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THE ROLE OF COOPERATION AND OBSERVATION IN INNOVATIVE ACTIVITY OF POLISH ENTERPRISES: RESULTS FROM CIS 2008

1. INTRODUCTION

Joseph Schumpeter (1934) was the first economist to use the term “innovation” in the sense in which it is used today, and in 1939 he developed a theory of innovation process as divided into three stages: invention, innovation and imitation. The innovation process entails investment to create an invention, transform the invention into a product innovation and diffuse the innovation across companies, industries or economies.

Since 1930s the perception of the innovation process, especially of determinants crucial to success at each stage of the process or the sequence and overlapping of tasks needed to be undertaken, has undergone a dynamic change. The best known classification of such models was proposed by Rothwell who distinguished five generations of models of innovation process (Rothwell, 1994). Rothwell noted that each new generation is a response to market changes which have occurred in the second half of the twentieth century such as economic growth after World War II, industrial expansion, inflation and stagflation during the oil crises, increased levels of competition, unemployment and the emergence of commodity restrictions in later years.

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In the first two generations of models, innovation is characterized by a simple linear process that is controlled by the forces of supply (technology-push) and demand (demand-pull).

The third generation of models is still sequential, but there are feedback loops, i.e. demand and supply interact in creation and dissemination of knowledge. In the late 1970s and early 1980s the strategies of innovative firms began to rely on consolidation and management of a portfolio of R&D projects in order to reduce the risk of R&D activities. Collaboration of R&D departments and marketing aimed at reducing operating costs. As stated by Berkhout et al., models of this generation can be seen as „open models of R&D” in which attention is paid to technological innovation (products and processes) and the importance of non-technological innovation (organizational and marketing) is neglected (Berkhout et al., 2006). This means that the primary purpose of business is the exploitation of technological capabilities.

The fourth-generation models point to the importance of integrated research teams and, thus, strong links between suppliers and customers (in terms of R&D and production cooperation). In the late 1980s and early 1990s new product life cycle was reduced, forcing innovators to switch from sequential to parallel tasks regarding R&D and manufacturing. To further shorten the time between invention and commercialization, a relatively long phase of „teaching the market” about a new product was dropped and innovators started to collaborate with suppliers and customers in the development of innovations (see eg. Graves, 1987).

The fifth generation models stress the importance of system integration and networking. Innovator collaborates with external experts, key customers and suppliers in the joint development of new products. Moreover, horizontal linkages – such as joint ventures, industry research groups, marketing agreements – are common. Models of this generation draw attention to the ever-increasing need for cooperation and, following Rothwell (1994), the importance of ICT to enhance such cooperation.

In short, the evolution of innovation processes involves: 1) parallel as opposed to sequential tasks, 2) greater importance of technological cooperation with innovator’s environment, and 3) the essential role of knowledge flows.

The paper builds on the previous literature and provides an updated econometric assessment of the role of knowledge flows in innovative processes of Polish enterprises as well as subsidiaries of foreign companies operating in Poland. We focus on formal (cooperation) and informal (observation) measures to access sources of disembodied knowledge in order to explain their impact on innovative activities of Polish enterprises.

The study in the paper is based on Community Innovation Survey microdata collected by Poland’s Central Statistical Office for the reporting period of 2006-2008 (*CIS-2008* henceforth). The data set covers 15 840 observations – individual companies which answered questions on innovative activity. As CIS questionnaire provides mainly categorical data, logistic regressions are used to test research hypotheses in the paper. We use binomial logit at the first stage of the procedure

(hurdle regression) and, due to limitation of Polish CIS data, zero-truncated negative binomial at the second stage.

The rest of the paper is organized as follows. Section 2. provides an overview of the previous research on technology cooperation in innovation process and notes that much of the research was based on CIS microdata which is described shortly in section 3. Section 4. lays out the methodology and hypotheses which are subject to formal testing in section 5. Section 6. concludes.

2. PRIOR STUDIES ON INNOVATION COOPERATION ACTIVITIES: AN OVERVIEW

The increasing importance of cooperation in innovation processes has shifted the focus of many studies towards the determinants and efficiency of innovation cooperation activities. One strand of analyses attempts to measure the effects of cooperation on the overall performance of firms and on the innovation and R&D performance. As shown by Abramovski et al. (2005) with the use of the data from the CIS-3 for four countries: France, Germany, Spain and the UK, cooperative firms have higher overall performance levels than non-cooperative firms (Abramovsky et al., 2005). The impact of inter-firm cooperation on innovation was investigated in the empirical study by de Propris (2002). The main finding was that firms' capacity to innovate could greatly improve if they cooperated with other firms on innovation in addition to or instead of investing in R&D.

Freel and Harrison noted that firms that engaged in innovation-related cooperation were likely to be more successful innovators. On the basis of survey of small firms in Scotland and Northern England these authors proved positive relation between product innovation success and cooperation with customers and the public sectors, and between process innovation success and cooperation with suppliers and universities (Freel, Harrison, 2006).

The innovation success and overall performance are also influenced by the nature of the cooperation partners. When defining their innovation cooperation strategies, firms search for two kinds of external partners: 1) those that allow them to incrementally build on the firm's existing internal knowledge and 2) those that provide knowledge to aid defining trajectories that are new to the firm (de Faria et al., 2010). The innovation cooperation with both kinds of partners requires communication channels – effective knowledge flows – between the participants which may take any form – e.g. joint research projects, informal discussions or participation in joint-ventures. These are referred to as the “linkage effects” and may take the form of vertical – “backward” (suppliers) or “forward” (customers), and horizontal links with competitors or institutional environment (Jindra, 2006).

Previous research finds several important benefits of innovation cooperation with suppliers, namely: 1) the possibility to incorporate the expertise and different perspective of a supplier to improve or create new methods for product development,

2) earlier identification of potential technical problems speeding up new product development and responses to market demand, 3) quality improvements, and 4) reductions in the time-to-market and in development costs (Clark, Fujimoto, 1991; Tsai, 2009). This is in line with the concept of “open innovation” which – in contrast to the company’s internal innovation process – focuses on involvement of external parties, such as suppliers for cooperation, idea generation etc. (Chesbrough, Garman, 2009). Suppliers’ knowledge can be used for improving the decision process by joining the customer’s requirements with the potential of the supplier (Tseng, 2009). Linkages with suppliers can result in increased demand for quality of products and supplies, which can also lead to the modernization of the business. The increase in the demand for suppliers’ products associated with the possibility to take advantage of economies of scale leads to increasing investments in innovation projects (Ahuja, 2000; Jenssen, Nybakk, 2009).

Miotti, Sachwald (2003) used the French CIS-2 survey to find a positive effect of collaboration with suppliers on the share of innovative product turnover and Faems et al. (2005) analyzed Belgian manufacturing firms and found a positive relation between suppliers and the share of turnover from improved products (Miotti, Sachwald, 2003; Faems et al., 2005). Several researchers estimated the impact of innovation cooperation with suppliers on other dependent variables – eg. de Faria et al. (2010) using the data from the Portuguese CIS-3 survey showed that firms from high-technological industries, with higher levels of absorptive capacity and of innovation investment, who paid importance to incoming spillovers management, and cooperated with firms from the same group or with suppliers, placed greater value on cooperation partners in the innovation process. In a survey of Spanish manufacturing firms, Nieto and Santamaría (2007) regressed product innovation on collaborative networks and found a positive link between collaboration with suppliers and the degree of product innovativeness (Nieto, Santamaría, 2007).

Two categories of customer’s knowledge in innovation processes can be distinguished: customer experience in the product and specialized knowledge showing client’s ability to further develop the product (Tseng, 2009). Thus, collaborating with customers not only helps to identify market opportunities for technology development, but also reduces the likelihood of poor design in the early stages of development. Moreover, understanding the needs of influential customers may help firms gain new ideas about solutions and identify market trends early on, thereby increasing the chances of new product development and success (Tsai, 2009). Miotti and Sachwald (2003) and Faems et al. (2005) found that collaboration with customers had a positive impact on product innovation performance. Nieto and Santamaria (2007) found that although customer collaboration had a positive impact on marginal product innovation, it did not affect significant innovation.

The least frequent type of collaborative network that firms adopt to achieve product innovation seems to be collaboration with competitors, but this type of collaboration still provides some advantages. Firms involved in a cooperative

agreement may share technological knowledge and skills with each other, producing a synergistic effect on solving common problems outside the competitor's area of influence (Tether, 2002). The case study of Inkpen and Pien (2006) suggests that firms collaborating with competitors may perform better in innovation than they otherwise would. Furthermore, firms can reduce the time and risk involved in technological innovation (Belderbos et al., 2004). Löf and Heshmati (2002) found that collaborating with competitors was positively related to new product sales. However, Nieto and Santamaría (2007) found that collaboration with competitors not only did not influence marginal product innovation, but it also negatively affected drastic product innovations.

Due to governments' encouragement, more and more firms are pursuing product innovations by collaborating with universities and research institutions. Cooperation with these partners is more likely to occur with large firms and with firms that patent and/or receive public funding for innovation since these firms have more resources to invest in research that does not have an immediate market orientation (Mohnen, Hoareau, 2003). Accordingly, Faems et al. (2005), and Nieto and Santamaría (2007) found that collaboration with research institutes and universities positively affected product innovation performance.

3. CIS DATA DESCRIPTION

The current study is based on CIS 2008 microdata collected by Poland's Central Statistical Office which consists of 15 840 observations – individual companies from Polish mining, manufacturing and services sectors which answered questions on innovative activity. All sectors originally divided by NACE codes were grouped according to R&D intensity and thus 9 usual OECD groups were created (4 for manufacturing and 5 for services) with an additional group for mining and quarrying (sector B of NACE classification).

The 2008 CIS data provide information on innovation activity grouped into several sections covering: 1) information about technical innovations introduced by the enterprise and their novelty; 2) the sources of information on innovation, 3) the objectives to develop the innovation; 4) the types of cooperation (if any) which were beneficial for innovation activity and 5) information about the type of undertaken innovation activity.

Polish version of CIS questionnaire extends Eurostat's questionnaire by adding two additional sections – one dealing with issues on international technology transfer (sales and purchases of technology in the form of licenses, R&D, consulting services, means for automating production processes), and the other reporting means for automating production processes used by enterprises (automatic production lines, machining centers, numerically controlled machine tools, industrial robots and manipulators).

Poland's Central Statistical Office (CSO) does not provide raw financial data and thus the data on turnover from new goods or services or on expenditures on

process and product innovations were transformed into, respectively, percentages of total turnover and of total expenditures.

Due to confidentiality policy of Poland's CSO, the CIS microdata on Poland is not available from Eurostat and thus Poland is not included in published analyses on science and technology in Europe, and reports comparing innovativeness of members of the EU. Although recently publications using the Polish microdata have started to appear (see eg. Wziątek-Kubiak et al., 2009a; 2009b; 2011), there are no previous publications on innovation cooperation using CIS microdata in Poland.

4. HYPOTHESES AND METHODOLOGY

The following three hypotheses are subject to formal analysis in the paper:

H1. Innovation cooperation and observation is effective in innovative activity – the predicted probability of higher innovative sales rises when a firm collaborates with or observes other institutions in its environment

H2. The observation of institutions able to develop the most advanced knowledge is the most effective in innovative activity. In case of Polish enterprises such institutions are: firms from the EU countries and foreign research institutes. Coefficients of collaboration and observation regarding these two types of institutions are expected to be the highest.

H3. The effect of collaboration and observation on innovative sales is more significant in more technologically advanced sectors.

In the above hypotheses we use as dependent variables a count outcome variable indicating the share of innovative sales of successful innovators and a categorical variable indicating whether an enterprise introduced a technical innovation (new or significantly improved products or processes). The set of regressors includes categorical variables constructed based on Polish CIS-2008 questionnaire data from section 6 "Sources of information and cooperation for innovation activities" and sector dummies. We use a degree of importance of information sources as an indicator of observation, esp. when no cooperation with this source was indicated by a respondent.

The choice of dependent variables and methodology was mainly dictated by the well known limitation of CIS database, consisting in not providing much data on non-innovators. Out of 11 sections of the CIS questionnaire only 4 are to be answered by non-innovating enterprises what causes the selection problem. Thus, most research on CIS use type-2 tobit model¹ to deal with the selection bias (see: Veuglers, Cassiman, 2004; Aralica, Racic, Radic, 2005; Criscuolo, Haskel,

¹ Type-2 tobit model is a two-part procedure in which two regressions are run sequentially – first, a probit or logit models for the censoring mechanism and, second, linear regression for the outcome conditional on the outcome being observed.

Slaughter, 2010; Garcia-Torres, Hollanders, 2009; Surinach et al., 2009; Mairesse, Mohnen, 2010; Surinach, Manca, Moreno, 2011).

Due to a limitation specific to the access to Polish CIS micro data we cannot use type-2 tobit model. As Polish CSO does not provide raw financial data and thus the data on turnover from new and/or significantly improved goods or services or on expenditures on process and product innovations were transformed into, respectively, percentages of total turnover and of total expenditures. From research perspective it invalidates the possibility to use type-2 tobit model as we lack the continuous variable available to researchers in other countries – the total turnover from new or significantly improved products and processes. Instead we will use a hurdle regression model in which, at the second stage, a count outcome variable can be used (Cameron, Trivedi, 2010).

In both, type-2 tobit and hurdle regression models, a two-step procedure is undertaken. The coefficients of the first-part regression (usually logit or probit) determine the probability of positive share of innovative sales – eg. the probability of successful innovation; the coefficients of the second part indicate the impact on the size of the sales conditional on it being positive.

Specifically, in order to verify the hypotheses, at the first stage of the HRM, we run binary logit models. Regression models are formed by parameterizing the probability p to depend on the index function $x'\beta$, where x is a $K \times 1$ regressor vector and β is a vector of unknown parameters. In standard binary outcome models, the conditional probability has the form:

$$\Pr(y = 1|x) = F(x'\beta) \quad (1)$$

where $F(\cdot)$ is a specified parametric function of $x'\beta$. In logit models $F(x'\beta) = \Lambda(x'\beta) = \frac{e^{x'\beta}}{1 + e^{x'\beta}}$, where the function $\Lambda(\cdot)$ is cumulative distribution function of the logistic distribution.

Effects for the logit models can be interpreted in terms of changes in the odds. The odds of observing a positive outcome versus a negative one are typically calculated as:

$$\Omega(x) = \frac{\Pr(y = 1|x)}{\Pr(y = 0|x)}, \quad (2)$$

which indicate how often something happens relative to how often it does not happen and range from 0 when $\Pr(y = 1|x) = 0$ to ∞ when $\Pr(y = 1|x) = 1$.

The odds are exponential of logit model coefficients and are more intuitive measure to interpret, especially when x 's of k -th regressor are allowed to change and odds ratios can be calculated. The odds ratio can be written as:

$$\frac{\Omega(x, x_k + \delta)}{\Omega(x, x_k)} = e^{\beta_k \cdot \delta}, \quad (3)$$

what can be interpreted as follows:

For a δ change in x_k , the odds are expected to change by a factor of $\exp(\beta_k \cdot \delta)$, holding all other variables constant. When a unit change is considered, the change in odds is $\exp(\beta_k)$.

The second stage of the hurdle regression uses any truncated parametric count density, eg. Poisson or negative binomial (NBRM) which is a generalization of Poisson regression model (PRM) commonly used in applied work as it addresses the failure of the PRM to fit the overdispersed data. The NBRM assumes that the observed count for observation i is drawn from Poisson distribution with mean μ_i (as in PRM) but adds an error term, ε , which is assumed to be uncorrelated with x_i and after defining $\delta \equiv \exp(\varepsilon)$:

$$\mu_i = E(y_i | x_i) = \exp(x_i \beta) \delta_i \quad (4)$$

We cannot compute $\Pr(y | x)$ as δ is unknown. This limitation is resolved by assuming that δ is drawn from a gamma distribution. Then $\Pr(y | x)$ becomes:

$$\Pr(y | x) = \frac{\Gamma(y + \alpha^{-1})}{y! \Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu} \right)^{\alpha^{-1}} \left(\frac{\mu}{\alpha^{-1} + \mu} \right)^y, \quad (5)$$

where $\Gamma(\cdot)$ is the gamma function and α is the variance parameter of the gamma distribution. The NBRM lets $\mu_i = \exp(x_i \beta)$ and leaves α as constant. If $\alpha = 0$ NBRM reduces to Poisson regression model, which turns to be the key in testing for data overdispersion.

As stated above, at the second stage of the hurdle regression model a zero-truncated count model must be used – observations with zeros are excluded from the sample and we want to compute the probability of each positive outcome given that we know that the outcome is greater than zero. By the law of conditional probability $\Pr(A | B) = \Pr(A \text{ and } B) / \Pr(B)$, so we can compute the conditional probability of positive outcome in (5) after computing $\Pr(y = 0)$ and $\Pr(y > 0)$ from this equation.

Given that $\Pr(y = 0 | x) = (1 + \alpha\mu)^{-1/\alpha}$ and $\Pr(y > 0 | x) = 1 - (1 + \alpha\mu)^{-1/\alpha}$ the conditional probability in zero-truncated negative binomial (ZTNB) is:

$$\Pr(y_i | y_i > 0, x) = \frac{\Pr(y_i | x)}{1 - (1 + \alpha\mu)^{-1/\alpha}}. \quad (6)$$

As with the NBRM, overdispersion in the ZTNB is based on LR test of $\alpha = 0$.

5. THE RESULTS

In order to test the hypotheses we have run a series of hurdle regression models with binomial logit models at the first stage and zero-truncated negative binomial at the second stage using statistical software package Stata.

In order to test **hypothesis H1** we have run a HRM model with the share of innovative sales as a dependent variable and different types of partnership in

innovation cooperation as a set of regressors. For brevity, we report in Table 1 only statistically significant coefficients of different types of cooperating partners².

Table 1. Innovation cooperation in Poland – the results of the HRM

Type of collaboration	I-stage logit (coef.)	II-stage ZTNB (coef.)
Any type	4.908 (***)	Insignificant
Any type from abroad	4.921 (***)	Insignificant
Any type from the EU	1.359 (***)	Insignificant
Consulting firms	-0.696 (**)	Insignificant
Suppliers	insignificant	0.131 (*)
Competitors	insignificant	0.233 (***)
Partner from Poland only	insignificant	-0.355 (***)
Customers from the EU	insignificant	0.249 (***)
Competitors from Poland	insignificant	0.256 (**)
Alpha	-	2.87

Note: (***) – significant at 1%; (**) – significant at 5%; (*) – significant at 10% level.

Source: CIS 2008 data.

Although no variable turned out to be significant at both stages of the HRM, we are able to conclude that the probability of successful innovation and hence the probability of innovative sales to be positive is increased by cooperation, especially with foreign partners. Taking into consideration directions of international trade in Poland, it is not surprising that within cooperation with foreign partners, the most significant collaboration is with partners from the EU. The results of the ZTNB model of the second stage of the HRM show that the share of innovative sales in total income of the enterprise rises for collaboration solely with market partners – competitors, customers and suppliers. The collaboration with competitors from Poland and customers from the EU turn to be the most significant. In case of suppliers the country of their origin is irrelevant. The negative coefficient of cooperation restricted only to partners from Poland further strengthens the importance of collaboration with foreign partners. The value of alpha in the lowest row indicates that the data is overdispersed and the ZNTB should have been used.

In order to check the importance of observation we restricted our sample of respondents to cases which selected the answers “the innovation was mainly

² The respondents were asked about cooperation with: other enterprises within the group, suppliers, customers, competitors, consulting firms, universities, research institutes. The potential partners were further divided into national and foreign. Additionally the respondents were asked about cooperation with any type of partner originating from Poland, the EU, the USA, China or India and other countries.

developed by other enterprises” or “the innovation was mainly developed together with other enterprises” to the question 2.2 of the CIS questionnaire and, at the same time, selected the answer “no cooperation was undertaken in innovative activity”. Similarly to Garcia, Hollanders (2009) we ascribed this to informal flows of knowledge – eg. observation. We then ran the HRM as above with dependent variable being the share of innovative sales and independent variables being the importance of different types of sources of information that provided information for new innovation projects or contributed to the completion of existing innovation projects identified by respondents in question 6.1 of the CIS questionnaire³. As not many enterprises identified the importance of particular sources as “high”, this category was combined with the choice of “medium” importance. Thus the answers were rescaled to three choices: not important, low, medium/high.

Table 2. Sources of information on innovation in Polish economy – the results of the HRM

Sources of information	I-stage logit (coef.)	II-stage ZTNB (coef.)
Enterprise (internal)	0.888 ^(***)	insignificant
The group	0.779 ^(***)	insignificant
Customers	0.787 ^(***)	insignificant
Competitors	0.412 ^(***)	insignificant
Polish Academy of Science	0.329 ^(*)	0.091 ^(*)
Trade fairs, exhibitions	0.297 ^(*)	0.152 ^(*)
Scientific/trade publications	0.419 ^(**)	0.065 ^(*)
Alpha	–	3.29

Note: (*) – significant at 10% level; (**) – significant at 5%; (***) – significant at 1%.

Source: CIS 2008 data.

The results of the logit model in the second column of Table 2 indicate that internal, market and “other” sources significantly explain the share of innovative sales to be positive, eg. respondents identifying such sources as important are more likely to innovate. It is worth noting that all internal and market sources turned out to be insignificant at the second stage of the HRM and hence we can state that these sources have impact on being innovative but do not contribute to achieve higher shares of innovative sales. The sources of information that do contribute to gain higher shares of innovative sales are mostly “other” – these

³ The question 6.1 divides sources of information into four categories: 1) internal (within the enterprises or enterprises group), 2) market (suppliers, customers, competitors, consultants), 3) institutional (universities, research institutes), 4) other (trade fairs, exhibitions, scientific journals, trade publications, professional or industry associations).

are sources of pure knowledge flows in the effect of observation as during trade fairs or exhibitions or acquiring new knowledge through scientific journals or trade publications. As pointed in the footnote 3, the range of “other” sources of information in the question 6.1 was richer than presented in the table and included also: universities, private or public research institutes and professional and industry associations – they are insignificant at both stages of the HRM. This confirms a well-known result of empirical studies on the effectiveness of innovation policy, that is an insufficient transmission of knowledge from universities to business.

The only source of information connected with country’s research infrastructure is Polish Academy of Science (added to the CIS questionnaire in Polish version of the survey). PAS represents a state institution able to develop the most sophisticated knowledge and as only this element of public research infrastructure is significant in our study, it confirms the hypothesis H2 stating that only the collaboration and observation with institutions able to develop the most advanced knowledge is effective in innovative activity⁴.

In order to test H2 further and supposing that the share of innovative sales may be sensitive to the company size, we have run the same HRM as above in the sample restricted to large enterprises only. The market sources are still not significant at the second stage of the HRM but Polish Academy of Science was “replaced” with foreign research institutes – with coefficient of 0.112(*). In the sample of medium enterprises, employing less than 250 employees, only competitors appear as an important source of information but the coefficient is negative indicating that this source is more important for companies with lower shares of innovative sales. In this sample Polish Academy of Science is also not significant and was “replaced” by a variable indicating informal knowledge flows from universities – with coefficient of 0,812(**).

These results seem easy to interpret – it is not an absolute level of sophistication of knowledge that drives enterprises to observe and absorb it but its perceived usefulness – the knowledge an enterprise is going to adopt must be newer than already possessed but must lie within a particular range of firm’s adaptive capabilities. The theory of vintage capital à la Parente made it clear – the more advanced knowledge comparing to the innovativeness level of an enterprise is going to be adopted, the higher the adoption costs (Parente, 1994). When the difference in the sophistication level between the knowledge to be adopted and already used by a firm is very large, the adoption costs are prohibitive and no adoption occurs.

Taking into consideration that large companies are generally more innovative than medium-sized ones and that foreign research institutes are able to develop

⁴ As noted by Kierzek in 2000-2008 research institutes of Polish Academy of Science provided 20% of all publications in Poland and this share is incommensurately high comparing to the PAS share of researchers employed in Polish public research infrastructure (Kierzek, 2008).

more advanced knowledge than Polish universities⁵, the matching of medium-sized enterprises with universities and large companies with foreign research institutes seems to be explained by avoiding too costly adoption. Although it may be argued that adopting costly innovations near the technology frontier may pay off eventually as it can bring higher revenues in longer run, the availability of resources to invest in research in smaller firms may be prohibitive. In a recent research using Polish CIS-2006 microdata (Wziątek-Kubiak et al., 2011) show that large firms are less sensitive to most innovation barriers than medium-sized and small ones.

It is worth noting however, that the results may reflect the fact that observation of foreign research institutes may be easier for large companies just because they are subsidiaries of international corporations. We have tested this possibility again using the same HRM as above but restricting the sample to subsidiaries only. In Table 3 we present the results of II-stage ZNTB model for subsidiaries which indicated that their innovations were not developed mainly by themselves but did not collaborated formally with any other organization.

Table 3. Sources of information on innovation for subsidiaries of foreign corporations in Poland – the results of the ZTNB model

Sources of information	II-stage ZTNB (coef.)
Enterprise (internal)	-0.536 ^(**)
The group	0.378 ^(**)
Competitors	0.470 ^(**)
Trade fairs, exhibitions	-0.506 ^(*)
Professional associations	0.744 ^(***)
Alpha	0.43

Note: Only significant variables are shown.

Source: CIS 2008 data.

Comparing to previous models' results it can be seen that no institutional sources – neither national nor foreign are significant. As should be expected in the group of subsidiaries an important source of information on innovation were other enterprises from the same group – especially parent enterprises. From the choice of “other” sources professional associations are highly significant along with trade fairs and exhibitions. The latter coefficient is negative informing that

⁵ Scientific productivity of Polish researchers reaches a half of the productivity of German or Austrian researchers and merely one third of their British or Finnish colleagues (Wolska-Derlacz, Parteka, 2010, 54). Kierzek's data on Hirsh Index show that only 2 Polish universities (University of Warsaw and Jagiellonian University) can be considered to be average European universities but were not listed among top European universities according to Webometrics Ranking of World Universities (Kierzek, 2008).

this source is important for companies with lower shares of innovative sales. The importance of professional associations is connected with identifying competitors as important sources of knowledge – sector or industry leaders are often members of such associations easing the knowledge flows and mutual observation within a group of strong competitors. The importance of observing competitors indicated by subsidiaries of foreign corporations may also result from greater perspective in identifying competitors – eg. not competing directly with the subsidiary but also with its parent corporation.

To verify **hypothesis H3** we have checked which types of collaborating partners significantly explain the incumbent's share of innovative sales in sectors grouped by the level of technology as proposed by OECD (*OECD sectors* henceforth). We have run a series of ZTNB models in order to capture the importance of all types of potential collaborating partners: 1) individually, 2) in grouping proposed in the CIS questionnaire (market partners – suppliers, competitors, customers; and institutional partners – consulting firms, universities and research institutes) and 3) in grouping based on partner's country of origin (Polish or foreign from the EU, the USA, China or India).

Table 4 presents only statistically significant coefficients of collaboration types in the OECD sectors.

**Table 4. Innovation cooperation in Poland in the OECD sectors
– the results of the ZTNB model**

Collaboration type	High-tech	Med.-high	Med.-low	Low-tech.
Suppliers	–	–	0.97 ^(***)	–
Competitors	–	0.32 ^(**)	–	–
Consulting firms	–0.24 ^(**)	–	–	0.61 ^(**)
Polish partners only	–	–	1.86 ^(***)	–0.52 ^(**)
Foreign partners only	0.86 ^(*)	–	–1.54 ^(***)	–
The EU partners	0.97 ^(**)	–	–	–
Market partners (all types)	–	–	1.45 ^(**)	–
Institutional partners (all types)	1.40 ^(***)	–	–	–
Market partners (Polish only)	–	–	2.03 ^(***)	–
Institutional partners (Polish only)	–1.82 ^(***)	–0.29 ^(*)	–	1.33 ^(***)

Note: (*) – significant at 10% level; (**) – significant at 5%; (***) – significant at 1%.

Source: CIS 2008 data.

After grouping enterprises in Poland into four sectors according to the level of production technologies, as proposed by the OECD, we obtained different

sets of statistically significant regressors – thus we cannot directly verify H3. Eg. technological cooperation with all types of market partners is significant only in medium-low technology sector, while the collaboration with institutional partners is significant solely in high-tech sector. This result, in fact, confirms earlier findings in the paper – firms in more technologically advanced sectors collaborate with, or observe, partners able to develop more sophisticated knowledge. This is even more evident when we notice that in high-tech sector restricting cooperation to Polish partners only is insignificant or the coefficient is negative –the coefficient of collaborating with only Polish institutional partners is -1.82^{***} , and it is insignificant regarding Polish only market partners; but significant and positive when collaboration with only foreign partners is taken into consideration (0.86^*). If the cooperation with more advanced partners from the EU is extracted from the group of foreign partners, the coefficient is higher and stronger (0.97^{**}). The importance of collaboration for firms in sectors based on lower technologies (medium-low or low-tech) reveals different pattern. In low-tech sector restricting collaboration to Polish institutional partners (eg. local universities) is beneficial for higher shares of innovative sales as well as the cooperation with consulting firms. In medium-low technology sectors the most crucial type of cooperation involves market partners of all types (the coefficient of 1.45^{**}) but it can be seen that collaboration with only Polish market partners is rated higher by the respondents (2.03^{***}). From the range of market partners the most significant type of collaborating partners in this sector are suppliers (0.97^{**}). As the coefficient of cooperation restricted to Polish partners is positive but it is negative when involves only foreign partners, we can state that innovation cooperation among similarly advanced partners is visible as in the high-tech sector but in this case it involves only Polish enterprises.

Negative coefficient of innovation cooperation with Polish partners only as well as positive coefficients of cooperation with universities and consultants in low technology sector, which is by definition populated by less advanced enterprises that medium-low technology sector, seems to be at odds with this conclusion. It must be noted, however, that this sector in Poland has undergone the most considerable technology change in recent decades which aimed at reduction of excessive employment and diminishing its negative impact on the environment.

CONCLUSIONS

The study presented in the paper confirms the need of knowledge flows, both formal (innovation cooperation) and informal (observation), as pointed out by authors of the fifth generation of innovation process models. Using the data of the Polish version of Community Innovation Survey 2008 we find that the probability of successful innovation and hence the probability of innovative sales to be positive increases with the cooperation with market partners – competitors,

customers and suppliers. For Polish enterprises the cooperation with foreign partners, especially from the EU countries, is most significant. As Poland is still a reservoir of cheaper labor force comparing to the EU countries it serves mostly as an exporter of cheap inputs or final goods – the most significant type of innovation cooperation is through linkages with foreign customers (to tailor products to foreign markets needs) and local competitors (to decrease production costs).

After dividing manufacturing enterprises in Poland into four sectors according to the level of technological advancement of production processes, we observe a specific “matching” of collaborating partners – technologically advanced enterprises collaborate with partners able to develop more sophisticated knowledge and, *vice versa*, less advanced enterprises tend to collaborate with similar partners. In high-tech sectors restricting cooperation to Polish partners only is insignificant (or the coefficient is negative) but it is significant and positive when collaboration with only foreign partners is taken into consideration. If the cooperation with more advanced partners from the EU is extracted from the group of foreign partners, the coefficient is higher and stronger. In low-tech sector restricting collaboration to Polish universities or consulting firms is beneficial to achieve higher shares of innovative sales. In medium-low technology sectors the most significant type of cooperation involves suppliers. As the coefficient of cooperation with Polish partners only is positive (and it is negative when involves only foreign partners), we can state that innovation cooperation among similarly advanced partners is visible as in the high-tech sector but in medium-low sector it concerns only Polish enterprises.

Regarding informal knowledge flows we note that internal and market sources of information on innovation have impact on being innovative but do not contribute to achieve higher shares of innovative sales. The sources of information that do contribute to gain higher shares of innovative sales are mostly sources of pure knowledge flows in the effect of observation as during trade fairs or exhibitions or acquiring new knowledge through scientific journals or trade publications.

Taking into account that the share of innovative sales may be sensitive to the company size we have run the same HRM in the sample restricted to large or medium enterprises only. In the group of large enterprises observation of foreign research institutes is significant. The same is true for informal knowledge flows from universities in the group of medium enterprises. Taking into consideration that large companies are generally more innovative than medium-sized ones and that foreign research institutes are able to develop more advanced knowledge than Polish universities, the matching of medium-sized enterprises with universities and large companies with foreign research institutes seems to be explained by avoiding too costly adoption – the same as in the case of innovation cooperation.

The analysis presented in the paper not only confirms empirically the importance of knowledge flows in innovation activity as indicated in the fifth

generation of innovation process models but also reveals a pattern of partners matching. As enterprises choose similarly advanced partners, from the perspective of a medium developed country such as Poland, such matching pattern means international collaboration of large companies in high-tech sectors and local collaboration of medium-sized enterprises in lower technology sectors.

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ZNACZENIE WSPÓŁPRACY TECHNOLOGICZNEJ I OBSERWACJI W DZIAŁALNOŚCI INNOWACYJNEJ POLSKICH PRZEDSIĘBIORSTW – WYNIKI BADANIA CIS (PNT-02)

STRESZCZENIE

Celem artykułu jest empiryczna analiza roli przepływów wiedzy w działalności innowacyjnej polskich przedsiębiorstw. Przeprowadzone badania dotyczą zarówno formalnych (współpraca), jak i nieformalnych (obserwacja) możliwości uzyskania dostępu do źródeł wiedzy w celu wyjaśnienia ich znaczenia dla powodzenia i efektów działań innowacyjnych. Badanie w artykule oparte jest na danych jednostkowych zebranych przez GUS w ramach sprawozdania o innowacjach PNT-02 związanego z *Community Innovation Survey*, prowadzonego pod egidą Eurostatu we wszystkich państwach Unii Europejskiej. Dane składają się z formularzy 15 840 przedsiębiorstw. Ponieważ kwestionariusz badania PNT-02 zapewnia głównie dane kategoryczne, do testowania hipotez badawczych w artykule są wykorzystywane regresje logistyczne w postaci dwuetapowej procedury HRM (*hurdle regression model*). Na pierwszym etapie tej procedury wykorzystany jest model logitowy, a na drugim – oceniany ujemny rozkład dwumianowy (ZNTB).

Analiza przedstawiona w artykule nie tylko potwierdza empirycznie znaczenie przepływów różnych rodzajów wiedzy w działalności innowacyjnej, jak wskazano w tzw. piątej generacji modeli procesu innowacyjnego, lecz także ukazuje sposób dobierania partnerów. Przedsiębiorstwa głównie współpracują z partnerami na podobnym poziomie zaawansowania technologicznego. W kraju średnio rozwiniętym, jak Polska, oznacza to międzynarodową współpracę technologiczną

dużych przedsiębiorstw w sektorach nowoczesnych technologii i współpracę lokalną średnich przedsiębiorstw w sektorach mniej zaawansowanych technologicznie.

Słowa kluczowe: działalność innowacyjna, Community Innovation Survey, ZTNB, HRM, współpraca technologiczna, PNT-02.

ABSTRACT

The aim of the paper is to assess econometrically the role of knowledge flows in innovative activities of Polish enterprises and subsidiaries of foreign companies operating in Poland. The study is based on CIS-2008 microdata collected by Poland's Central Statistical Office. The data covers 15 840 observations – individual companies which answered questions on innovative activity. As CIS questionnaire provides mainly categorical data, logistic regressions are used to test research hypotheses in the paper. We use binomial logit at the first stage of the procedure (hurdle regression) and, due to limitation of Polish CIS data, zero-truncated negative binomial at the second stage.

The analysis presented in the paper not only confirms empirically the importance of knowledge flows in innovation activity as indicated in the fifth generation of innovation process models but also reveals a pattern of partners matching. As enterprises choose similarly advanced partners, from the perspective of a medium developed country such as Poland, such matching pattern means international innovation cooperation of large companies in high-tech sectors and local collaboration of medium-sized enterprises in lower technology sectors.

Keywords: innovative activity, Community Innovation Survey, ZTNB, HRM, technology cooperation, Poland.

JEL Classification: O33, O5