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Abstract

This study investigates how vertical linkages impact the innovative activity of both medium-high and high technology industries in Poland. The data for this research were collected in structured telephone or e-mail interviews with managers and company owners. The final data set includes 1,355 firms. The analysis is based on probit modeling that allows us to determine the probability of innovative activity in relation to a number of supplier and customer groups or a type of vertical linkage. We find that the number of suppliers and customers shape innovative activity; specifically, the more groups of suppliers and customers the higher level of innovative activity. This analysis suggests that appropriate suppliers and customers can greatly accelerate innovation activity.

Keywords: innovative activity, vertical linkages, industry, HT, MHT
JEL: O32, O33

Introduction

A substantial body of literature in management and organization (studying strategy, supply chain management, organization behavior), as well as in economics, has explored the effect of cooperation along the value chain on innovation processes (Powell et al., 1996; Jacobides et al., 2006; Schilling et al., 2007; Soosay et al., 2008). However, most of these studies focus on leading developed economies, and research involving less developed coutries is scarce. This gap is not easily filled, since results obtained in developed countries may not take into account essential conceptual differencies between them and emerging economies [Hoskisson et al., 2000]. Poland is a particular case of an emergingeconomy that abandoned communist style central planning in favor of free markets twenty-five years ago, but (as is typical in transtion economics) remains burdened by its rcent history. For example, a low level of mutual trust is an outgrowth of the former system that still influences the structure of industry and innovation cooperation patterns.

In the context of the global economy, vertical linkages have been studied as a way that multinational foreign firms shape the development of local firms through their purchasing behavior. Vertical linkages support the local supply industry and transfer knowledge to local suppliers [Lall, 2002]. Most literature on this activity focuses on foreign direct investment technology spillovers via vertical linkages, and examines vertical spillovers from foreign firms to domestic suppliers [Markusen, Venables, 1999; Javorcik, 2004; Blalock, Gertler, 2008]. Globalization makes supply chains more competitive by increasing the number of firms and customer expectations of performance, quality and cost. Manufacturers are now a part of complex business networks spanning different industries in different countries. To survive they build strategic partnerships with suppliers, foster customer relationships, and learn to share key information with their partners [Vickery et al., 2003]. Firms realize that it is important not only to improve efficiencies within an organization, but also in their whole supply chains, to be more competitive. Hence, the essential condition for remaining competitive in the global race is to prioritize effective supply chain management (SCM) to enhance profitably [Tan et al., 2002]. Firms in supply chains are under constant competitive pressure to reduce costs, increase quality, improve customer service and ensure continuity of supply [Goebel et al., 2003; Pearson et al., 1996]. Most academics agree that a substantial part of the innovation process occurs between buyers and sellers in the supply chain [Lundwall, 1986; Hakansson, 1987; Hakansson, Snehota, 1995]. Companies adopt innovation in various ways, including innovation cooperation with their suppliers [Soosay et al., 2008], and the most likely core innovative suppliers are specialized, technically competent firms located close to buyersain an embedded trusted relationship [Schiele, 2006].

Li et al. [2007] showed an empirical link between trust in suppliers and operational effectiveness – defined as low cost and high quality. Trust enables the informal exchange of technical knowledge. It speeds up the process of cooperative agreements (but varies on the industry level) [Harabi, 1998]. Close interaction with customers leads to developing and introducing innovations [Bellingkrodt, Wallenburg, 2013], who are a source of knowledge and ideas that can lead to new products and services [Chesbrough, 2006].

The main goal of this paper is to determine the impact of vertical linkages on the innovation activity of both medium-high and high technology industries in Poland. Our main hypothesis is that in Poland's low trust environment, a higher diversity of both suppliers and customers facilitates greater innovation activity, and that firms with more supplier and customer linkages invest more, implement more new technologies, and are more willing to cooperate with various partners to innovate.

The Structure of Medium-High and High Technology Industries and Innovation Activity

Manufacturing industries can be grouped into four categories according to their research and development (R&D) intensity: high, medium-high, medium-low and low technology. They are classified using the ISIC Rev. 3 breakdown of activity.[2] This ranking uses data on R&D expenditure divided by value added, and R&D expenditure divided by production for 12 OECD countries during the period 1991–1999.[3] The medium-high-technology group is composed of: chemicals (excluding pharmaceuticals); machinery and equipment; electrical machinery and apparatus; motor vehicles; trailers and semi-trailers; railroad equipment and transport equipment. The high-technology group includes: pharmaceuticals; office, accounting and computing machinery; radio, television and communication equipment; medical, precision and optical instruments; aircrafts and spacecrafts [Hatzichronoglou, 1997].

Innovation can be defined as a process or the result of a series of actions [Dolińska, 2010]. The typical innovation process includes creation of the idea, research and development, design, production and dissemination [Stawasz, 1999]. The result may refer to any good, service or idea that is perceived by the customer as new [Pomykalski, 2001]. There are numerous innovation definitions, but in this paper the OECD definition of innovation is adopted. The OECD Manual defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [Oslo Manual, 2005, p.46]. Innovation encompasses three levels of novelty (new only to the firm, new to the industry in the country or to the operating market of the firm, and new to the word). It can include both product and process. [Oslo Manual, 2005, p.80]. Innovation is the result of various scientific, technical, organizational, financial and commercial activities that lead or are intended to lead to their implementation. There are three main areas of innovation activity: research and development (R&D), acquisition of knowledge in the form of patents, licenses, technical services and the purchase of innovative machinery and equipment needed to produce new processes and products [Janasz, Kozioł-Nadolna, 2011]. Firms can support a rich set of specific innovative activities to develop or acquire innovations. These may include: (a) R&D to develop new product or process concepts and occasionally marketing or organizational innovations, (b) buying technical information (paying fees or royalties for patented inventions, purchasing trademarks or buying know-how), (c) investing in equipment, machines and software or in land or buildings (including enhancements, modifications and repairs) required to implement product and process innovations, (d) developing human skills and new methods of marketing new or enhanced goods, (e) such other activities as designing, planning and testing new products and services, process implementations or production methods [Dwojacki, Hlousek, 2008]. Companies can carry internal R&D activity based on in-house investment in buying equipment and software, or they can invest in new capabilities purchasing R&D services from others.

Methodology

The methodological part is based on probit modeling. The value of the dependent variable is dichotomous, which prevents the use of a multiple regression. Binary probit models have only two categories in the response variable: event A (1) or non-A (0). The assumption here is that data come from a random sample and Y values are statistically independent whereas the probability that Y = 1 is defined by the normal distribution. In the case of the model where an independent variable can only take values of 0 or 1, the expected value of the dependent variable can be interpreted as the conditional probability of the event at fixed values of the independent variables [Liao, 1994]. Estimation of parameters in models containing a dichotomous variable can be performed using the maximum likelihood method (MLE). This method computes the set of values of the model parameters that maximizes the likelihood function, which ensures the best match of the obtained model with the observed data, and for discrete random variables it maximizes the probability of the observed data under the resulting distribution. The maximum-likelihood method offers a unified approach to estimation, which is well-defined in the case of normal distribution [Welfe,- 1998].

The nonlinear estimation procedure uses a quasi-Newton algorithm to find the minimum of the loss function. Hence, a collection of the best estimators for the loss function is calculated [Stanisz, 2007]. Maximizing the likelihood function for the probit model is based on a nonlinear estimation [Maddala, 2006].

The statistical verification of models and their parameters relies on Wald's tests with Chi-square statistics and Student's *t*-tests. All calculations were performed with Statistica software. For the sake of brevity, the author presents only models with statistically significant predictor variables. Due to difficulties in interpretation, the probit calculations were performed only for models with one predictor variable. In interpreting the models, a positive sign in front of a parameter means that the probability of an innovative event (P1) is more likely in a given group than the probability of it (P2) in other groups.

Variables used as factors to distinguish between comparison groups for which separate probit models were estimated, include the number of groups of suppliers (0,1,2,3,4 and more), the number of groups of customers (0,1,2,3,4 and more) and linkage types (homegenous, heterogenous). The models explain whether firms are more likely to take a particular innovation action if they cooperate with a higher number of suppliers or customers groups depending on the diversity of their suppliers and customers.

Research Sample

The scope of this study concerns innovation activity in medium-high and high technology industry. It concers both product and process innovations new only to the firm.

We employed a questionnaire sent by e-mail and a telephone interview with a manager or company founder. All data were gathered between 2008–2013 in Poland. Information was collected from all Polish regions and stored in a database based on commercial and non-commercial sources of information such as Teleadreson, PKT and others. The response rate was about 15 percent. The final data set includes 1,355 questionnaires, including 981 (72.4 percent) from medium-high technology enterprises and 374 (27.6 percent) from the high technology sector. Table 1 shows the sample structure by technology and firm size.

TABLE 1. Sample by technology and firm size (number and share in percent)

Technology	Micro (0–9)		Small (10–49)		Medium (50–249)		Large (>249)		Total	
Medium-high	252	25.69	350	35.68	275	28.03	104	10.60	981	72.4
High	172	45.99	103	27.54	66	17.65	33	8.82	374	27.6
Total	424	31.29	453	33.43	341	25.17	137	10.11	1355	100

Source: own elaboration.

National capital are represented by 1,105 enterprises (81.55 percent) whereas foreign capital firms include 142 companies (10.48 percent) and 108 (7.97 percent) units have mixed capital. Table 2 shows the sample structure by industry.

TABLE 2. Sample structure by industry

Industry	Number (Share in percent)
Total high technology	***374 (27.60)***
Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks	187 (13.80)
Manufacture of basic pharmaceutical products and pharmaceutical preparations	60 (5.17)

Industry	Number (Share in percent)
Manufacture of communication equipment	70 (4.43)
Manufacture of computers and peripheral equipment	52 (3.84)
Manufacture of air and spacecraft and related machinery	5 (0.37)
Total medium-high technology	***981 (72.40)***
Manufacture of machinery and equipment (28)	480 (35.42)
Manufacture of electrical equipment Electrical machinery and apparatus, n.e.c.	227 (16.75)
24 without 24.4 Manufacture of chemicals and chemical products	156 (11.51)
34 Manufacture of motor vehicles, trailers and semi-trailers	82 (6.05)
35.5 Manufacture of other transport equipment	21 (1.55)
35.2 Manufacture of railway locomotives and rolling stock	15 (1.11)

Source: own elaboration.

The Impact of Vertical Linkages on Innovation Activity

Both suppliers and customers were assigned to 24 manufacturing sectors.[4] The total number of linkages between firms and groups representing suppliers is 2,591 while the total number of linkages between firms and groups representing customers is 850. Thus, for a hundred surveyed companies, we have 190 links with groups representing suppliers and 60 links with groups representing customers.

Of 1,355 firms 381 firms (28.12 percent) cooperate with at least one group of suppliers and one group of customers at the same time. Moreover, 331 firms (81 percent out of 381) cooperate with sectors representing different industries. When analyzing the structure of suppliers we found that 13.71 percent of firms cooperate with 4 or more divisions representing suppliers whereas 17.87 percent of firms claim close relations with 3 divisions. The number of firms cooperating with two or one group of suppliers is similar and amount to 27.72 and 27.17 percent, respectively. The structure of customers is different: 4.6 percent of firms cooperate with four or more groups representing customers, 5 percent of firms work with three groups, 9.5 percent of firms have close relations with two groups and 12.53 percent of firms cooperate with one group. Nearly 70 percent of firms do not cooperate with industry customers.

The technology-intensity classification of sectors of both suppliers and customers reveals different patterns.[5] The share of suppliers from medium-low-technology industries (MLT) is 45.08 percent whereas the share of suppliers from medium-high-technology (MHT) is 47.16 percent. The number of suppliers from low-technology industries is the lowest, amounting to 6.21 percent. The share of customers from medium-high-technology (MHT) industries is 47.16 percent and from medium-low-technology (MLT) is

22.46 percent. The number of customers from high-technology (HT) industries is the lowest, amounting to 10.52 percent.

The top four groups of suppliers have a nearly 50 percent share, whereas the top five groups of customers have about 45 percent share. The share of the largest groups of suppliers is as follows: Manufacture of basic metals (14.78 percent), Manufacture of machinery and equipment n.e.c. (12.47 percent), Manufacture of fabricated metal products (except machinery and equipment) (11.08 percent), Manufacture of electrical equipment (10.88 percent), and Manufacture of rubber and plastic products (10.5 percen) t. On the other hand, the share of the largest groups of customers includes Manufacture of machinery and equipment n.e.c. (15.48 percent), Manufacture of motor vehicles, trailers and semi-trailers (11.58 percent), Manufacture of electrical equipment (9.34 percent), Manufacture of other transport equipment (6.26 percent), and Manufacture of food products (6.15 percent).

The next step is to examine the impact of the number of supplier groups on innovative activity. Table 3 includes probit models for zero, one, and two groups of suppliers.

TABLE 3. Probit models for none, one and two groups of suppliers

Innovation feature	Number of groups											
	None				One				Two			
	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2
Investment in new fixed assets (including): buildings and grounds required to implement new products and processes	---				---				-.21	.08	.23	.30
Investment in new fixed assets (including): technical equipment and machinery	---				-.16	.08	.66	.72	---			
Investment in computer software	-.23	.10	.62	.70	-.16	.08	.65	.71	---			
Implementation of new technology processes, including:	---				-.23	.08	.70	.78	---			
b) non production systems	---				-.36	.08	.40	.27	---			
Innovation cooperation with suppliers	---				-.26	.08	.22	.30	---			

Source: own elaboration.

No links or a low number (0, 1 or 2) weakens innovative activity, while a large variety of connections (3, 4 or more groups) stimulates enterprises to innovative. The lack of links with suppliers negatively affects decisions related to the purchase of computer software. Relationships within a single industrial group adversely affect the introduction of new technological processes, including implementation of non-production systems. Companies tend to limit their investment in machinery and technical equipment, as well as in computer software. Furthermore, they cooperate less with suppliers. Links with two groups of suppliers limit investment in new fixed assets including buildings and grounds required to implement new products and processes.

Table 4 includes probit models for three, four, or more groups of suppliers. Maintaining relationships with suppliers coming from three different industrial groups makes firms more likely to invest in new fixed assets including machinery and technical equipment. In addition, such companies implement new technological processes more often, including new production methods.

Working with suppliers representing four or more industrial groups fosters innovative activity the most. The greatest positive impact relates to investment in new fixed assets including technical equipment and machinery, the implementation of new technology processes, and investment in computer software. Firms tend to increase their investment in new production methods and non-production systems. High supplier diversity stimulates investment in research and development and encourages cooperation with universities.

TABLE 4. Probit models for three and four or more groups of suppliers

Innovation feature	Number of groups							
	Three				Four or more			
	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2
R&D expenditure	---				.30	.10	.61	.50
Investment in new fixed assets	.21	.10	.83	.77	.33	.12	.86	.77
Investment in new fixed assets (including): buildings and grounds required to implement new products and processes	---				.28	.10	.37	.27
Investment in new fixed assets (including): technical equipment and machinery	.25	.10	.77	.69	.22	.11	.76	.69
Investment in computer software	---				.22	.11	.76	.69
Implementation of new technology processes (including):	.25	.10	.82	.75	.34	.12	.84	.75
a) new production methods	.26	.09	.57	.47	.24	.10	.57	.47
b) non production systems	---				.37	.10	.49	.34
Innovation cooperation with universities	---				.29	.13	.13	.08

Source: own elaboration

Table 5 includes probit models for none and one group of customers. The lack of links with a specific group of customers encourages companies to launch new products, while other types of innovative actions are weakened. Investment in new fixed assets and investment in computer software are suppressed the most. Firms limit their implementations of new production methods and support systems and their readiness to invest in research and development decreases. No dominant group of customers has a negative impact on the propensity to take the innovation cooperation including suppliers and customers.

Innovation cooperation with customers representing one industrial group has a negative effect on the propensity to launch new products, though it facilitates the development of innovation cooperation in general, especially with customers.

TABLE 5. Probit models for none and one group of customers

Innovation feature	Number of groups							
	None				One			
	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2
R&D expenditure	-.18	.07	.49	.56	---			
Investment in new fixed assets	-.17	.09	.77	.82	---			
Investment in computer software	-.34	.08	.66	.77	---			
Launching new products	.16	.08	.66	.60	-.32	.11	.53	.65
Implementation of new technology processes (including):	-.22	.08	.74	.81	---			
a) new production methods	-.28	.07	.45	.56	---			
c) support systems	-.25	.08	.27	.36	---			
Innovation cooperation with suppliers	-.23	.08	.25	.33	---			
Innovation cooperation with customers	-.33	.08	.21	.32	.44	.11	.38	.23
Overall innovation cooperation	-.32	.07	.48	.60	.24	.12	.60	.50

Source: own elaboration.

Table 6 presents a set of probit models for two, three, four or more groups of industrial customers. Maintaining relationships with customers from at least two different industrial groups encourages innovative actions. It helps to increase the frequency of investments in computer software. In addition, companies more often introduce innovative cooperation in general, including suppliers.

Having customers from three industrial groups affects investment in new fixed assets, including investments in machinery and equipment, computer software, and (most positiviely) the implementation of new technology processes. They also facilitate new methods of production and new support systems.

Firms that maintain relationships with four groups of customers are more likely to investment in computer software and research and development. They implement new technologies including new production methods and both non-production and support systems.

TABLE 6. Probit models for two, three and four or more groups of customers

Innovation feature	Number of groups											
	Two				Three				Four or more			
	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2
R&D expenditure	---				---				.54	.17	.71	.50
Investment in new fixed assets	---				.59	.22	.91	.77	---			
Investment in new fixed assets (including): buildings and grounds required to implement new products and processes	---				.33	.16	.40	.28	---			
Investment in new fixed assets (including): technical equipment and machinery	---				.48	.19	.84	.69	---			
Investment in computer software	.30	.13	.78	.69	.38	.18	.81	.69	.50	.19	.84	.69
Implementation of new technology processes (including):	---				.58	.21	.90	.75	---			
a) new production methods	---				.52	.16	.67	.47	.34	.17	.61	.48
b) non production systems	---				---				.33	.16	48	.36
c) support systems	---				.32	.16	.41	.30	.38	.16	.44	.29
Innovation cooperation with suppliers	.29	.12	.37	.27	---				---			
Innovation cooperation with research units (PAN)	---				---				.50	.24	.08	.03
Overall innovation cooperation	.25	.12	.60	.50	---				---			

Source: own elaboration.

They are the only group of firms cooperating with public research units (PAN). As in the case of suppliers, a large variety of customers encourages companies to take actions that may contribute to the emergence of products based on knowledge, i.e. products which require R&D expenditure, innovation cooperation with universities or research units. Thus, the increase in the number and diversity of industrial associations with both suppliers and customers has a positive effect on the frequency of introduction of new solutions.

The next part of the analysis introduces two types of vertical linkages: homogeneous, which define links with suppliers and customers in the same group; and heterogeneous, which describe links with suppliers and customers in different groups. Table 7 shows probit models for two types of vertical linkages: homogeneous links include suppliers and customers within the same group and heterogeneous ones consist of suppliers and customers within different groups.

The results indciate that simultaneous cooperation with suppliers and customers strengthens innovative activity in almost all areas. The influence in both cases is similar. However, homogeneous links facilitate cooperation with suppliers, whereas heterogeneous ones foster cooperation with universities.

TABLE 7. Probit models for homogeneous and heterogeneous vertical linkages

Innovation feature	Type of vertical linkages							
	Homogeneous				Heterogeneous			
	Parameter	Std	P_1	P_2	Parameter	Std	P_1	P_2
R&D expenditure	.20	.08	.57	.49	.16	.08	.56	.50
Investment in new fixed assets	.23	.09	.83	.76	.21	.09	.83	.77
Investment in new fixed assets (including): technical equipment and machinery	.18	.08	.75	.68	.18	.09	.75	.69
Investment in computer software	.43	.08	.80	.65	.42	.09	.80	.66
Implementation of new technology processes (including):	.21	.09	.81	.74	.26	.09	.82	.74
a) new production methods	.30	.08	.57	.45	.31	.08	.58	.46
c) support systems	.27	.08	.37	.27	.29	.08	.38	.28
Innovation cooperation with suppliers	.19	.08	.32	.26	---			
Innovation cooperation with universities	---				.24	.11	.11	.08
Innovation cooperation with customers	.31	.08	.31	.22	.24	.08	.30	.22
Overall innovation cooperation	.29	.08	.60	.48	.26	.08	.59	.49

Source: own elaboration

Empirical findings from developed economies show that different innovation activities lead to different types of innovation. More advanced innovations – such as products new to the market – require to a higher extent and internal R&D and patenting and are stimulated and supported by cooperation with universities and research organizations. The introduction of products new to the firm only – such as adoptions or incremental changes – requires less R&D activities. Regarding external relations, cooperation with external business partners (suppliers, customers) rather than with universities facilitates such innovation. [Tether 2002; Tödtling et al. 2009; Heidenreich 2009].

In contrast to developed economies, firms representing the MHT & HT industry in Poland tend to focus on in-house activities and are generally unwilling to cooperate. They tend to be passive beneficiaires of technology transfer and the low number of suppliers decrease their willingness to innovate. In this case the probability of taking innovation action is relatively low. The situation changes when the number of suppliers increases. With relatively low domestic demand for high technology products and services in Poland, firms tend to cooperate not only with suppliers and customers, but also with competitors to survive. By taking part in global chains, firms increase their technology, invest more in fixed assets, and implement new technology and processes. However, their ability to launch new original products and services is not increased due to the uncertain impact of knowledge diffusion. Hence, the best policy in terms of encouraging greater technology transfers from developed countries is to help domestic firms improve their technological capability through education, subsidies in research & development, and/or labor training. This findings can help better tailor Polish innovation policies and also be helpful for managers responsible for managing innovation.

Conclusions

Innovation activity depends on the type and diversity of vertical linkages in the medium-high or high-tech industry in Poland and this dependency is critical for its intensity. The more groups of suppliers and customers, the higher level of innovation. The increase in number of partners generates more activities leading to the development of products based on research and development and innovation cooperation with universities and research units. This phenomenon can be explained by analyzing the role firms play within these relationships. Companies aspiring to play the role of leaders are more willing to build and manage linkages, while others focus on direct advantages. Firms with numerous linkages invest more in fixed assets, implement new technologies and are willing to cooperate with various partners. The simultaneous cooperation with suppliers and customers strengthens innovative activity in almost all areas. By contrast,companies with no partners tend to limit their innovative activity. The impact is the greatest on the most frequently undertaken activities, such as investment in technical equipment and machinery, implementation of new technology processes and investment in computer software. Medium-high and high technology industries have their distinguishing characteristics. Our analysis suggests that the appropriately chosen suppliers and customers can accelerate innovation activity. However these industries are going through a period of rapid change involving the production system as a whole, which calls for identifying the supply relationship evolution to better reveal the circulation of information and technology. Such finindgs should broaden the understanding of industry-specific factors that affect firms' competitive strategies.

Notes

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[2] ISIC is the United Nations International Standard industrial Classification of all economic activities.

[3] USA, Canada, Japan, Denmark, Finland, France, Germany, Ireland, Italy, Spain, Sweden and Great Britain.

[4] NACE Rev. 2 Statistical classification of economic activities in the European Community, Eurostat Methodologies and Working Papers European Communities, 2008, pp. 65–69.

[5] ISIC Rev. 3 Technology intensity definition. Classification of manufacturing industries into categories based on R&D intensities, OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division, 2011.

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