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Interactions in Innovation Process as a Factor of Innovativeness and Efficiency of Enterprises – Analysis Based on the Polish Innovation System.

Abstract:

According to the concept of an innovation system, an innovation system consists of institutions and interactions between them. Thanks to them a given economy is an efficient mechanism of distribution of knowledge for its further recombination. The concept shows how the linear and network-based character of innovation process affects the functioning of an economy, which for growth depends on innovations. The analysis of the impact of the more intense interactions of the Polish enterprises in the innovation process on their innovativeness and competitiveness proves the concept of innovation system to be right. Analysis performed through different methods confirmed the validity of the hypothesis that there is a positive relationship between an interactive way of innovation activity and the effectiveness of innovation process and hence success of firms.

Key words: innovation process, innovation system, enterprises, networks and interactions

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The concept of an innovation system is quite a new approach to innovativeness. The concept shows how the linear and network-based character of innovation process affects the functioning of an economy that depends on innovations to grow. The concept perceives the economy not only as institutions, entities, but also as synergetic effects created due to reciprocal interactions and co-operation of agents. That is why, apart from institutions generating innovations, such as enterprises, the R&D sphere, and bridging institutions, the concept of innovation system appreciates the role of interactions between them. Thus an innovation system consists of institutions and interactions between them, thanks to which a given economy is an efficient mechanism of distribution of knowledge for its further recombination. Enterprises are the most important component of an innovation system and hence their standing determines the competitiveness of states and well being of societies.[2] According to the new growth theory, knowledge is the main factor determining productivity. Efficient innovation system, which is a system distributing knowledge, will stimulate a quicker development of the whole economy.

The concept of the innovation system is not a fully-fledged theory. Hence an investigation was carried out whether there is a positive impact of interaction and co-operation based style of innovation process on the higher innovativeness and competitiveness of enterprises of the Polish Innovation System. A verification of this hypothesis would prove that the statements of the conception of an innovation system are right.

1. The model of the innovation system

The model, which was the framework of the analysis, was based on the OECD approach (OECD 1997). The innovation system according to the model consists of entities generating knowledge and innovations and of knowledge transferring channels that make the

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on PhD dissertation carried out at the Gdańsk University

[2] OECD (1996) The Knowledge Based Economy

agents to be a system fulfilling function of knowledge distribution for stimulation of innovativeness.

The concept of an innovation system stresses the role of interaction and co-operation between various agents such as companies, public research and development (R&D) institutions, including universities, scientific institutes and public and private bridging institutions (technology transfer centers, knowledge intensive business services etc.). These organizations create and distribute knowledge and innovation. The key components of the environment of the innovation system are consuments of innovation, as they create demand for it. Public policy is also crucial, which should stimulate innovation rather than handicap it. Sometimes this policy may be an active agent of the innovation system, for example in the case of R&D consortia with the participation of the government. Another important aspect of the environment is infrastructure, that is communication and financial infrastructure, as well as all the regulatory aspects, such as intellectual property law. The enterprises are perceived as the most important component of the system. This model, first of all, underlines the direct and indirect connections between individual agents of the system. The direct linkages are those concerning joint research or innovation activity based on co-operation between enterprises and between firms and R&D institutions, as well as between firms and knowledge intensive services (KIBS). Indirect linkages are less connected with a particular innovation, but improve the overall innovation potential of a firm. These are technology transfer and mobility of personnel. Due to the connections, knowledge is transferred between agents and external benefits occur that stimulate higher innovativeness and effectiveness both of individual agents and the whole system.

One could speak about any system of innovation where there are both static elements, such as institutions, and dynamic elements, such as interactions. Linkages are kind of a glue that holds the elements together into a system which is a distinguishable unit having specific

functions. Interactions and co-operation of agents in a system cause a quicker distribution and growth of the existing knowledge, hence innovativeness and competitiveness also increase. It is supported by the new growth theory, which says that knowledge is the main factor determining productivity and economic growth. Co-operation networks have many advantages: they lead to lower transaction costs and help to overcome some market failures. With better information, they also cause savings by consolidating work into a single effort. Moreover, there are some particular resources such as people with specific abilities to whom many agents would like to have access. Co-operation in such situations is the best solution. The necessity of networks in today's economy also originates in the changing character of some sciences, which crosses the borders of traditional sciences and industries, such as biotechnology, and co-operation is needed for their applications. On the other hand, now it is easier to communicate and co-operate due to the development of modern means of communication such as Internet and modern transportation. The interactive character of the innovation process leads to a transformation of firms. Namely, such a firm will always have more functions realised by subcontracting to other entities because it is anyway impossible to gather all the functions required for innovation in one place.[3]

2. The state of the Polish innovation system

Based on the statistical data and the empirical data gathered during research in the years 2000-2003, it was investigated whether enterprises in Poland create linkages in the innovation process[4]. The analysis examined the innovation system in Poland from the perspective of enterprises. The analysis of all the institutional sectors of an innovation system was not carried out as well as the analysis of linkages from the perspective of other than enterprise agents in the system. The main conclusions of this analysis are as follows:

[3] Wojnicka et. al (2002); Basing on: OECD, KBN (1998) Nauka, technika, przemysł – przegląd 1998; Rheines P.(2002) How to set up a local cluster, EPRC, presentation during the international conference on territorial development Paris 28-30 January 2002; Delphie'98, Introduction: How we will shape our future?, Fraunhofer Institute Systems and Innovation Research.

The analysis has shown a dramatic situation especially in the field of research and development activity of firms. Along with the low overall R&D expenditure in Poland it leads to the decrease of innovativeness of enterprises. This is accompanied by their declining profitability in the years 1995-2001. It derives partially from the lack of large enterprises, which would conduct R&D. A significant fraction of large enterprises in Poland are foreign investors, which carry on R&D activity in Poland only to a small degree. Most of the Polish enterprises nowadays are small and medium sized firms and their potential to conduct research is usually slender. Yet the high-technology sector that conducts research is growing in Poland to a larger extent. However, the intensity of R&D that exists is lower by international standards. Similarly, innovativeness of SME in Poland is also weak, if perceived as a sector. Nevertheless, some examples of innovative and technologically advanced enterprises are present among them. Yet most of the firms focus on current issues, without long-term strategies of development. These may be secured only by innovativeness.

To some extent it derives from the lack of preparation of many of the Polish entrepreneurs to operate in a market economy. Low innovativeness of SME is also partially caused by their inability and fear of joining networks, creation of linkages in innovation process, and overall economic activity. As a result, the intensity of connections in the innovation process in Poland from the perspective of all the enterprises is very weak. Only relatively few innovative enterprises, especially large firms, create connections with other agents of the innovation system. The weakest is the co-operation among enterprises and R&D sphere. Thus the development of different forms of co-operation of enterprises, especially SME, in the R&D sphere should be the key component of the innovation policy of Poland. Horizontal interactions among firms are also weak, which stem from the fear of co-operation. They are superficial and conformed to short-term profits perception of

[4] The research carried out for the analysis as well as the statistical data used are presented in the bibliography

competitiveness as a “fight” in which only one party may win. The concept of an innovation system based on external benefits from knowledge assumes however that a “win-win” situation in a market game is possible. Indirect linkages of the Polish enterprises in the innovation system are quite strong, such as technology transfer and mobility of personnel. No significant barriers in the accessibility of technology, that is intermediaries and suppliers, occur. Yet it is mainly a transfer of foreign technology, which resembles the weakness of the research activity in the Polish enterprises and in the field of technology commercialization of the Polish R&D sphere. The Polish enterprises start to appreciate employees and their mobility as a source of tacit knowledge essential for innovativeness and competitiveness of enterprises. However, still the interactions between enterprises and their employees in the form of participation in trade fairs, conferences, professional trainings and organizations of entrepreneurs are in Poland weak. A positive sign is that some of the international corporations present in Poland conduct here research activity, as well as appreciate the role of accessibility of skilled personnel. Moreover, international corporations create links to the Polish enterprises, but they are mainly transactional.

The existence of an innovation system as a scheme of interconnected entities is hard to detect in Poland. The real innovation system, namely intensive linkages in the innovation process between entities in Poland, concerns only a small group of innovative firms. This means that the Polish innovation system may be an efficient framework for knowledge transfer, but the barriers in the access to knowledge transferring channels for the majority of firms are difficult to overcome. This partially derives from an insufficient knowledge of the entrepreneurs.

The analysis of knowledge transferring channels from the perspective of all the types of entities, as well as the analysis of their innovation potential, would make the overall assessment of the distributing power of the Polish innovation system possible. Assuming

however that enterprises are the most important component of an innovation system, the diagnosed blockades of the particular knowledge transferring channels in the innovation system seem to be the most important "weak points", which should be overcome to increase the efficiency and effectiveness of the whole economy.

3. Verification of the hypothesis

Verification of the hypothesis of the positive impact of interactions and co-operation based style of innovation process on higher innovativeness and competitiveness of enterprises was done using statistical and econometric tools. Different tools were used for different kind of data. For statistical- quantitative data linear regression and Pearson's coefficient of correlation was used. For qualitative data, the most suitable turned out to be logit regression and path modeling, as well as Spearman's coefficient. For some data grouping and comparison were used as the method of analysis with the "z" test for the importance of the difference between the averages. The conclusions of the analysis basing on these methods are as follows:

3.1. Linear regression and correlation

On the level of industrial branches in Poland the positive impact of higher intensity of innovation co-operation agreements with different agents on the share of revenues from innovations in the overall revenues of a branch was noticed.

Significant positive correlation (coefficient of correlation 0,64 at the significance level p=0,05) was noticed between quotient of concentration of agreements in branches and the share of sale of new and modernized products in the sale of branches.[5] The quotient of concentration of agreements relates to the period 1998-2000. The indicator of the innovation revenues concerns the years 1999-2001, so it is lagging in comparison with the agreements in

[5]Concentration quotient is defined as the relation of the share of a given branch in the total number of innovation agreements to the share of a given branch in the total number of firms. The data concerned all the industrial enterprises of Poland investigated by the Central Statistical Office.

the innovation process.[6] It suggests that the intensity of co-operation in the innovation process has an impact on the innovativeness of industrial branches. This thesis was investigated with the help of linear regression estimated using the method of least squares. As a result the theoretical function of the exogenous variable $y' = \beta_0 + \beta_1 x$ where y= share of innovation revenues in the i- branch, and x = intensity of agreements in the i– branch, such that, $y' = 10{,}8942 + 4{,}43x$. Intensity of agreements has significant impact on the share of innovation revenues in a branch in the next period with the t-Student statistic and the F-test showing that the probability that $\beta_1=0$ is only 0,001. Hence, with other conditions constant, the 1% increase of the level of concentration of agreements in a branch causes the 4,43% increase of the share of innovation revenues in a branch in the next period (with the +/- 1,18% accuracy).[7]

3.2. Logit regression and Spearman's correlation

Econometric analysis of the qualitative data was done using logit regression and path model. Logit regressions are used to point out the factors that increase chances that the exogenous variable will have the given character. They define probability that the exogenous variable will be 1 or that it will be 0 with the given parameters and values of the endogenous variables, which also should be but do not have to be binary. In the analysis of interactions in the innovation process and their impact on innovativeness the precise values of parameters are not the most important. The logit regression is here used to confirm positive relationships between co-operation in innovation process and innovativeness and competitiveness. The aim is to show the impact of the co-operation on competitiveness with the assumption that the relationship is indirect that is the co-operation is required for innovation process and innovations for competitiveness of firms. The path model is a tool to find the direct and

[6]Similar value of the indicator was noticed for the percentage of firms having agreements in the branch and innovation revenues (indicator of linear Pearson's correlation = 0,64)

[7] $R^2 = 42$, DW statistic and Godfray's test proves lack of autocorrelation of disturbances, RESET Ramsay's test proves that linear model is the correct form.

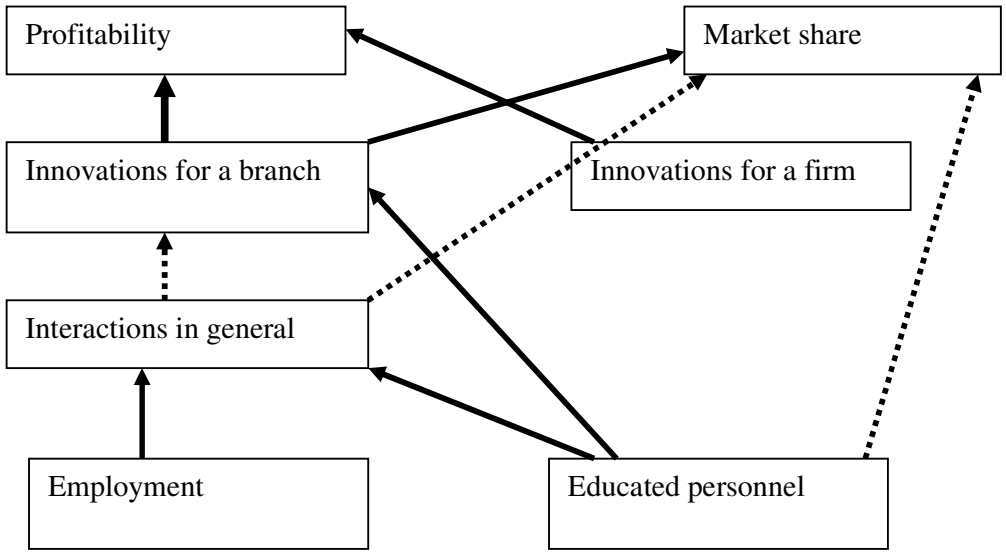
indirect relationships. The variables in this model are once exogenous and described by other variables and later on endogenous and describing other variables according to the conceptual model of linkages. As a result a set of paths is created, which shows the linkages between the variables. The variables in the paths may be both dependent on other variables as well as describing other variables.

In the estimation of different models for the data collected in the research into enterprises located in the places of the highest statistical probability of the existence of local production systems (data from 140 – logit 1 and logit 2 and for 224 enterprises – logit 3) three significant sets of paths were obtained. The paths confirm the hypothesis of the positive impact of interactions in the innovation process on competitiveness of firms by its impact on the innovativeness of firms (diagrams 1-3). The diagrams 1-3 show the relationships between variables describing co-operation (interactions in general, co-operation with universities and knowledge intensive services – KIBS) and resources (educated employees, number of employees) and variables connected with innovativeness (innovations for the branch and for the firm) and variables describing competitiveness (the growth of market share and the growth of profitability).

As the diagrams show interactions of enterprises in an innovation process and especially co-operation with knowledge intensive business services and universities increase chances that a firm will introduce innovations new to the market, and indirectly the chances for higher profitability and growth of the market share. Moreover, particularly important for effective innovation process is the level of education of the employees and their mobility. The enterprises employing more personnel with university level education, located in the places of the highest statistical probability of the existence of a local production/innovation system, are characterized by stronger interactions with R&D sphere, higher innovativeness

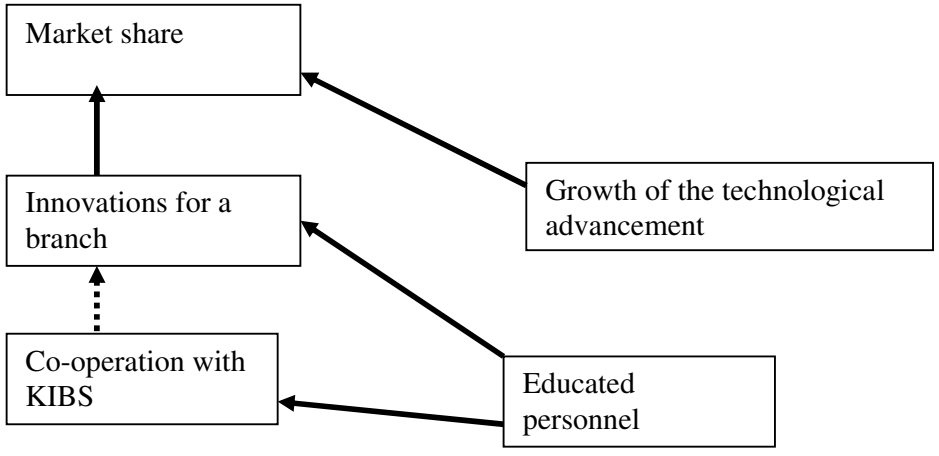
and effectiveness. The analysis has shown that interactions have impact on the firms' competitiveness, however chiefly indirectly that is through their impact on innovativeness.

Diagram 1. Paths estimated in the model Logit 1.



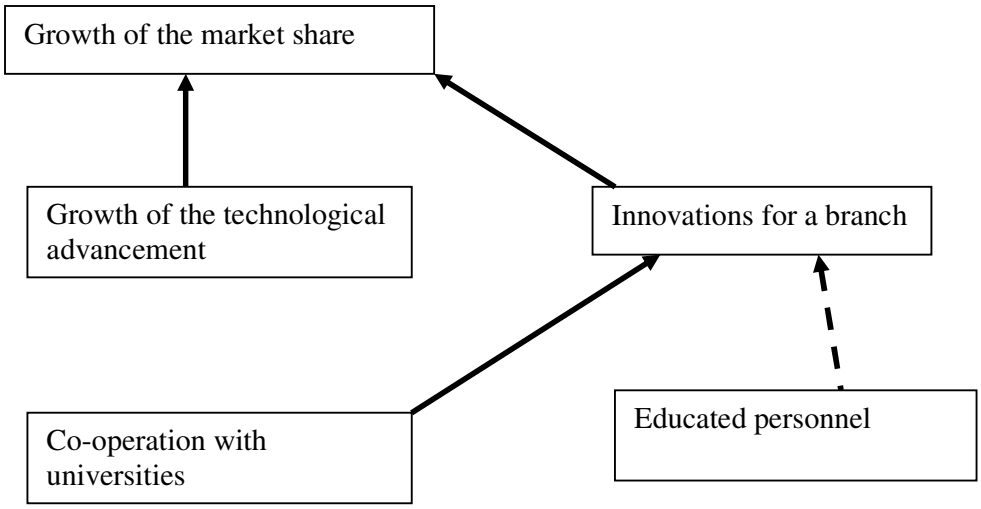
Source: On the basis of author's analysis of the paths estimated using logit regression. Uninterrupted arrows indicate strong relationships (p<0,05 t>1) intermittent arrows mean weak relationships (t>1 ale p>0,05).

Diagram 2. Paths estimated in the model Logit 2



Source: On the basis of author's analysis of the paths estimated using logit regression. Uninterrupted arrows indicate strong relationships (p<0,05 t>1) intermittent arrows mean weak relationships (t>1 ale p>0,05).

Diagram 3. Paths estimated in the model Logit 3



Source: On the basis of author's analysis of the paths estimated using logit regression. Uninterrupted arrows indicate strong relationships ($p<0,05$ $t>1$) intermittent arrows mean weak relationships ($t>1$ ale $p>0,05$).

For the data on the enterprises located in the potential clusters also the analysis of correlations was done. Because of the qualitative character of the data, Spearman's co-efficient of correlation was used. Analysis of correlation has shown many positive and significant relationships between co-operation in the innovation process and innovativeness and competitiveness of enterprises. Table 2 shows positive and significant correlations between these variables.

Table 2. Positive and significant correlations between variables of innovativeness and the variables of co-operation and resources and competitiveness.

Co-operation and resources	Innovativeness	Competitiveness
Mobility of personnel Interactions in general Co-operation with universities Co-operation with KIBS Co-operation with R&D sphere in general Educated personnel	**Branch level innovations**	Growth of profitability Growth of market share Sale's dynamics
Co-operation with R&D sphere in general Co-operation between firms and R&D Interactions in general Mobility of personnel Co-operation with KIBS Co-operation between firms in innovation process Educated personnel	**Firm level innovations**	Growth of profitability Growth of demand

Mobility of personnel Co-operation with R&D sphere in general Interactions in general Co-operation with technical universities	**Technological advancement**	Growth of market share Growth of demand Growth of profitability

Source: Author's calculations

A well-educated personnel is the variable that is positively and directly correlated with almost all the variables describing innovativeness, co-operation and competitiveness. Greater shares of employees with university level education are connected with stronger interactions of firms in innovation process, as well as with higher innovativeness and growth effects in terms of competitiveness that is growth of a market share. Moreover, firms employing more people with tertiary level education experienced growth of demand for their products. The highest co-efficient of correlation– 0,42 was observed for the level of education and co-operation with technical universities, which means that the employees keep relationships with their academia. Significant role of educated personnel reflects the strait connections between the conception of innovation system and the knowledge-based economy. Namely, innovation system in the dynamic approach is a scheme for transferring knowledge in the economy. Knowledge, however, as the new growth theory states, and as the above analysis supports, on the micro level has impact on productivity and efficiency. High coefficients of correlations were also noticed between the branch level innovations and the growth of market share and profitability – respectively 0,34 and 0,33 as well as between technological advancement and the growth of market share – 0,32. The relationship between firm level innovations and the growth of profitability was weaker, with the coefficient equal 0,26. The analysis of correlation also showed strong positive correlations between branch level innovations and variables of co-operation in the innovation system. That is especially mobility of personnel and interactions in general, respectively 0,3 and 0,28.

3.2. Grouping and comparison

The hypothesis of the positive impact of interactions with other entities on innovativeness and competitiveness was also confirmed using grouping and comparison methods. These were applied to the data from the research, quoted below, into the whole sector of micro, small and medium-sized enterprises of Poland and for high-technology SMEs of the Eastern and Western Regions of Poland. In the sector of micro, small and medium sized (SME) enterprises of Poland, it was observed that firms co-operating with R&D institutions had higher shares of exports in sales (table 3). Firms co-operating with other enterprises in research and development had higher average revenues from innovations. SME co-operating in the innovation process perceive better their competitive position in terms of technology and in relation to the domestic and foreign competitors (table 4).

Table 3. The share of export in sales among SMEs not co-operating and SMEs co-operating with R&D sphere.

Average (%)	**Sales on local markets (%)**	**Sales on domestic markets (%)**	**Sales on foreign markets**		
			Average	Standard deviation	„z" test (P(C=NC))
SMEs co-operating with R&D sphere	59,5	32,2	8,4	21	0,02
SMEs not co-operating with R&D sphere	77,7	19,4	2,9	12	

Source: Own calculations on the basis of firms' questionnaire

Table 4. Technological lagging behind competitors (1- lack of lagging behind 2- less than 1 year 3 - 1 – 3 years 4 –3 to 5 years 5 - 5-10 years 6 – more than 10 years)

Technological lagging behind domestic competitors				
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
SMEs performing joint R&D with other firms	1	1	1	5
SMEs co-operating with other firms	1	1	2	6
SMEs not co-operating with other firms	1	1	3	6

Technological lagging behind competitors from EU-15				
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
SMEs performing joint R&D with other firms	1	2	3	6
SMEs co-operating with other firms	1	3	5	6
SMEs not co-operating with other firms	1	3	5	6

Source: Own calculations on the basis of firms' questionnaire

High-tech SME from the Western and Eastern regions of Poland co-operating with R&D sphere are more innovative, characterized by higher net profitability and have higher shares of exports in sales than the non co-operating firms examined in the research. The highest differences in favor of the co-operating firms concerned the share of innovation revenues in total revenues and the net profitability (table 5 and 6).

Table 5. Co-operation/Innovations according to the indicator of the share of innovation revenues – structure of innovativeness of the high-tech SME in the groups co-operating and not co-operating with R&D sphere

	1999		2000		2001	
	Co-operating	**Not co-operating**	**Co-operating**	**Not co-operating**	**Co-operating**	**Not co-operating**
0%	24%	31%	17%	36%	12%	33%
1-5%	17%	38%	27%	43%	27%	40%
6-15%	29%	23%	20%	14%	24%	7%
16% - 30%	15%	8%	15%	7%	10%	13%
31% and more	15%	0%	22%	0%	27%	7%

Source: Firms' questionnaire

Table 6. Co-operation/ Net Profitability – structure of profitability of the high-tech SME in the groups co-operating and not co-operating with R&D sphere

	1999		2000		2001	
	Co-operating	**Not co-operating**	**Co-operating**	**Not co-operating**	**Co-operating**	**Not co-operating**
Loss	13%	15%	9%	31%	20%	31%
0%-3%	20%	46%	33%	44%	28%	38%
3,1% - 10%	36%	23%	33%	13%	30%	25%
10,1% and more	31%	15%	26%	13%	22%	6%

Source: Firms' questionnaire

Analysis performed with the help of different methods confirmed the hypothesis of the positive relationship between an interactive way of innovation activity and the effectiveness of innovation process and hence success of firms. It means that the assumptions of the concept of innovation system are right and that the intensification of connections between the agents of the innovation system of Poland may enhance the innovativeness and competitiveness of enterprises.

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