamlined work organization and methods
   c. Increased sales of products/services and increased norms
   d. Strengthening of the competitive position, higher market shares
   e. Obtaining new knowledge, skills, competencies
   f. Other
11) What activities have been taken up to obtain external knowledge?
   a. Entering strategic partnerships
   b. Technological scouting (the analysis of research conducted by universities in terms of commercialization potential, and then an attempt to utilize it)

c. Investments in start-ups
d. Activities within technological incubators/parks
e. Other
f. None of the above/none

12) What are the institutional and legal barriers to the implementation of open innovations?
    a. Bothersome bureaucratic procedures
    b. No governmental regulations
    c. Insufficient infrastructure supporting innovative initiatives,
    d. Problems with normalisation and quality control
    e. Governmental programmes favouring less risky R&D initiatives,
    f. Other
    g. None/no barriers
13) what are the potential or current barriers to cooperation with other enterprises
    a. Insufficient resources and uncertain market,
    b. Unrealistic expectations,
    c. Organisational and administrative barriers,
    d. Division of rights and management of intellectual property,
    e. Poor bottom-top management,
    f. Insufficient support from top management,
    g. Other
    h. No barriers/no factors
14) What are the potential and current barriers to cooperation with universities on the process level?
    a. Concerns about agreements and privacy regarding access to data
    b. Intellectual property conflicts
    c. Avoiding the use of technologies and ideas from external sources
    d. The use and acceptance of new R&D methods
    e. No trust
    f. Differences in institutional and operational norms
    g. Other
    h. No barriers/ none
15) What are the potential and current institutional and legal barriers to cooperation with universities?
    a. Stiff administrational and organisational structure
    b. Different values (in terms of relevance of projects, power of empirical evidence, risk)
    c. No interest
    d. No trust
    e. Different terminology and communication channels,

   f. Division of rights and management of intellectual property,
   g. Other
   h. No barriers
16) What are the main incentives and motivations to engage in innovative cooperation?
   a. Reduce the cost of technology development or market entry costs
   b. Reducing the risk associated with the development of technology or entering new markets
   c. Achieving economies of scale, especially in production,
   d. Accelerating the commercialization process – introducing new products to the market
   e. Joint university process and access to new/supplementary knowledge;
17) Which of the following activities within the company were undertaken to obtain external knowledge?
   a. Technological scouting
   b. Strategic partnership
   c. Corporate venture capital
   d. Cooperative incubator
   e. Acquisition of external knowledge
18) What institutional and legal factors hinder the implementation of the open innovation model?
   a. Bothersome bureaucratic procedures:
   b. no government regulation
   c. Inability to allocate workforce to innovative activities because production has a higher priority
   d. Government programs favoring less risky R&D
   e. lack of sufficient infrastructure to support innovative activities
   f. no industry standard
19) What factors hinder innovative cooperation with other enterprises at the level of project management?
   a. insufficient resources and an uncertain sales market,
   b. division of rights and intellectual property management,
   c. insufficient support from top management,
   d. poor bottom-up management,
   e. organizational and administrative barriers,
   f. unrealistic expectations
20) What factors hindered innovative cooperation with universities at the level of project management:
   a. different terminology and communication channels,
   b. different values (in terms of project relevance, strength of empirical evidence, risk),

   c. lack of interest,
   d. rigid administrative and organizational structure,
   e. division of rights and intellectual property management,
   f. lack of confidence.

21) What factors hinder innovative cooperation with universities at the level of R&D and testing processes?
   a. intellectual property conflicts
   b. application and acceptance of new R&D methods
   c. contractual and privacy concerns regarding access to data
   d. differentiation of institutional and operational standards,
   e. not-invented here syndrome
   f. lack of confidence.
22) What personality traits hinder innovative cooperation?
   a. No courage to take risks
   b. No internal engagement
   c. Negative approach
   d. Resistance to changes
   e. Communication problems and reluctance to learn
   f. No trust
   g. Other
23) What activities in which it is most difficult to trust partners?
   a. While sharing new knowledge and intellectual capital
   b. When discussing problems and risks
   c. When developing prototypes
   d. When testing and optimizing the concept
   e. During lab works
24) What are the benefits and disadvantages of open innovation from the perspective of your company/activity?
25) What challenges (organizational, legal, socio-cultural, systemic, other) do you see in the implementation of open innovations at the level of the company and the entire sector?

This monograph shares the latest empirical insights and knowledge about attitudes towards open innovations, as well as drivers and barriers of open innovation collaboration from the perspective of the Polish and knowledge-intensive SMEs sector. The introduction is followed by a presentation of the theoretical and conceptual framework of the open innovation paradigm, open innovation ecosystem and its major dimensions. The next section focuses on the specific features of high-tech and knowledge-intensive SMEs and their innovative collaboration with key stakeholders (with firms, academia, public authorities, end users etc.) as well as the problem of knowledge sharing. Section three presents the dynamics, structure and development of the selected R&D and knowledge-intensive industries in Poland. It introduces the specifics of four selected sectors: biotechnological and pharmaceutical sectors, electronics and computer industries, the chemical industry, as well as the media, publishing and printing industries, from the global perspective as well as that of the Polish market perspectives. Finally, chapter four presents the results of the research survey conducted on the Polish market. It provides insights on major drivers and barriers of open innovation in a high and medium-high tech SMEs, as well as the description of attitudes, behaviours and experiences observed in this group of entrepreneurs. The monograph ends with conclusions and policy implications.

Innovation in science and modern business is not a choice, but a necessity. The subject of open innovation ecosystem and open innovation collaborative environment, which involves various groups and resources, both material and intangible, to create conditions conducive to the development of innovation is a complex topic that is difficult to grasp but much needed. The book contains rich theoretical material as well as results from the study, which address the research gap through empirical analysis of Polish enterprises. The way in which this difficult topic has been presented, by conducting the thread in a logical and interesting way, makes the reader await each subsequent approximation of the topic with great anticipation until it comes to precise conclusions and recommendations for Poland. The description of the observed behaviours and attitudes in Polish enterprises and the conclusions on major drivers and barriers of open innovation collaboration will be inspiring and highly useful for anyone who deals with the topic of innovation as a scientist or practitioner from various fields.

– Extract from the review by Barbara Kozierkiewicz, PhD

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