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Structural Determinants of Innovation in Industry: The Pavitta Model in the Polish Economy

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The subject of this paper is the question of assessing the impact of structural industrial diversification of companies in terms of their innovative activities in Poland. The authors attempt to answer three basic questions: Firstly, is the domestic aggregation sufficient for diversifying innovation in Polish industry? Secondly, do companies in various industries behave differently in terms of their innovative efforts? Thirdly, are technologically advanced industries more interested in the active creation of knowledge or its passive transfer to domestic industry and to what extent? The main goal of the study was an attempt to seek out the directions and influence of various industries on the innovative activities of companies in Poland. The methodological section was developed using logit modeling based on probability theory. The study has shown that the key to accelerating research and development in Poland is the stimulation of such activities, primarily in the case of entities in the high and medium-high technology sectors. The low technology sector is a significant burden and limits possibilities for the active creation of new solutions in Poland. The passive transfer of knowledge should only be supported by companies included in these technologies to a limited extent. In other industries, the transfer of knowledge generated significant interest regardless of type of activity. At this stage of economic development, research and development processes are evolving in the direction of high technologies, while investments remain the domain of a broad group of companies unless they relate to traditional technologies.

Keywords: innovation, system, industry, technology, country.

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Strukturalne uwarunkowania aktywności innowacyjnej w przemyśle – model Pavitta w polskiej gospodarce

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Przedmiotem artykułu jest problem oceny wpływu strukturalnego zróżnicowania przemysłowego przedsiębiorstw na ich aktywność innowacyjną w Polsce. Autorzy starają się odpowiedzieć na trzy zasadnicze pytania: po pierwsze, czy agregacja krajowa jest wystarczająca dla zróżnicowania aktywności innowacyjnej w polskim przemyśle; po drugie, czy przedsiębiorstwa z różnych przemysłów zachowują się odmiennie w zakresie prowadzonej działalności innowacyjnej i po trzecie, czy oraz w jakim stopniu przemysły zaawansowane technologicznie są częściej zainteresowane aktywnym kreowaniem wiedzy lub pasywnym jej transferem do krajowego przemysłu? Głównym celem badania była próba poszukiwania kierunków i siły oddziaływania różnych przemysłów na aktywność innowacyjną przedsiębiorstw w Polsce. Cześć metodyczna opracowania została przygotowana na podstawie modelowania logitowego bazującego na rachunku prawdopodobieństwa. Prowadzone badania wskazały, że kluczem do akceleracji badań i rozwoju w Polsce jest stymulowanie tej aktywności głównie w podmiotach zaliczanych do wysokich i średnio-wysokich technologii. Sektor niskich technologii istotnie ciąży i ogranicza możliwość aktywnego kreowania nowych rozwiązań w Polsce. Pasywny transfer wiedzy powinien być tylko w ograniczonym zakresie wspomagany w przedsiębiorstwach zaliczanych do tych technologii. W pozostałych przemysłach transfer wiedzy cieszy się wysokim zainteresowaniem, bez względu na typ działalności. Na tym etapie rozwoju gospodarczego zaangażowanie w procesy badawczo-rozwojowe ewoluuje w kierunku wysokich technologii, inwestycje zaś pozostają domeną szerokiej grupy przedsiębiorstw, o ile nie dotyczą technologii tradycyjnych.

Słowa kluczowe: innowacja, system, przemysł, technologia, kraj.

JEL: E61, R48, L16, O38

1. Introduction

Today's topical literature on the structural determinants of innovation in industry focuses its attention on industrial districts, new industrial space, or other specialized industrial agglomerations. Conducted research is mainly based on quantitative data. Moreover, bearing in mind trends in the new geographic economy and regional studies, they usually concentrate on the local or regional perspective, less so on a domestic one. Furthermore, a separate place is occupied by the systemic perspective – industrial, technological, socio-cultural, and others. An interesting supplement to these studies is the disaggregation of industries on the division level in the context of innovation in domestic industry. The authors of this paper strive to demonstrate the fact that the system of industry in Poland as well as its structure on a domestic level strongly determine innovation activity. Thus, the local or regional constellations are not necessary in order to define directions of development of innovation processes in Poland.

Sector analyses, with special stress on the level of manufacturing technology applied by companies allows the receiving of an answer to the question of whether the domestic system of industry has achieved the critical mass necessary in order to create innovation in advanced technology industries

in spite of the existence of civilizational delays with respect to the more developed economies of the world. On the other hand, it is necessary to find out what innovative potential is found in companies of the traditional technology sectors and thus assess if their importance in the reality of Poland is undervalued or if, perhaps, their innovative potential is overestimated. Finding these answers will make possible the indication of potential directions for support through innovation policy.

The primary hypothesis behind this research is the statement that innovative mechanisms functioning in the domestic industrial system are significantly determined by the type of industry being represented. Skill in the proper identification of the character of innovative processes, inclusive of their domestic restrictions, makes it possible to create adequate solutions in the area of stimulating the development of innovation in Poland.

The main objective of this study was an effort to seek out the directions and determinants of industrial diversification and their impact on the innovativeness of companies in Poland and thus, the defining of boundary conditions for a model structure of the domestic innovation network taking it specifics into account.

This paper provides a broad overview of literature on research into the competitiveness of industry. The research hypothesis can be verified thanks to the application of multinomial logit regression, which provides quotients of the probability of the analyzed innovative phenomena. Thanks to the selection of this research method, it is possible to define the impact of individual divisions of industry on the innovativeness of domestic industrial companies.

2. Overview of Literature

Contemporary research on industry currently concentrates on relations between companies and their environment. Many researchers are of the view that these relations are significantly linked to the environment in which the given entity exists (Miller, 1988; Tan and Litschert, 1994). Porter (1980) maintains that a company is more dependent on the influence of its immediate surroundings than on the more distant environment and innovation habits are a consequence of the specifics of the industry (Pavitta, 1984; Von Hippel, 1988; Archibugi et al., 1991; Evangelista, 1996). In line with this logic, company strategies are more often the resultant of conditions reigning in the industrial system than on overall economic conditions. This is because there is a greater chance of acquiring knowledge from partners and on discovering the strategic possibilities occurring in such a system (Granovetter, 1985). Moreover, the structural transformations of industry as stemming from technological progress lead to labor savings in favor of a more intensive utilization of phenomena such as mechanization, automation, robotics, and computerization in manufacturing processes. Of

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particular interest are the multiplicative effects brought in by the presently functioning industrial structure in Poland in the context of the conducting of innovative activities. This has its consequences with respect to the development of the economy as a whole (Domański and Gwosdz, 2008; Rachwał and Wiedermann, 2008).

Companies, depending on the character of their activities, belong to one or more industrial systems. The industrial system itself may be defined as a group of organizations or people that (Kieżun, 1997):

- Participate in the joint development, evolution, and control of a defined industry, and
- Develop, depending on case, relations in collaboration, trading, control, and mutual support or competition, with companies that belong to the given industry.

Contemporary industry is characterized by certain qualities that do not occur or are of significantly less importance in other areas of the economy. They may be formulated as follows (Łukasik and Szopik, 2005):

- Industrial development is very dynamic, not only in terms of production volume, but also with respect to structure,
- Industry is constantly undergoing far-reaching changes in technology and production technology organization, which makes possible a rapid increase in work output,
- Industrial development is strictly tied to the turbulent development of science and technology (and is the quickest in assimilating their results),
- To a great extent the development of domestic industry is dependent on the development of the economy and foreign trade throughout the world as well as international specialization, and industrial cooperation and its opposite – the development of industry fosters foreign economic cooperation, and
- Industrial development that is not properly controlled poses a serious threat to Man's natural environment and this necessitates the manufacture and introduction of equipment eliminating or limiting this danger.

Research on industrial structures conducted throughout the world, including in Poland, are not extensive and limited due to the confidentiality of statistics. Moreover, they are a rarity in the context of innovation activity. K. Pavitta is the first researcher in the world who tried to evacuate this phenomenon. He conducted his research on data from Great Britain for the years 1945–1979 (Pavitta, 1984). He created an interesting categorization of industries from the perspective of creating innovation as well as its utilization, demonstrating that there is a group of sectors that are providers of new solutions for others in which he included the chemical, machine and equipment manufacturing, and non-metallic product manufacturing industries of that time.

According to Pavitta, innovation dynamics and trajectory are diverse and dependent on the type of industrial activities of the analyzed companies.

In the case of entities strongly dependent on their suppliers (traditional industrial processing divisions), it is the suppliers and the research services they buy that are the source of technology as are significant users. New technical solutions are acquired and used mainly in areas linked to marketing and advertising and the primary reason for introducing change in the lowering of costs.

Another category of companies consists of entities that are characterized by significant intensity of production who achieve the benefits of scale – the manufacture of large-volume products (steel and glass) and the assembly industries (consumer durable goods and the automotive industry). The source of technology for this group is its own research and development work as well as suppliers of parts and components. The basic method for acquiring new technical solutions is the dynamic benefits of the learning process as well as occurring technological delays. These companies concentrate their activities on perfecting manufacturing processes, know-how, and the creation and acquiring of patents. The main goal of introducing change is the lowering of the costs of designing new products. In contrast to the previous group in which small, homogeneous units dominate, the foundation of innovation processes is a large and significantly diversified company.

The third category of entities is the group of suppliers of specialized gear and equipment (the machine and precision instrument manufacturers) that achieves significant intensity of production. In this category, the source of innovation is the users who are sensitive to changes in quality. New solutions involve knowledge, know-how, design, and the use of the knowledge of major users as well as patents. The fundamental objective of activities is the perfecting of the product design process. The source of technology consists of in-house work by the entity and consumers. In such cases it is small entities that are dominant.

The fourth category encompasses companies based on scientific research (the electrical, electronic, and chemical industries). In this group technology is acquired on the basis of knowledge derived from public sector research and development work as well as in-house research and development work. New technological solutions are based on patents, manufacturing secrecy, and unique know-how, and is also created as a result of participation in the dynamic learning process. Dominant entities include major companies serving as integrators (Pavitta, 1084).

It is on the basis of his conducted research that Pavitta noticed industrial diversification and the special role of small companies-suppliers in innovation activities. Thus, attention should very specifically be called to the sector level in order to actively influence effective innovation policy. However, in light of the passage of time and changes in the classification of industry, these analyses are incongruent with the current state of knowledge in this field.

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Research conducted in Italy in the 1990s by E. Evangelista and others noted that at that time there were no quantitative studies performed in the area of changes in innovative behavior by various industries as influenced by time (Evangelista et al., 1997). Certain companies can be continuous innovators, especially in high-opportunity sectors, while frequency in other industries can be lower – occasional innovators (Malerba and Orsenigom, 1995). Also confirmed was the fact that innovative habits change depending on type of industrial activity and company size. This is of value from the point of view of possibilities for molding adequate innovation policy instruments.

Small companies are rarely innovative. For this reason, care should be taken to expand rather than strengthen the industrial base of such entities.[1] E. Evangelista also came to the conclusion that the leading sector maintains its position regardless of the applied indicator for innovativeness. Moreover, the Italian research confirmed the existence of a broad perspective for understanding and measuring technological changes based on the relation between financing research and development and innovation. The process of accumulating knowledge in industry is very important for the shaping of the innovativeness of companies and also applies to industries with high technological potential. This points to strong diversification in involvement in thee activities among industries and the minimal link between sales dynamics and the introduction of new products (Evangelista et al., 1997).

Similar research was conducted in the 1990s by a team of researchers headed by R. Quadros (2001) in Brazil, a developing country. They discovered that there is a lot of innovation in the Sao Paulo district, but little new knowledge. The source of new solutions is research and development to only a small extent. It rather tends to be customers and competitors. Transnational companies seem to be the most innovative, but they limit themselves to the transfer and adaptation of research and development work. This explains the significant technological gap separating developed countries from the analyzed one. Moreover, this is in agreement with the studies of Bielschowski (1999) on mini-cycles in investment and modernization of the Brazilian economy. That research supports the relation between industrial sector type, company size, and innovation. It was also noted that the greatest technological intensity is coupled with high production scale industries. The specifics of research in Brazil showed a strong correlation between research and development and the manufacturers of mechanical and electrical equipment. This is a consequence of strong public support for these intermediate industries in the 1970s and 1980s when high technology found itself under the influence of the free market. The last important conclusion was that the occurrence of the innovative effect as well as activity in the new technology area is characteristic of foreign companies (Quadros et al., 2001).

Research conducted in Malaysia by a team led by W. P. Kam (2001) clearly demonstrated the differences between that country and the most economically developed ones. Although progress in the area of innovation efforts is visible, as was the case in the previous research, that activity is tied to company size, sales volume and dynamics, employment rate, and internationalization. Shortages in the area of collaboration between companies and the public research and development sector were shown. A strong link was discovered between the intensity of research and development and innovation, and the manufacture of electronic, chemical, and precision goods. In the area of vehicle manufacturing, strong ties with the purchase of new machines and equipment as well as relatively weak ones with research and development activity were proven (Kam, 2003).

In Poland, analyses of the competitiveness of industrial structures on the basis of GUS Central Statistical Office of Poland data were performed under the leadership of T. Rachwał who compared the years 1995 and 2007, taking into account the number of employees as well as the added value from industry (Rachwał, 2010). He came to several interesting conclusions. Firstly, he determined that over the studied years, changes in the indicator defining diversification in industrial divisions were minimal. At the same time, however, there was an observable fall in the importance (labor intensiveness) of traditional divisions, such as the production of clothing, textiles, and leather, as well as machines and equipment, and the chemical industry. At the same time, divisions such as the production of metal, rubber, and plastic goods increased their share in terms of employees, as did furniture and vehicle manufacturing, which was primarily a consequence of significant foreign investment.

Worth noting is the fact that choosing labor intensiveness as the reference point does not influence the objectiveness of the assessment of phenomena. This is because high technology industries are characterized by very low labor intensiveness, but also significant multiplicative effects and, therefore, high added value. T. Rachwał indicated that structural changes in industry have advanced Poland to the group of countries such as Belgium, France, Great Britain, the Netherlands, Spain, and Denmark, but at the same time the low employment potential and production sales value for the advanced industries is observable against a backdrop of the other countries.

Research conducted in Poland, though it contains many interesting final finding, continues to be an effort at often qualitative perceptions (conjectures) and assessments of phenomena in Poland based on cited quantitative data. However, they lack a basis for direct assessment of the impact of industrial structure on the innovative behavior of companies.

Discussions conducted in topical literature generally pertain to overall relations between high and medium-high technology in industrial development, and low and medium-low technology. For many years, the high-tech industry was deemed a synonym for high competitiveness and growth. Such

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an approach resulted in a truly "obsessive" treatment of often incidental solutions in this area by the political elites of the new member states of the European Union. However, new studies on low technology industries have shown that their growth is also based on innovation, although their sources differ from those of the high technology area, where their innovation is an equally important element of economic growth. It is for this reason that many regional innovation strategies and intelligent specializations in Poland are aimed at strengthening the potential of companies in traditional industries. It is expected that in spite of the extensive approach to innovation, in combination with the unique specifics of the region, their significant number will be capable of generating systemic and endogenic technological changes within the framework of existing development paths.

On the one hand, it is a known fact that the economies of the new member states of the European Union are based on traditional industries to a significantly greater extent than the mature market economies. On the other hand, such countries should catch up. Currently, it is known that the greatest source of innovation in the traditional industries is not research and development activity (Heidenreich, 2009; Barge-Gil and López, 2015). The basic source of innovation for these divisions of the economy is knowledge found in semi-finished products, machines, and raw materials – the passive transfer of technology (Alcaide-Marzal and Tortajada-Esparza, 2007; Robertson and Patel, 2007; Von Tunzelmann and Acha, 2005; Laestatadius, 2005; Heidenreich, 2008). This shows the weight of the technological trajectory aimed at collaboration with suppliers. It is for this reason that what dominates in this case is primarily accumulating innovation, rather than radical innovation (Pavitta, 1984; Świadek, 2013; Ardito et al., 2015). For their part, companies from modern industries procure new knowledge as a result of cooperation with the science sphere (Grimpe and Sofka, 2009; Bodas Freitas et al., 2013; Barge-Gil and López, 2014). Entities from the traditional sectors hold practical, disembodied knowledge that is a consequence of their functioning within the framework of networks (Radauer and Streicher, 2007). Their competitiveness is reflected in their ability to apply the knowledge found there, while technological competition is directly tied with the process of the diffusion of technology among those industries (Carayannis and Grigoroudis, 2014; Kirner et al., 2015). Thus, what should be checked is the level of innovativeness in the domestic industrial system in the various industrial divisions.

3. Characteristics of the Research Sample and the Methodological Aspects of the Conducted Analyses

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 itself of the questionnaire took place over the years 2008–2013, but is ongoing and continuously updated.

The structure of the examined companies as based on their size, technological class, and geographical location is presented in Table 1.

No.	Company size	Company structure in the study (%)	Company structure in accordance with GUS (%)
Company size			
1	Micro and small	72.6	75.5
2	Medium	21.5	19.7
3	Large	5.9	4.8
Company technological class			
1	Low	52.2	47.5
2	Medium-low	29.6	36.4
3	Medium-high	13.2	13,7
4	High	5.0	2.3
Company geographical location			
1	Lower Silesia	7.4	7.4
2	Kuyavia-Pomerania	6.0	6.0
3	Lublin	3.3	3.3
4	Lubusz	3.3	3.3
5	Łódź	9.0	9.0
6	Lesser Poland	8.0	8.0
7	Mazovia	12.9	12.9
8	Opole	2.3	2.3
9	Subcarpathia	5.0	5.0
10	Podlasie	2.1	2.1
11	Pomerania	6.1	6.1
12	Świętokrzyskie	2.7	2.7
13	Silesia	12.3	12.3
14	Warmia-Masuria	3.8	3.8
15	Greater Poland	11.6	11.6
16	Western Pomerania	4.2	4.2
Total		100.0	100.0

Tab. 1. Number and Structure of Studied Industrial Companies in Terms of their Size, Ownership Form, Technological Class, and Location. Source: own work on the basis of conducted research and the BDL Local Data Bank.

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The functioning of the company within the framework of a given division of the industrial processing section according to NACE Rev. 1 (PKD 2007) was assumed in the form of independent variables in order to accept or reject the basic research hypotheses. Low technology divisions encompassed as independent variables include the following: division 10 – food products, division 11 – beverages, division 12 – tobacco products, division 13 – textiles, division 14 – clothing and furs, division 15 – leather and leather goods, division 16 – lumber and wood, straw, and wicker products, division 17 – pulp, paper, and paper products, division 18 – publishing, printing, and reproduction of information media, division 31 – furniture, and division 32, excluding group 32.5 – other products not classified elsewhere. Medium–low technology divisions include: division 19 – coke and petroleum products, division 22 – rubber and plastic products, division 23 – non-metal products, division 24 – metal production, division 25 – metal products, excluding machines and equipment, and group 30.1 – ship and vessel building. Medium-high technology divisions include: division 20 – chemical and chemical products, division 27 – electrical equipment, division 28 – machine and equipment not classified elsewhere, and division 29 – mechanical vehicles, trailers, and semi–trailers, excluding motorcycles, group 30.2 – locomotives and tramcars, rolling rail and tram stock, and motorcycles and bicycles, group 30.9 – other transportation equipment not classified elsewhere, group 33.1 – repair and maintenance of ready metal products, machines and equipment, and group 33.2 – installation of industrial machines, equipment, and furnishings. The high technology divisions include: division 21 – pharmaceuticals and division 26 – computers and electronic and optical equipment, group 30.3 – spacecraft and airships, and group 32.5 – medical equipment and instruments.

For their part, dependent variables have been assumed as the occurrence in the company of research and development activities and innovation in the form of material assets (investments), subdivided into buildings and structures, machines and technical equipment, and computer software.

The above-listed variables mirror the questions that were included in the questionnaire survey forwarded to industrial companies throughout Poland. The questions were closed in character, which means that it was necessary to choose the appropriate answer from a list of provided possibilities.

The adoption by the dependent and independent variables of dichotic values means that other popular methods of modeling, such as multiple regression, can only be applied to a limited extent. However, it is possible to use logistic or logit modeling.

The logistic regression model describes the influence of the $x_1, x_2, \ldots, x_k$ variables on the dichotomous variable Y. The dependent and independent variables used in the study are dichotomous in character. This means that they assume a value of 0 or 1. In the case of dependent variables (describing innovation activities), this means that the given type of innovation activity was present in the company (in which case in assumed a value equal to 1)

or it was not present (and the variables assumed a value of 0). As to the independent variables, the value 1 was assigned to the PKD Polish statistical classification of economic activity division or group representing the given company, while the 0 value was applied to all other PKD divisions or groups.

In logistic functions, the probability model may be presented using the following mathematical formula:

$$P_i = P(Y = 1 \mid x_1, x_2, \ldots, x_k) = \frac{e^{\left(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i\right)}}{1 + e^{\left(\alpha_0 + \sum_{i=1}^{k} \alpha_i x_i\right)}}$$

Where:
P_i – Probability of the occurrence of a situation where $Y = 1$
α_i – The regression coefficient for $i = 0, \ldots k$
x_i – The independent variable for $i = 1, 2, \ldots k$

In its turn, the probability of a situation in which $Y = 1$ not occurring may be stated as follows:

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

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

In comparing the probability of the occurrence of $Y = 1$ with the probability of this situation not occurring, what is received is an odds ratio that can be stated as follows:

$$\frac{P_i}{1 - P_i}$$

In its turn, the natural logarithm of the odds ratio is known as a logit that takes on the following form:

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

The received odds ratio describes the strength of the relation or lack of independence between the two variables. In the event that the odds

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ration achieved a value that is greater than one, this means that for the given independent variable the chances of the dependent variable achieving a value that is equal to one are greater than for all other independent variables put together. In its turn, the achieving of an odds ratio less than one means that for the given independent variable the chances of the dependent variable achieving a value equal to one are less than the chances of the remaining independent variables put together. The difference between the achieved value of the odds ratio and one demonstrate the strength of influence of the given independent variable.

4. The Impact of Industrial Structure on Financing Innovation

For a cumulative assessment of the contribution of individual industries on innovative activity in the domestic system, it was decided to interpret the main categories responsible for input (the financing of innovation) in line with international methodological standards in this area (OECD, 2005). These included the active creation of technology in the form of expenses channeled to research and development, the purchase of new fixed assets, including the passive transfer of technology (the purchase of machines and equipment as well as computer software), and investment in buildings where the new technologies are to be applied.

Most controversial and often raised in Poland is the relation between outlay on research and development (the creation of technology) and machines and equipment (the transfer of technology). In as much as that in developed countries approximately 60% of total outlay on innovation falls to research and development and the remainder mainly consists of investment outlay, in Poland these relations are different (the opposite). According to the GUS Central Statistical Office of Poland, investment expenditures amount to 75.6% of the outlay on innovation in Poland. Expenditure on research and development accounts for 19.3% (*BDL Local Data Bank*, 2015). The share of the latter should, in fact, be considered quite high and an actual breakthrough because their significant increase has only been noted for the past two years as the effect of financing programs utilizing European Union funding. Together, the two groups account for 94.9% of all outlay on innovation in Poland. For this reason they shall be discussed in detail from the perspective of input by individual industries in molding innovation in Poland.

Several interesting regularities were noticed upon analyzing the collected research material (Table 2). The first of these was the fact that unequivocally indicates that companies utilizing low technology have a much lower tendency to conduct research and development work than entities in the medium-low, medium-high, and high technology sectors. Moreover, as the level of utilization of technology grows, so too does the chance of implementation of research projects by the examined companies.

Variable	Research and development	New investments	Including		
			Buildings and structures	Machines and equipment	Computer software
Low technology					
Food and beverages	0.818 (**)	0.715 (***)	–	0.768 (***)	0.511 (***)
Tobacco products	0.153 (*)	–	–	–	
Textiles	0.770 (*)	0.487 (***)	0.726 (**)	0.605 (***)	0.591 (***)
Clothing and furs	0.495 (***)	0.514 (***)	0.590 (***)	0.679 (***)	0.517 (***)
Tanned leather and leather goods	–	0.233 (***)	0.303 (*)	0.679 (***)	0.438 (**)
Lumber and wood, straw, and wicker products	–	0.751 (**)	–	–	0.610 (***)
Pulp, paper, and paper products	–	–	–	–	
Publishing, printing, and reproduction	–	–	0.617 (***)	–	3.086 (***)
Furniture and other unclassified activities	0.778 (**)	–	–	–	
Medium-low technology					
Coke, petroleum products, and nuclear fuel	2.914 (**)	–	–	–	
Rubber and plastic products	–	–	–	–	
Other non-metal products	–	–	–	–	
Metals	1.602 (**)	–	–	–	
Ready metal products, excluding machines and equipment	–	–	–	1.235 (**)	
Ships and vessels	–	–	–	–	
Medium-high technology					
Machines and equipment	2.009 (***)	–	–	–	1.584 (***)
Machines and electrical equipment	1.969 (***)	–	–	–	1.751 (***)
Mechanical vehicles, trailers, and semi-trailers	–	–	–	–	–
Chemical products, excluding pharmaceuticals	3.370 (***)	–	1.465 (*)	–	–
Motorcycles and bicycles	–	–	–		

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Tab. 2 cont.

Variable	Research and development	New investments	Including		
			Buildings and structures	Machines and equipment	Computer software
High technology					
Office machines and computers	4.204 (***)	–	–	3.020 (**)	4.420 (***)
Radio, television, and communication equipment and devices	3.644 (***)	–	–	–	2.534 (**)
Medical, precision, and optical instruments	2.353 (***)	–	–	–	1.740 (***)
Pharmaceutical products	3.577 (***)	–	–	–	–
Airships and spacecraft	–	–	–	–	–
Company size					
Micro	0.574 (***)	0.524 (***)	0.513 (***)	0.644 (***)	0.342 (***)
Small	–	–	–	–	0.602 (***)
Medium	1.901 (***)	1.514 (***)	1.519 (***)	1.374 (***)	–
Large	4.007 (***)	1.476 (**)	1.657 (***)	1.501 (***)	–
Company ownership					
Domestic company	0.620 (***)	0.746 (**)	0.813 (**)	0.810 (*)	–
Foreign company	–	–	–	–	1.657 (***)
Constant	0.741 (***)	5.669 (***)	0.473 (***)	2.923 (***)	2.783 (***)
Sample size	5209	5209	5209	5209	5209
Chi^2	668.02	262.50	364.83	178.89	515.60
p value	0.00	0.00	0.00	0.00	0.00

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

Tab. 2. Odds Ratios in Multiple Logit Regression Portraying the Influence of Industrial Structure and Company Size and Ownership in Research and Development as well as Investment in New Fixed Assets, including Machines, Equipment, and Computer Software in Poland. Source: own calculations on the basis of conducted questionnaire surveys.

In was noted that in companies from the low technology sector, it was entities involved in tobacco products that had the lowest chances of conducting research and development work. Their chances were 85% lower than in the case of other sectors. A consequence of the declining phase in the life of the clothing and fur product sector in domestic industry (Rachwał, 2010) is that the chances of conducting research and development work are over 50% lower than in the case of other sectors. Textiles and activities related to the manufacturing of furniture and other unclassified activities are characterized by chances of conducting research and development work that are over 20% lower than in the other sectors, while the figure for food and beverage production is 18.2%.

Among companies applying medium-low technology, the greatest potential linked with research and development activities is a characteristic of entities producing coke, petroleum products, and nuclear fuel. The chances of such work are almost three times greater than in the case of other companies. In the case of entities making metals they were 1.5 times greater than in the other groups of companies.

In companies representing medium-high technology, the increase in chances of conducting research and development activities were higher. Compared with the other groups of companies, the chances of conducting such work in entities making chemical products was 3.3 times greater and two times greater in the case of machines and technical equipment. Chances of conducting research and development work were almost two times greater in the case of companies manufacturing machines and electrical equipment.

The greatest potential tied with the conducting of research and development work was a quality of companies in the sector utilizing high technology in manufacturing. The chances of conducting research and development work in entities manufacturing office machinery and computers were over four times as high as in the case of other companies. The figure for entities making radio, television, and communication equipment as well as pharmaceutical products was over 3.5 times as high. The chances of companies making medical, precision, and optical instruments to conduct research and development activities was over twice as high.

On the basis of research the results received, it is possible to agree that the high-tech sector has achieved the critical mass necessary to self-maintain development. Its activity is not isolated. It is both strong and systemic. Its chances of actively creating new high technology are the highest in relation to the other industrial groups.

At this point it is worth noting that the industrial groups that have not achieved statistically significant parameters are a major burden on research and development in Poland. This mainly applies to the companies of the low technology areas. Their chances of such activity are lower by 25.9% than in the case of other entities.

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The relation is somewhat different in the case of investment incurred on new fixed assets and computer software. In as much as in the case of the conducting of research and development work it is the positive relations – i.e. there was a greater number of models portraying an increase in chances of conducting research and development work in line with an increase in applied manufacturing technology – that are primarily noticeable in the evaluated models, in the case of investment, most of the evaluated models stress a fall in chances to incur them in entities of the low technology sector. In entities from the medium-low, medium-high, and high technology sectors, chances for the appearance of such investment were greater and made their appearance incidentally.

The greatest fall in chances for new investment made its appearance in the group of companies producing leather and leather products. Overall, they were lower by over 75% as compared to the remaining companies, where in the case of buildings, the fall amounted to almost 70%, 32% for machines and equipment, and 55% for computer software. Chances of investment fell by about 50% in entities involved in making textiles, clothing, and fur products. In companies from the first sector, chances of investment in new buildings decreased by 27%, new machines by 40%, and new software by 41%. As to companies of the second sector, in two cases the falls were greater. Chances for investment in new buildings decreased by 40%, new machines by 32%, and new software by 48%. In companies that produced food and beverages, the probability of incurring expenses in connection with new investment is 29% lower than in other companies. This particularly pertains to the purchase of new machines and equipment, where the fall amounted to 23%, and new software, with a fall of 49%. For entities producing lumber and wood, straw, and wicker products, the probability of new investment is 25% lower than in other companies, where in the case of new software, the fall in chances amounts to 39%. What is noticeable in the case of companies involved in publishing, printing, and reproduction is the fall in chances of investment in new buildings, which amounts to 38%. At the same time, this is the only group of companies in the low technology sector where the chances of buying new computer software grew threefold.

Companies from the medium-low, medium-high, and high technology sectors note minimal connections between individual industries and investment in new fixed assets and software. A single parameter meeting conditions of statistical significance has been estimated for companies utilizing medium-low manufacturing technology. In entities making ready metal goods (excluding machines and equipment), the growth in chances for investment in new building amounted to 23%.

In companies utilizing medium-high technology, chances for investment in new computer software were greater than in companies that provide the market with machines and technical equipment (by 58%) and machines

and electrical equipment (by 75%) than in the case of other companies. The probability of investment in new buildings is 1.5 times greater than in entities producing chemical goods.

In companies from the high technology sector, parameters meeting conditions for statistical significance were estimated for three industries – office machines and equipment, radio, television, and communication equipment, and medical, precision, and optical instruments. In the first of them, chances for investment in the machine park are three times greater than in the other group of companies, while for computer software then are 4.4 times greater. For the second industry, the probability of investment in software increases by 2.5 times and 1.7 times in the case of the third with respect to other companies.

Not without meaning is the question of interpretation of free terms in the models as well as the absence of significant parameters for many industries in the medium-low, medium-high, and high technology areas. In the case of the model describing total new investments, the odds ratio for the free term achieved a value of 5.7. What this means is that for the group of companies for which no significant parameters were evaluated, the combined chances of such investments are 5.7 times greater than for low technology, without any special differentiating between types of industry, size, and ownership.

In the case of the model portraying company engagement in investment in new buildings and structures, the free term provides information that together, the industries that did not achieve statistical significance, burden chances for such investment by 52.7%. In models describing the passive transfer of technology (machines and equipment as well as software), what is seen is a situation in which the odds ratio for the free terms increases chances of the indicated activity in the others for which there is no individual statistic significance.

An unequivocal trend is visible in the impact of this variable on the creation of technology and new investment in the company when taking into account company size. On the basis of the estimated parameters, it is possible to forward the proposition that chances of conducting research and development work as well as for new investment grow with the size of the company. Micro-companies burden the examined variables because their chances of conducting research and development activities and total new fixed assets and new buildings are almost 50% lower than in other companies, 36% lower for new machines, and 66% for new software. A reversal of this trend is seen on the level of small companies. In their case only a single estimated parameter met statistical significance and proved that in these entities chances for investment in new software are almost 40% lower than in the case of other companies. Medium and large companies demonstrate significantly higher chances of conducting research and development work, where in the first group they are 1.9 times higher and in the

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second they are four times higher. Chances for incurring new investments are on a similar level in both groups. In the case of total size, they grow by 51% for medium companies and 48% for large ones. The probability of investment in new building by medium entities is greater by 51% and 66% for the larger ones than in the remainder of the group, while the figures for a new machine park are 37% and 50%, respectively. In comparing the character of ownership of the examined companies, what can be seen is that domestic entities are characterized by a low level of investment in innovation. Chances of conducting research and development work in their case are 38% lower than for entities in which foreign capital has a whole or partial share, while in the case of new investment the figure is lower by 25%. The probability of incurring expenses for new building and machines is 19% lower in their case. Chances of investment in new computer software grow in foreign companies. They are 66% greater than in the case of domestic entities.

In summary, subject to Polish conditions, the involvement of industries in financing innovation is strongly determined by type and membership in a specific group of technological advancement and core activity. In as much as in the case of research and development, what can be observed is the low involvement of the most mature industries (outdated) and growth with each level of technological advancement, in the case of the remaining types of innovative activities behavior is completely or partially different and requires separate interpretation.

New investment is encumbered as to chances of implementation in the case of low technology industries. At the same time, all other technological groups are strongly involved in such activities without any significant differentiation among industries, with the exception of isolated cases for which statistical significance was achieved. There, what is visible is low interest in such investment overall. As to the purchase of machines and equipment as well as software, exploited industries are a strong and systemic burden, where other entities, individually or jointly, are accelerating technological change in domestic industry.

5. Conclusions

In the very few studies performed to date in other countries over the past few decades on the impact of industrial structure on innovation, there is only one case of an attempt to statically verify such links – the Pavitta analysis. In all other cases, the studies were primarily based on qualitative analyses of simple quantitative comparisons, which is mainly a consequence of the accessibility of data – restrictions stemming from statistical confidentiality. The multinomial logit modeling used in this paper in order to verify basic hypotheses turned out to be an interesting and rewarding method that, apart from defining the input of individual industrial divisions

into innovation on a domestic level, demonstrated qualitative and systemic inter-sectorial interactions depicting the Polish economy, its specifics, and its level of technological advancement.

In connection with the Pavitta model, the Polish economy is dominated by a strong dependence on suppliers representing transitional branches of industrial processing whose technological trajectory is linked to a lowering of costs and where the source of technology is the suppliers, with their purchased research services as well as major users. In the case of companies achieving significant benefits of scale (manufacture of large-volume products, assembly industries, and the automotive industry), the source of technology is parts and component suppliers as well as in-house research and development. The smallest group consists of companies that are based on scientific research (the electrical and electronic industries and the chemical industry), where the source of technology is public sector research and development as well as in-house research and development work.

It is on the basis of performed analyses that it may be stated that companies operating in traditional manufacturing industries have less of a tendency to finance innovation coupled with research and development activities, investment in new fixed assets, and computer software. For their part, medium-low, medium-high, and high technology companies conduct research and development work more often. Bearing in mind the significance of the evaluated models and the number of their parameters, it is possible to agree that the regularities are systemic in character.

Statistically, companies utilizing low technology in manufacturing are much less willing to financing innovation. This especially pertains to investment in new fixed assets as well as new computer software. There are several exceptions to this principle, however. Companies involved in printing have higher chances of implementing new computer software. This means that these entities are dynamically keeping pace with changes that are making their appearance on the software market and are absolutely necessary (supporting industries) to set up text or images for printing. Companies making clothing and fur products, textiles, leather and leather products are uniformly little inclined to finance innovation.

The lack of activeness connected with the financial aspects of innovation in low technology entities, especially in the area of research and development activities, confirms the static nature of their functioning. The proposition may be forwarded that these entities have achieved a certain market balance and until such a time as strong perturbations appear that might threaten their functioning, they will not be interested in incurring expenses in order to analyze areas of innovative activities.

It is on the basis of the described relations that it is possible to clearly see that in the case of Poland entities utilizing low technology in manufacturing do not have the knowledge and feel no need to compete through new solutions by developing them. In its turn, what is significant is the

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information that entrepreneurs from the remaining sectors appreciate the importance of undertaking research work, which is visible in the activities in this area. Particularly large differences are observable between manufacturing entities qualified as low technology and those qualified as medium-high and high technology. This may bring with it a passage from the technological-dependence model for creating novelties to anticipating events, the appearance of new products, and their introduction to foreign markets even if these will be solutions that are imitations of those applied by other entities to date.

What is noticeable in the case of companies from the medium-low, medium-high, and high technology sectors is the minimal links between the examined sectors and investments in fixed assets and computer software. However, if they do appear they show that chances of their occurrence are higher than in the case of other companies. The systemic conducting of research and development work in these companies is noticeable in not only the high and medium-high technology sectors. It can also be seen in the medium-low technology sector. A negative phenomenon in this case the small number of significant parameters coupled with investment in new machines and technical equipment. Thus, research work does not bring with it the modernization of production systems.

What is clearly visible on the basis of the conducted analyses is the weakness of the Polish sector of traditional industries. With a single exception, not only do they not conduct research and development work, but there is also a lack of any passive transfer of technology in the form of machines and equipment or new computer software. This means that these sectors, making up the bulk of economic entities in Poland, strongly burden the domestic industrial system.

The other industries diverge significantly from the low technology sectors. Specifically, with growth in advanced technologies, chances for conducting research work improve. This proves that the importance of knowledge and intellectual property grows in the awareness of entrepreneurs. However, there is a lack of diversified behavior between industries in the passive transfer of knowledge in medium-low, medium-high, and high technology manufacturing. Simultaneously, this signifies systemic character – it applies to all jointly. Also important is the fact that in spite of models meeting conditions of statistical significance, entrepreneurs from these sectors, jointly, are much more willing to transfer knowledge than entities applying low technology manufacturing. Perhaps, such relations between research and development activities and the passive transfer of knowledge is a sign of reaching the moment when an economy starts to be saturated with outside innovation and the creation of own innovative solutions is becoming a prerequisite for achieving a competitive advantage. This would be a witness to positive changes in Polish industry.

An important element of research is the inclusion for analysis of variables tied with the size and ownership of the examined companies. Unfortunately,

an anti-innovation position on the part of micro-companies is visible. The locomotives of technological change are the medium and large companies. At the same time willingness to conduct research and development and to invest in new fixed assets and computer software is low among domestic entities.

The conducted research has not only shown the specifics of the domestic industrial system as well as its level of technological advancement, but it has also taken into account the interaction among the industries through the lens of their statistical significance and input into the analyzed system. As a result, the divisions of industry responsible for innovation in Poland as well as those that do not influence it have been recognized. What is more, statistical chances – the strength of influence of individual industrial manufacturing divisions on the innovativeness of the domestic economy – have been identified.

Due to its time-related limitations, the conducted analysis does not show the directions and dynamics of change in innovation activities as taking place in the individual types of industries. Understanding them requires a repetition of the conducted research in the future and the performance of a comparative analysis. A different challenge tied with the nature of the Pavitta classification is the minimal degree to which the services sector is encompassed, including services of the highest added value such as services offered users throughout the country and services that are the subject of international trade (e.g., logistics, shipping, business, and tourist services) as well as services with significant knowledge content (e.g., information technology, design and engineering, consulting, and research an development services) that are becoming the foundation of each and every modern industrial system. Thus, it seems that there is an immediate need to supplement knowledge in this area in the nearest future.

Endnote

[1] This paper only concentrates on questions of industrial structure. Nevertheless, detailed and statistical research on the influence of company size and ownership on innovation in the domestic industrial system has been conducted by A. Świadek (Świadek, 2014; Świadek, 2015).

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