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Sectoral patterns of innovation cooperation in Polish industry

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Abstract
Research background: Contemporary research on industry concentrates on the relations between enterprises and their environment. Research on industrial structures conducted throughout the world, including Poland, are not extensive and limited due to the confidentiality of statistics. K. Pavitt (1984) was the first researcher who evaluated the relationship between industry structure and innovation activity. According to Pavitt, innovation dynamics and trajectory depend on the structure of domestic industry and is unique. In Poland T. Rachwal (2010) determined that over the studied years, changes in the indicator defining diversification in industrial divisions were minimal, but at the same time there was an observable fall in the importance of traditional divisions, such as the production of clothing, textiles, and the leather. In contrast, divisions as the production of metal, rubber, and plastic goods increased their share in terms of employees, as did furniture and vehicle manufacturing.
Purpose of the article: The purpose of the paper is to identify sectoral patterns of innovation cooperation as revealed by data on about 5209 Polish enterprises. The authors attempt to find the

answer to the following three questions: (1) Is the domestic aggregation sufficient for stimulating innovation cooperation in the Polish industry? (2) Is there any sectoral heterogeneity in innovation cooperation? (3) Are enterprises representing high technology industries the most involved in innovation cooperation? The main goal of the study was an attempt to seek out the directions and influence of various industries on the innovation cooperation of enterprises in Poland.
Methods: Empirical data that served as the basis for conducting calculations were collected with the help of a questionnaire survey sent to industrial companies throughout Poland. A total of 5,209 properly completed forms were collected. The average rate of return was 11,6%. The collection was held over the years 2008–2013. The methodological part of the study was developed using the logistic regression method based on probability theory of the study.
Findings & Value added: The study has shown that the higher the technology, the more often enterprises cooperate in the area of innovation. The research has not only shown the specifics of the domestic industrial system as well its level of technological advancement, but it has also taken into account the significance and input into the analyzed system.

Introduction

More than thirty years ago Pavitt (1984, pp. 343–373) introduced his taxonomy to describe the behavior of innovating firms, to predict their actions and to suggest a framework for policy analysis. Ten years later, a significant shift from the traditional view of innovation as a linear process spanning technology development activities and new product and process introduction was introduced. Following the works of Freeman (1989), Lundvall (1992), and Nelson (1993), the innovation process is defined as the interactions and knowledge exchanges among a variety of heterogeneous actors, mainly identified in suppliers, customers, science partners, universities, research organizations, government and financial institutions, and so on. The key role in this perspective, is played by technological change and its dynamics at the industry level, since technological change can be cumulative or revolutionary in nature (Dosi, 1982, pp. 147–162; Dosi, 1988). A detailed understanding of technological change as an evolutionary process leads to identifying the main knowledge flows and user-producer linkages. Pavitt's taxonomy of innovating firms can easily be used to map not only static state of technology change at the industry level, but it can also be easily used to explore the evolution of innovative firms (Evangelista *et al.*, 1997, pp. 521–536; Freel, 2003, pp. 751–770). Innovation processes differ greatly from sector to sector in terms of development, rate of technological change, linkages and access to knowledge, as well as in terms of organizational structures and institutional factors (Malerba, 2005, pp. 63–82). Scholars recognize that the ability to exploit external knowledge is critical to firm innovation (Teece *et al.*, 1997, pp. 509–533). Technological innovations related to products and processes are now unavoidable for

companies which want to develop and maintain a competitive advantage and/or gain entry into new markets (Stock *et al.*, 2002, pp. 537–549).

The Polish economy has attained impressive growth since the late 1990s. One of the most apparent features of this growth is the spillover of technology and knowledge. Drawing on an original survey of Polish manufacturing establishments in industry, the paper investigates sectoral patterns of innovation cooperation as revealed by data on about 5209 Polish enterprises. The authors pose three main questions: (1) Is the domestic aggregation sufficient for stimulating innovation cooperation in Polish industry? (2) Is there any sectoral heterogeneity in innovation cooperation? (3) Are enterprises representing high technology industries the most involved in innovation cooperation?

The main hypothesis is the statement that low technology industries facilitate innovation cooperation with suppliers more than other industry sectors, but high technology industries facilitate innovation cooperation with competitors the most. The methodological part of the study is developed using logit modelling based on probability theory. The study shows that sectoral patterns of innovation cooperation vary in the technology level and the type of innovation partners. Low technology industries limit their innovation cooperation in general, whereas high technology industries facilitate cooperation with competitors the most.

The first section of this paper includes the introduction. Section 2 briefly surveys the literature linking various partners with innovation cooperation. Section 3 describes our methodology and the research sample. Section 4 presents results and Section 5 concludes.

Literature review

The need to develop specific external relationships depends on the type of industry and technology. Pavitt (1984, pp. 343–373) introduced four categories of firms: (1) supplier dominated firms can be found mainly in traditional industries characterized by weak R&D, such as clothing and furniture, (2) specialized-suppliers including small mechanical and instrumental engineering firms which engage users and other firms outside the sector to develop customized product-innovation and to solve technological problems, (3) science-based firms born to exploit new scientific discoveries in fields such as electronics, chemicals, pharmaceuticals and aerospace, and (4) scale-intensive firms, such as automobile or steel manufactures, which achieve competitive advantage by exploiting economies of scale, and tend to innovate more in the product than in the process. The major contribution

of Pavitt's work was the reduction of the apparent wide sector diversity of the nature, sources, directions and strategic implications of innovation. Although, firms within Pavitt's sectoral classes demostrate technology-related similarities, groups are not homogeneous thanks to a differences in industrial dynamics (Niosi, 2000, pp. 429–444). The highest disparities concern firms in science-based industries. Several competing evolutionary models have tried to explain this phenomenon, but all of them share a common assumption that the innovation process involves interaction among a wide variety of actors for the generation and exchange of knowledge (Cohen & Levinthal, 1989, pp. 569–596; Freeman, 1989; Lundvall, 1992; Malerba, 2002, pp. 247–264; Nelson, 1993; Nelson & Winter, 1982).

Having regard to increasing uncertainty, related to changing technology and global competition, firms concentrate on core competencies, relying upon trade, or cooperation, for others (Archibugi & Iammarino, 2002, pp. 98–122; Fleming, 2001, pp. 117–132). Evidence suggests the economic performance of organizations and countries is growing more dependent on knowledge production (Furman *et al.*, 2002, pp. 899–933). The evidence on interorganizational networks of learning and innovation and collaborative activities is very rich, pointing at their importance for fast-changing environments where flexibility is highly prized (Ahuja, 2000, pp. 425–455; von Hippel, 2007, pp. 293–315; Westerlund & Rajala, 2010, pp. 435–442).

The knowledge required to innovate successfully varies depending on the type of both innovation that firms want to develop and the sector firms belong to. As a consequence, firms may choose to interact with specific actors in order to introduce specific innovations (Singh & Fleming, 2009, pp. 41–56). In developed countries more than 50% of firms innovate cooperating with firms that belong to the similar sector or with their competitors (Harbison & Pekar, 1998) benefiting from economies of scale, the lower level of risk, complementarities, lower costs of entering new markets and shared resources (Chen, 1996, pp. 100–134). Strategic partnering and coopeting has become the standard in knowledge-intensive, highly complex, and dynamic environments including high technology industries, such as semiconductors, aerospace, software, telecommunications, where firms collaborate to compete in knowledge generation and exchange (Carayannis & Alexander, 1999, pp. 197–210; Schiavone & Simoni, 2011, pp. 136–154; Quintana-García & Benavides-Velasco, 2004, pp. 927–938). In addition, high R&D costs, relatively short product lifecycles, and the combination of different technologies puts pressure on firms to partner with even their fiercest competitors (Bouncken & Fredrich, 2012, p. 1250).

Evidence of the role of demand in innovation comes from numerous sources. Mowery and Nelson (1999) illustrated the major role of demand in innovation in machine tools, software and computers sectors. Other works explored the demand in ICT and software, scale-intensive sectors and motorcycles in developing economies (Malerba & Mani, 2009). While playing different roles, users are widely recognized as crucial for carrying out product innovation in medical equipment sector (von Hippel, 1988), software (Hippel, 2005, pp. 63–78), automobiles and motorcycles (Sawhney *et al.*, 2005, pp. 4–17) and semiconductors (Glimstedt *et al*., 2010, pp. 431–464).

Reichstein and Salter (2006, pp. 653–682) investigating the sources of process innovation among UK manufacturing firms find that knowledge from suppliers enhances process innovations in firms with a cost-focus strategy, while it is negatively associated with involving customers as a source of knowledge. Collaborating with suppliers provides the biggest boost to product innovation (Belderbos *et al.*, 2004, pp. 1237–1263; Yu, 2008, pp. 8–9). According to Nishiguchi and Ikeda (1996), suppliers provide a source of innovative ideas and critical technologies. Consequently, better-targeted suggestions can be provided, which allows for improvement of design and performance of parts or even entire products (Gadde & Snehota, 2000, pp. 305–316). The core innovative suppliers are highly specialized, technically competent firms, located in the proximity of the buyer, being embedded in a trusted and intensive relationship (Schiele, 2006, pp. 925–935). Manufacturers pursuing process innovation, which entails investments in machinery and equipment, seem to require mainly interaction with suppliers (Malerba, 1992, pp. 845–859).

In the automotive industry, supplier willingness to invest in and share technology is known to be a major differentiator of successful customer/supplier collaborations (Geffen & Rothenberg, 2000, pp. 166–186; Henke & Zhang, 2010, pp. 41–46). By cooperating with suppliers, manufacturers learn to differentiate products in the market (von Hippel, 1988). Furthermore, manufactures get permanent access to suppliers' new technologies, which may be of strategic importance for future product development activities (Wynstra *et al*., 2000, pp. 129–141). Considering close cooperation with key suppliers, manufactures are able to match future product and technological needs with the available technological opportunities (Handfield *et al*., 1999, pp. 59–82).

In contrast to developed economies, developing economies, including Poland, comprise more than 70 percent manufactures from traditional industries delineated by low level of research and development activities. In low technology sectors, the main source of information for innovation is

knowledge included in exported machines and technology (Heidenreich, 2009, pp. 483–494; Robertson & Patel, 2007, pp. 708–721). Manufactures focus on implementing incremental innovations (products and processes) more than radical ones (Świadek, 2013, pp. 44–55). Research including low, medium and high technology sectors detect significant variances in sectoral patterns of innovative cooperation in comparison to sectoral patterns in innovation cooperation in developed countries (Dzikowski, 2015, pp. 40–49). On the other hand, Rachwał (2010, pp. 105–124) showed that the Polish industry structure moderately evolves. A number of firms representing low-technology industries, including clothing and textiles sectors, is decreasing, but at the same time substantial number of firms representing low-medium technology sectors including the production of metal, rubber, and plastic goods increased their share in terms of employees, as did furniture and vehicle manufacturing.

To sum up, innovation is a complex phenomenon and typically firms cooperate with several actors at the same time as they need the integration of various types of knowledge. The need to interact might be the consequence of the industry structure, but interaction with several actors might be the consequence of the fact that firms may do several types of innovation which differ in terms of novelty and integration of market and production. In this paper, we analyze the impact of industry structure on the propensity to cooperate to innovate with suppliers, competitors and customers.

Research methodology

We used a survey for the data collection. To generate our survey database, we use commercial and non-commercial sources including Teleadreson and Polskie Książki Telefoniczne. Such databases include customers' names and addresses, phone numbers, e-mails, and any other data that can be legally and accurately collected Information. The survey was based on a questionnaire sent by email or conducting during a telephone interview with a manager or a company founder. It was conducted between 2008 and 2013. A total of 5109 successfully completed forms were gathered. The rate of success was 11,6%. The statistical structure of our data corresponds to the Polish GUS statistical structure. The majority of firms represent SME's group (micro and small 72,6%, medium 21,5%, large 5,9%) and low and medium-low technology level (low 52,2%, medium-low 29,6%, medium 13,2%, high 5%).

Due to dichotomous values of both dependent and independent variables, we use a logistic regression (Aldrich & Nelson, 1984; Liao, 1994; Stanisz, 2016). The logistic regression model describes the influence of the *x1*, *x2*, …, *xk* variables on the dichotomous variable Y. In logistic functions, the probability model may be presented with the following mathematical formula:

$$P_i = P(Y = 1 | x_1, x_2, ..., x_k) = \frac{e^{(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i)}}{1 + e^{(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i)}} \quad (1)$$

where:
Pi – probability of the occurrence of a situation where Y=1;
α_i – the regression coefficient for i = 0, … , k;
x_i – the independent variable for i = 1, 2, …, k.

In contrast, the probability of a situation in which Y = 1 may be described as:

$$1 - P_i = \frac{1}{1 + e^{(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i)}} \quad (2)$$

where:
$1 - P_i$ – the probability of a situation in which Y =1 does not occur.

Comparing the probability of the situation Y = 1 with the probability of not occurring the same situation, we get the so-called odds ratios, which can be written as follows: $\frac{P_i}{1 - P_i}$. Hence, the natural logarithm of the odds ratio is called a logit and it takes the following form:

$$\ln\left(\frac{P_i}{1 - P_i}\right) = \ln e^{\left(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i\right)} = \alpha_0 + \sum_{i=1}^{k} \alpha_i x_i + \varepsilon_i \quad (3)$$

The calculated odds ratio describes the strength of the relation or lack of independence between the two variables. Our explanatory variables correspond to firms divisions defined by 2-digit codes within Section C —

Manufacturing of Statistical classification of economic activities in the European Community NACE Rev.2 (Europäische Kommission & Statistisches Amt, 2008). We have our explanatory variables grouped into four technology classes and innovative cooperation is the response variable (dependent variable). We defined four variables representing innovative cooperation types including cooperation with suppliers, competitors, customers.

The impact of industrial structure on innovation cooperation

Low-technology industries generally decrease the likelihood of overall innovation cooperation. It is noted that the likelihood of overall innovation cooperation is about 30% lower in textiles and manufacture of wearing apparel than any other divisions (see Table 1). On the contrary, the downturn is the lowest (17%) in printing and reproduction of recorded media industry. The odds of taking overall innovation cooperation are the highest in medium-low technology sector. Furthermore, the odds increase more than 3,18 times in manufacture of coke and refined petroleum products and building of chips and boats. Comparing to medium-low technology group, in medium-high technology sector the odds of taking overall innovation cooperation are lower, but still greater than 1. The odds are the highest (170% increase) for manufacture of chemicals and chemical products sector whereas for manufacture of machinery and equipment n.e.c. and manufacture of electrical equipment the increase is about 140%. Overall statistics for high technology industries are moderately high. However, these numbers clearly demonstrate the stage of economic development of Polish high technology sector. The odds are the highest in manufacture of computer, electronic and optical products, but still lower than in some medium-low technology industries. In industries for which statistically significant parameters are not estimated, the chances of innovation cooperation are nearly 25% lower than in the industries, which yields individual statistical significance, as reported by a constant of 0.753.

Deeper analyses shed much more light on the structure of the innovation cooperation. The results of analysis of innovation cooperation with suppliers demonstrate which types of industries are being developed on the basis of external technologies. Traditionally, low-technology industries are the beneficiaries of solutions provided by higher-tech companies. Hence, in the low- and medium-low-technology groups, the number of models representing the increase in the chance for innovative cooperation with the suppliers

is higher in comparison to the high- and medium-high technology groups. Most of the estimated models underline the increased opportunities for innovation cooperation with suppliers in low-tech and medium-low technology sectors.

In low technology sector, the impact of individual industries on innovation cooperation with suppliers varies from the 200% increase in chances in manufacture of leather and related products to nearly 30% decrease of chances in manufacture of textiles and manufacture of wearing apparel. In the medium technology sector, the influence of individual industries also varies. The chances of taking innovation cooperation with suppliers are more than 3,34 times higher in building of chips and boats. In contrast, manufacturers of fabricated metal products, except machinery and equipments decrease the odds of cooperation about 18%. The highest chances of cooperation with suppliers are found for manufacture of other transport equipment belongs to the medium-high technology sector. In industries for which statistically significant parameters are not estimated, the chances of innovation cooperation with suppliers are nearly 67% lower than in other industries, which yields individual statistical significance.

A unique feature of the Polish culture is the phenomenon of unification and cooperation in the face of an external threat. Under favourable market conditions, companies have a low willingness to cooperate with competitors, but under the influence of unfavourable factors, the frequency of cooperation is growing, and the degree of technical advancement, at least in the Polish conditions, is not decisive. In the low-technology sector, tobacco manufacturers more than 5.3 times more often cooperate with competitors. In the medium-low technology sector, a similar increase concerns ship and boat manufacturers. In the medium-high technology sector, motor vehicle manufacturers, trailers and semi-trailers are more than 2.5 times more likely to cooperate with their competitors, and finally in the high technology group, a 6.6-fold increase in the chance exists for the group of aircraft and spacecraft manufacturers. In industries for which a statistically significant parameter has not been estimated, the chances of innovation cooperation with competitors are seriously decreased by nearly 96%.

As the level of technology increases, the tendency to undertake innovative cooperation with consumers is increasing (see Table 1). The lowest number of statistically significant models occurs in the group of low and medium-low technology. The medium-high technology group shows the most favourable models, and the highest growth rate concerns the high technology group. In the low technology group, manufacture of paper and paper products shows an increase of 1.4 times the chance of innovative cooperation with customers, while in the medium-low technology group the

odds are nearly 1.4 times higher for manufacture of rubber and plastic products.

In the medium-high technology group, manufacturers of motor vehicle, trailers and semi-trailers are nearly 1.7 times more likely to cooperate with customers. Furthermore, in the high technology group, a 2.3x increase in the chance is made for the group of manufacture of computer, electronic and optical products. In industries for which a statistically significant parameter has not been estimated, the chances of innovation cooperation with consumers are almost 75% lower than in industries that have been individually statistically significant.

Discussion

We begin by analyzing the results for LT & MLT industries. Pavitt (1984, pp. 343–373) characterized these groups as weak in-house R&D entities that rely on the competences of external technology suppliers in order to produce a product as cheaply as possible, or a design-intensive product. Several studies confirm the importance of suppliers in both developed and developing countries (Chung & Kim, 2003, pp. 587–603; Johnsen, 2009, pp. 187–197). The role of collaborative approach when it comes to innovation has increased significantly in the MHT sector (Belderbos *et al*,, 2013, pp. 1–32). Firms representing HT industries tend to cooperate more both with customers and competitors independently from the level of development of the origin country (Candi *et al.*, 2016, pp. 418–434; Cui & Wu, 2015, pp. 516–538). Hirsch-Kreinsen *et al.* (2006, pp. 3–21) show that innovation depends not only on industries with frontline technological knowledge, but also on low-tech industries and the interrelationships of low-tech with high-tech sectors. Other pieces of evidence illustrate that those firms which do not cooperate and which do not, formally or informally, exchange knowledge limit their knowledge base in a long term. Furthermore, network relationships with suppliers, customers and intermediaries such as professional and trade associations are important factors affecting innovation performance and productivity (Pittaway *et al*., 2004, pp. 137–168). The relationships between high tech and non-high tech sectors are highly symbiotic and that the health of high tech firms and industries depends heavily on their ability to sell their outputs to other sectors in developed economies (Robertson & Patel, 2007, pp. 708–721). Generally, firms operating in countries with less developed research infrastructure are shown to be more likely to cooperate with foreign partners including suppliers, competitors and customers (Srholec, 2014, pp. 133–155; Srholec, 2015, pp. 159–182). Carvalho *et al.* (2018, pp. 506–525) show that the

group consists of Eastern European countries that have joined the European Union more recently, have similarities that inhibit private cooperation, the collaborative competition and networks type and reward a more formal and institutional cooperation, suggesting that there could still be an influence of the central leadership structures in these economies.

Conclusions

The study has shown that the higher the technology, the more often enterprises cooperate in the area of innovation. The research has not only shown the significance of the domestic industrial system as well as its level of technological advancement.

In general, low technology industries limit chances of innovation cooperation with other firms. However, there are some exceptions concerning cooperation with suppliers (manufacture of feather and related products and manufacture of furniture and other manufacturing) what it suggests that these industries accumulate knowledge to innovate. Furthermore, manufacture of tobacco products supports cooperation with competitors what it suggests that the economic situation is difficult (high competition). Finally, manufacture of paper and paper products supports coopetition with customers what it suggests that this sector is highly specialized.

All industries within medium-low technology sector facilitate innovation cooperation with other firms, excluding machinery and equipments in relation to cooperation with suppliers. The highest level of influence concerns building of ships and boats.

The impact of medium-high technology industries on cooperation with firms is also positive, but it is lower than in medium-low sector. The highest value of probability concerns cooperation with suppliers in manufacture of other transport equipment industry and cooperation with competitors in manufacture of motor vehicles, trailers and semi-trailers and manufacture of chemicals and chemical products.

The characteristic feature of high technology industries in strong cooperation with competitors (manufacture of air and spacecraft and related machinery and manufacture of computer, electronic and optical products).

The study shows that sectorial patterns of innovation cooperation vary with industry, their technology level and the type of innovation partners. Low technology industries limit their innovation cooperation in general, whereas high technology industries facilitate the cooperation with competitors the most. Hence, our main hypothesis seems to be true.

Central and Eastern European economies concentrate on low- and medium-low-technology industries, which can be functionally and spatially separated from advanced industries and services. The consequences are ambiguous. On the one hand, LMT industries are both an important employment sector and an important prerequisite for the development of high- and medium-high-technology industries, but they are also no 'engine of growth'. Business strategy, even in 'lower-tech' sectors, cannot afford ignoring innovation. The same should be true for science and technology policy.

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Annex

Table 1. Odds ratios in multiple logit regression portraying the impact of industrial structure on innovation cooperation, including suppliers, competitors, customers

Division	Overall innovation cooperation	Cooperation with:		
		Suppliers	Competitors	Customers
Low technology (LT)				
Manufacture of food products and beverages	0.735 (***)	------	------	------
Manufacture of tobacco products	------	------	5.316 (**)	------
Manufacture of textiles and manufacture of wearing apparel	0.702 (**)	0.695 (**)	------	------
Manufacture of leather and related products	------	1.981 (**)	------	------
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.790 (**)	------	------	------
Manufacture of paper and paper products	------	------	------	1.414 (*)
Printing and reproduction of recorded media	0.829 (*)	------	------	------
Manufacture of furniture and other manufacturing	------	1.362 (***)	------	------
Medium-low technology (MLT)				
Manufacture of coke and refined petroleum products	3.185 (**)	------	------	------
Manufacture of rubber and plastic products	1.263 (**)	1.256 (*)	------	1.345 (**)
Manufacture of other non-metallic mineral products	------	1.245 (*)	1.904 (***)	------
Manufacture of fabricated metal products, except machinery and equipments	------	0.825 (*)	------	------
Building of ships and boats	3.185 (***)	3.343 (***)	5.696 (***)	------
Medium-high technology (MHT)				
Manufacture of machinery and equipment n.e.c.	1.425 (***)	------	------	1.380 (**)
Manufacture of electrical equipment	1.398 (**)	------	------	------
Manufacture of motor vehicles, trailers and semi-trailers	------	------	2,556 (**)	1.692 (*)
Manufacture of chemicals and chemical products	1.770 (***)	------	2.192 (**)	1.519 (*)
Manufacture of other transport equipment	------	5.943 (**)	------	------

Table 1. Contined

Division	Overall innovation cooperation	Cooperation with:		
		Suppliers	Competitors	Customers
High technology (HT)				
Manufacture of computer, electronic and optical products	2.654 (**)	------	4.089 (***)	2.305 (**)
Manufacture of basic pharmaceutical products and pharmaceutical preparations	1.706 (*)	------	------	------
Manufacture of air and spacecraft and related machinery	------	------	6.645 (*)	------
Constant	0.753 (***)	0.337 (***)	0.038 (***)	0.251 (***)
Sample size	5209	5209	5209	5209
Chi2	84.189	43.525	30.588	21.440
P value	0.00	0.00	0.00	0.00

(***) – significance at a level of 1%, (**) – significance at a level of 5%, (*) – significance at a level of 10%.