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Complementarities between barriers to innovation: data evidence from Poland

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Contents

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Abstract

This paper investigates the barriers to innovation perceived by Polish manufacturing firms. It refers to the heterogeneity of innovation active firms. We introduce a taxonomy of innovative firms based on the frequency with which they introduce commercialised innovations using data from both CIS4 (for 2002-2004) and CIS5 (2004-2006). Two groups of innovation-active firms are distinguished: those which introduced innovation in both periods covered by both CIS (which we call persistent innovators) and those which introduced innovation either in CIS4 or CIS5 (which we call occasional innovators). We use a four step analysis covering binary correlations, Principal Component Analysis, probit model and correlations of disturbances. Two types of explanatory variables describing firms' characteristics and innovation inputs used are considered. The paper shows that there are considerable differences in sensitivities to the perception of innovation barriers and in complementarities among barriers between persistent and occasional innovators. In the case of occasional innovators, a kind of innovation barrier chain is observed. This has an impact on differences in the frequency of innovation activities between the two groups of innovators and results in a diversification of innovators.

1. Introduction

Innovation is a critical factor for competitive advantage. In the literature there are two approaches to factors determining innovation. The first approach focuses on factors that are conducive to and enhance innovation, while the second one focuses on factors that inhibit innovation, i.e. obstacles, barriers or impediments to innovation. The first approach in the literature indicates that innovative firms are heterogeneous in many ways, for example in terms of intensity and types of innovation inputs they use and their degree of engagement in innovation activities. The reported differentiation of innovation patterns, strategy and behaviour (Jensen, et al., 2007; Jong, de, and Marsili, 2006; Llerene, Oltra 2002; Clausen and Verspagen,2008;. Damanpour and Wischnevsky, 2006), and other classifications of innovators (for example pioneers, laggards, imitators and potential, early and late adopters) confirm the heterogeneity of innovative firms in many respects.

The barriers approach to innovation has focused on the impact of differences among innovative firms' characteristics and innovation inputs on the perception of barriers. These analyses show a positive relationship between the engagement of firms in innovation activities and the importance that firms attach to barriers. However this approach has treated all innovative firms as an undifferentiated group (e.g. Daniel and Grimshaw, 2002; Tourigny and Lee 2004; Baldwin and Lin, 2002; Iammarino et al., 2006). Only a few contributions on barriers to innovation refer to the heterogeneous nature of innovative (Pihkala et al. 2002; Blanchard et al. 2010) and non-innovative firms (D'Este et al. 2008, 2009) and the distinct factors that affect their assessment of the importance of barriers to innovation. With respect to New Member States, the existing literature is limited to the first approach (Kramer, 2009), descriptive analyses and case studies (Piech, Radosevic, 2006). To the best of our knowledge, only few research (Wziątek-Kubiak, Balcerowicz, Pęczkowski, 2009, 2009a) has been done on the heterogeneity of innovative firms in New Member States. However no research has been done on the differences in their perceptions of innovation barriers and complementarities between innovation barriers.

This paper argues that by looking more in detail into a group of innovative firms, we may gain a richer picture that will help us uncover the heterogeneous nature of these firms, and the distinct knowledge sources that affect their assessment of sensitivity to perception of

barriers. Exploring the barriers approach to innovation and considering the linkages and interrelationship between factors that hinder innovation, we tend to show evidence for complementarities between innovation barriers, an issue that is very significant for policy. Based on the frequency of commercialized innovation (innovation output), and exploring the Community Innovation Survey (hence forth CIS) data for two periods: 2002-2004 (CIS4) and 2004-2006 (CIS5), we focus on the differentiation of innovation barriers between two groups of innovators: the group that innovates continuously (introduced innovation in both CIS3 and CIS4) and the other that does it on occasion, that is either in the first (CIS4) or second (CIS5) period. In short, the introduced taxonomy is based on the frequency of engagement of firms in innovation activities.

A large proportion of Polish manufacturing firms do not introduce new products to the market or are simply indifferent to innovative activities altogether. Poland CIS5 shows that in 2008, only 23.1% of firms engaged in innovative activities, which is significantly less than in the European Union incumbent countries. Little is known about firms that do innovate, the characteristics that distinguish different groups of innovating firms, and whether or not differences among these firms exist in relation to their assessment of sensitivities to perception of barriers to innovation. In our understanding, policy should not only stimulate the innovation activities of non-innovating firms, but also strengthen the innovation activities of innovative firms.

This paper refers to differentiation in the innovation activities of firms that are active in innovations with respect to differences in sensitivity to perception of innovation barriers. Its aim is threefold. First, to distinguish those innovating firms that do engage in innovation activities continuously from those that do on occasion. We intend to detect differences in characteristics, knowledge sourcing activities and frequency of perception of innovation barriers between the two groups of innovators. Secondly, we intend to show the influence of characteristics and knowledge sourcing activities on differences in sensitivity to perception of innovation barriers between the two groups of innovative firms. Third, we hope to establish groups of barriers that are complementary, i.e. interdependent and reinforce each other and present similarities and differences between the two groups of innovators with this respect .

The paper builds on the previous literature (Mohnen and Roller, 2005; Galia and Legros, 2004) and provides an updated and comprehensive overview of barriers faced by innovative

manufacturing firms in Poland. It provides an econometric analysis of complementarities between barriers to innovation conditional on characteristics of firms and knowledge sources. The structure of the paper is as follows. Section 2 reviews the contribution of the literature on the relationship between innovation barriers and firms' characteristics and knowledge sources used. Section 3 presents methodology introduced and data used. Section 4 examines in detail the differences between the two groups of innovators in terms of their characteristics, innovation activities and frequency of perceived barriers which are important to innovation activities. In the next section we calculate the binary correlations between barriers to select their interrelated groups. The groupings of barriers are confirmed by the Principal Component Analysis. Section 6 provides an econometric analysis on the sensitivity to perception of innovation barriers conditional on firms' characteristics and knowledge sources activities and in this respect the differences between the two groups of innovators. Establishing groupings of interrelated barriers, in Section 7 we show complementarities between them. Similarities and differences in terms of complementarities between barriers influencing differences in innovation activities between the two groups of innovators are underlined. The summary and conclusions wrap up the paper.

2. Overview of the relevant literature

Many researchers have dealt with the determining factors of innovation to understand which factors are conducive to innovation and what is the relationship between them and a firm's performance. Fewer studies have used alternative approaches to investigate this issue, i.e. to assess which factors inhibit innovation, their role in innovation and the extent to which they actually slow down innovation activities (Leitao et al. 2007) as well as abandon, prematurely stop or do not begin an innovative project (Mohnen et al., 2008). So at the firm level, the literature has proceeded along two parallel strands reflecting two different approaches to factors of innovation. In both approaches the question on the extent of complementarities and the substitutability among different individual factors of innovation has been raised. To our knowledge, very few analyses have been conducted on to complementarities among barriers of innovation.

Most of the contributions on barriers to innovation focus on the relationship between impediments to innovation and various firm characteristics such as a firm's size, industrial affiliations (technology intensity), the competitive pressure of the environment and the type of ownership of the firm. They show that these characteristics matter for barriers to innovation as perceived by the firms. On the other hand, some innovation inputs, like R&D activities or inter-firm cooperation that are conducive to innovation, also reveal barriers to innovation.

Although the results of the existing literature on differences in barriers to innovation between large and small firms are ambiguous, many contributions show that firms face different barriers to innovation depending on their size. The descriptive statistics show that small firms are generally less innovative. Larger firms are better equipped with internal innovation resources and expertise, are better able to finance R&D from internal sources, are able to reap the rewards from innovation, and can diversify the risk of introducing innovation (Vossen 1998). The relative strength of small firms lies in behavioural characteristics such as flexibility and more improvisation in the task (Rothwell 1989). Different analyses find mixed results regarding the perception of barriers according to a firm's size. Baldwin and Lin (2002) posit that large firms are more likely to report barriers to innovation than small firms due to differences in technology advancement. Baldwon and Lin, as well as Tourigny and Lee (2004), argue that large firms are more likely to report cost-related and organization-related barriers to innovation than small firms. This is in opposition to Mohnen and Rosa (1999), Hyytinen and Toivanen (2005) and Immmarino at al (2007), who found that small rather than large firms recognize financial barriers as a significant barrier to innovation.

Many studies that deal with barriers to innovation consider technology intensity or the technological environment within which firms operate (Dossi 1988). It is assumed that technology intensity has an impact on the type of barriers that are encountered. As there are considerable differences in intensity of innovation across industries, firms in different industries face different barriers (Baldwin and Lin, 2002; Tourigny 2004). Firms in low and medium low technology industries are less likely to face impediments to innovation than those in high and medium high technology industries.

The rationale to include competition in the analysis of barriers to innovation is yielded by the literature. Baldwin and Lin (2002) as well as Mohen and Rosa (1999) show a positive and significant relationship between barriers to innovation and competition. Mohnen and Rosa

(1999) find that firms which face less competition have a tendency to consider questions related to barriers irrelevant. Baldwin and Lin (2002) and Tourigny (2004) posit that the more competition firms face, the higher the likelihood they also face cost, labour and other problems, for example expertise-related problems. This suggests that the barriers to innovation are strongest when competition is at its highest level or that the most innovative firms are those which perceive impediments to innovation most strongly.

There are very few analyses on differences in perception of innovation between domestic and foreign firms. Immmarino at al. (2007) show that foreign-owned and Italian-owned multi-national corporations (MNC) operating in northern and central Italy have different perceptions of barriers to innovation. Foreign-owned firms are more aware of the problems encountered when innovating than domestic ones. Studies have shown that important differences in firms' perceptions of barriers to innovation occur across types of firms in terms of their size, ownership, technology intensity, and competition pressure.

The next stream of research on factors influencing barriers to innovation concerns the relationship between these barriers and a firm's propensity to innovate (Blanchard et al. 2010), the degree of innovation (Pihkala et al. 2002), and between barriers and innovation factors (for example Canijels and Verspagen, 2001 who write about the impact of barriers on knowledge spillovers).

Pihkala et al. (2002) relate a different set of barriers to different categories of small firms. They show that perceiving barriers to innovation is negatively correlated with a firm's degree of innovation. For example, market conditions are perceived as the most significant for high-innovation firms, while in-house knowledge and information are perceived as the most significant for low innovation firms.

The third strand of research on factors of innovation concerns complementarities between them. Most of the research focuses on complementarities between factors that are conducive to innovation (Cassiman and Veugelers, 2002, Polder et al, 2010, Mazzati 2007, Love and Roper 2009) as they act as partially intangible assets to the competitiveness of firms. It is studied along different conceptual and empirical perspectives: evolutionary, systemic-oriented and dynamic-focused streams of research. There are very few analyses on the complementarities of barriers to innovation (Mohen and Roller 2005; Galia and Legros, 2004).

Mohen and Roller (2005) developed a framework for testing complementarities and substitutability in innovation policy. Based on Ireland, Denmark, Germany and Italy, and using a generalized Tobit model, they investigated two phases of the innovation process: the decision to innovate or not to innovate and the intensity of innovation. They found that these two phases of innovation process are subject to different constraints. Moreover they show that some barrier pairs are substitutable in the propensity to innovate, while complements in the intensity of innovation. For example the lack of finance and the lack of opportunity to cooperate are complements for the intensity to innovate, but substitutable for the propensity to become an innovator.

Galia and Legros (2004) use the French CIS2 data and use a different approach than Mohen and Roller (2005), and this is the multivariate probit model. They analyse differences and complementarities between barriers to innovation of the two types of firms: those that postponed projects and those that abandoned projects. They found that these two types of firms are subject to different barriers and different complementarities of barriers.

There are some analyses on barriers to innovation in less developed countries. Using factor analysis, Hadjimalis (1999) found that barriers to innovation are not correlated to innovativeness and horizontal networking in Cyprus. The differences in perception of barriers to innovation in Cyprus as compared to more developed countries are due to the deficiencies in the business environment in Cyprus, i.e. the shortage of resources and technology.

3. Data and methodology

The study uses firm level data from both the Third and Fourth Community Innovation Survey (CIS4 refers to the period 2002-2004 and CIS5 to period 2004-2006) for Polish manufacturing firms that were released by the Central Statistics Office. The dataset for CIS6 do not have barriers to innovation questions.

Our analysis covers a 5 year period, 2002-2006. This was a growth phase in the Polish economy so changes in innovation activities and the perception of innovation barriers of analysed firms were not influenced by change in the economic cycle. As the considered

period is rather short and our analysis shows small changes in performance in 2006 as compared to 2004, in the paper we present data only for 2006.

The focus of the paper is on innovative firms exclusively. We do not analyse firm non-innovating firm in the period under considerations as the CIS do not cover data on their knowledge inputs. We use the CIS definition which says that innovation firm is the one which introduced a new or significantly improved product (either a good or service) or any new or significantly improved processes for producing or supplying products new or significantly improved to the enterprise in the period covered in a given CIS. This definition is consistent with the standard definition of innovation as recommended by the Oslo Manual (OECD, 2005). However as we consider CIS3 and CIS4, innovation firms are those that introduced new or significantly improved products or processes in either CIS4 or CIS5.

Using weighted data we examine private (domestic and foreign owned) manufacturing firms that were included in both CIS3 and CIS4 and excluded from our analysis firms that were included only in one of the two CIS. Our panel covers 3,600 manufacturing firms that were innovators either in both periods (both CIS) or only over one period. Based on the criteria of the frequency of introduction of innovation, we introduced a taxonomy of Polish innovating firms. The firms that introduced innovation in both periods are named as persistent innovators. The firms that introduced innovation in one of the periods, either in 2002-2004 or in 2004-2006 are called occasional innovators. Our panel covers 2,371 persistent and 1,229 occasional innovators (Table 1).

In the paper, the size of the firms is measured by 3 binary variables capturing the number of employees: 20-49 employees (small firms), 50-249 employees (medium) and more than 249 (large). In terms of technology intensity, firms are classified into four groups based on the OECD definition: low technology, medium-low technology, medium-high and high technology. As a proxy of the internationalization of production reflecting differences in competitive pressure, we used the share of export of innovative products. Based on these criteria, we selected non-exporting and exporting firms. The latter are divided into two groups: the ones whose share of exported products that are innovative is below 10% and the ones in which the share is above 10%. Only private firms are analysed in the paper and we check for domestic and foreign owned firms.

On characterizing the innovative activities of the firms, we will distinguish between five different knowledge inputs into the innovation process and their sources. First, we consider the continuity of R&D activities which reflects the differences in the frequency of in-house R&D and developing a firm's own technology. We also consider the acquisition of other (intangible) external knowledge (purchase or licensing of patents and not-patented inventions, know-how, and other types of knowledge from other enterprises and organisations). As the new member states' innovation activities are based mostly on other external sources of innovation, we consider the ones that are included in the CIS. They cover types of partners while developing innovation, partners in cooperation in innovation activities, and other sources of market information . We also consider within-firm innovation activities while developing product and process innovation.

We investigate all eleven barrier items listed in CIS3 and CIS4 sometimes referring to barrier groupings: financial barriers (lack of funds within an enterprise or group, lack of finance from sources outside an enterprise and innovation costs too high), knowledge barriers (lack of qualified personnel, lack of information on technology and markets, difficulty in finding cooperation partners for innovation), market barriers (market dominated by established enterprises and uncertain demand for innovative goods) and reasons not to innovate (no need due to prior innovations and no need because of lack of demand for innovations). Our approach varies from the one used by Mohen and Roller, (2005) who selected one innovation barrier item out of each four sets of barriers.

There are three approaches used in the literature on complementarities (Athey and Stern 1998; Galia and Legros, 2004; Mohen and Roller, 2005). In this paper we pursue the correlation approach on eleven variables. We implement a four-step procedure which includes both barriers to innovation and explanatory variables. At first, the binary correlation between eleven barriers is estimated to show possible complementarities among them, that is to detect barriers which go hand in hand and the possible groupings. Then – and this is the second step – the Principal Component Analysis is carried out in order to confirm formed in the correlation procedure groups of barriers. Next (third step) we introduce econometric analysis based on a probit model. It covers eleven independent equations which estimate the eleven barriers separately and examine correlations between the residuals of each equation. Barriers are binary: 1 - if firms perceive the barrier as important or very important; 0 - if the importance is low or a barrier is no important. A dependent variable is a given barrier, while independent variables are characteristics of firms and innovation inputs used. The same set

of independent variables is used in the equations. The reference categories for the analysis are presented in Tables 4 -10 and in the Appendix (Table A1). The general specification of the probit model is as follows:

$y_j^* = \alpha_j + x\beta_j + u_j$, j=1,...,11

y_j^* are the latent variables corresponding to the probability that a firm perceives j-th barrier as important, x is a vector of explanatory variables, αj and βj are coefficients of j-th equation, uj are disturbances of j-the equation. We use the same explanatory variables for all equations. Variables y_j^* are unobserved. We observe binary variables yj, where

$y_j = 1 \; if \;\; y_j^* > 0$ and $y_j = 0$ otherwise

We assume that the disturbances have a multivariate normal distribution with mean vector 0 and covariance matrix with diagonal elements equal to 1.

The probit model shows differences in sensitivities to perception of innovation barriers conditional on four firm characteristics and on sources of five types of innovation inputs that firms used. In the fourth step of analysis, correlations between residuals of each equation of probit model are estimated. Taking into account the explanatory variables, this step intends to confirm (or reject) the simple binary correlations.

4. Characteristics of persistent and occasional innovators

There are slight differences in characteristics between the two types of innovators in terms of size, ownership of firms, technology intensity and export intensity. The sample is dominated by domestic firms and only about 20% are foreign owned. Moreover the share of the latter in the persistent innovators population is slightly larger than in the case of occasional ones (Table 1).

Table 1. Description of persistent and occasional innovators in 2006

	Permanent		Occasional	
	No of firms	% of persistent population	No of firms	% of occasional population
Number of firms	2371	100	1229	100
Exports share of innovation products in total exports revenue				
No exports of innovation products	1246	52.5	1165	94.8
From 0% to 10%	832	35.1	46	3.7
Above 10%.	293	12.4	18	1.5
No of firms by ownership				
domestic	1814	76.5	995	80.9
Foreign	557	23.5	234	19.1
No of firms by size				
Small firms	304	12.8	345	28.1
Medium-sized firms	1487	62.7	742	60.4
Large firms	580	24.5	142	11.5
No of firms by technology intensity industries				
High technology (HT)	106	4.5	62	5.0
Medium-high technology (MHT)	639	27.0	247	20.1
Medium-low technology (MLT)	665	28.0	336	27.4
Low-technology (LT)	961	40.5	584	47.5

The share of medium-sized firms in both groups of innovators is similar. However they differ in terms of the share of large and small firms. The proportion of large firms in the persistent innovator population was two times larger than in occasional innovator. The opposite is the case in small firms.

If we look into technological intensity, there are not large differences between the two types of firms. The share of high and medium-low technology industries in both groups of firms is similar. The differences between persistent and occasional innovators concern the share of medium-high and low technology intensive industries. A slightly larger share of medium high technology industries is typical for persistent innovators. The opposite occurs in the case of low technology industries.

The largest difference between the two analysed groups of innovators concerns the innovation intensity of exports (the share of innovation products in export sales). Only few (5.2%) occasional innovators export innovative products, while as much as 52.5% of persistent ones. The innovation intensity of exports share of persistent innovators exceeds 10% of sales is eight times larger than the occasional ones (Table 1). Let us notice that

persistent innovators operate under much stronger competitive pressure than occasional innovators. The latter focus on sales of innovative products on the domestic market.
All in all the population of persistent innovators is characterised by a higher share of large-sized, foreign-owned and medium-high technology industry firms than the population of occasional innovators. The first group of innovators is also export oriented while the occasional innovators focus on domestic market sales.

The small (except for export exposure, where the difference is substantial) differences in characteristics between the two groups of firms are accompanied by significant differences in frequency in firm's knowledge sourcing activities, i.e. the frequency of the use of knowledge inputs.

As commonly used data on in-house R&D intensity measured by the share of in-house R&D in sales revenues have not been disclosed to us, therefore as a proxy of R&D intensity, we use the continuity of in-house R&D activities in a firm. We explore the CIS question of whether a firm conducts in-house R&D continuously, occasionally or not at all. Almost 82% of occasional innovators and 60% of persistent innovators do not conduct in-house R&D activities. Only 14% of persistent innovators conduct regularly in-house R&D activities but this proportion is three and half times bigger than for population of occasional innovators; in case of occasional innovators in-house R&D, the ration is 2:1. Persistent innovators are much more prone to conducting R&D activities and their R&D intensity is possibly higher. However, we find the opposite in case of acquisition of external knowledge. The share of persistent innovators that acquire this type of knowledge is three times lower than the share of occasional ones. The more frequent involvement of persistent innovators in in-house R&D activities is accompanied by less frequent acquisition of external knowledge. The frequent use of external knowledge (like purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge bought from other organisations or enterprises) by occasional innovators substitutes for conducting own research. In-house R&D activities of persistent innovators substitute rather than complement above mentioned external knowledge. Our results are not in accordance with the existing literature, which presents arguments for complementarity between in-house R&D and external knowledge (Cassiman and Veugelers 2002).

Research studies (Veugelers and Cassima,1999; Fabrizio,2009; Mazzanti, Mancinelli, 2007) provide strong evidence for R&D active firms to be more active in using various types of

external sources of knowledge. Persistent innovators that are more often engaged in in-house R&D activities also more frequently use various external knowledge sources, including participating in networking. Their expenditure on R&D is complementary to their networking activities. As networking cannot exist without R&D activities acting as the primary engine, the R&D intensive firms use external sources of innovation intensively. For example other firms within their group are sources of market information on innovation for 56.5% of persistent innovators and for 18.6% of occasional innovators. Persistent innovators cooperate in innovation activities five times more frequently with other firms within their group and with suppliers of equipment and materials, competitors, and/or scientific institutions than occasional ones.

Table 2. Differences in knowledge sources between persistent and occasional innovators in 2006

	Permanent		Occasional	
	No of firms	% of persistent population	No of firms	% of occasional population
R&D activities				
In-house R&D continuous	334	14.1	47	3.8
R&D on occasion	615	25.9	176	14.3
None- R&D activities	1423	60.0	1006	81.9
Acquisition of other external knowledge	471	19.9	799	65.0
Institutions and firms cooperating in developing product innovations				
Mainly your enterprise or enterprise group	1525	64.3	297	24.2
Your firm together with other firms or domestic scientific institutions	194	8.2	27	2.2
Your firm together with other firms and /or foreign scientific institutions	65	2.7	10	0.8
Domestic scientific institution	7	0.3	2	0.2
Mainly foreign enterprises and /or scientific	23	1.0	9	0.7
Mainly other domestic firms	21	0.9	13	1.1
Institutions and firms cooperating in developing process innovations				
Mainly your enterprise or enterprise group	1421	59.9	580	47.2
Your firm together with other firms or domestic scientific institutions	357	15.1	143	11.6
Your firm together with other firms and /or foreign scientific institutions	131	5.5	28	2.3
Domestic scientific institution	21	0.9	6	0.5
Mainly foreign enterprises and /or scientific	79	3.3	37	3.0
Mainly other domestic firms	155	59.9	107	47.2
Cooperation partners in innovation activities				
Other firms within your firm group	420	17.1	44	3.6
Suppliers of equipment. materials. components. or software	979	41.3	104	8.5
Clients and /or customers	658	27.8	58	4.7
Competitors or other firms in your sector	281	11.9	27	2.2
R&D sector*	593	25	593	4.2
Sources of market information on innovation				

	Permanent		Occasional	
	No of firms	% of persistent population	No of firms	% of occasional population
R&D activities				
Other firms within your firm group	1340	56.5	229	18.6
Suppliers of equipment. materials . components and software	383	16.2	107	8.7
Clients or customers	744	31.4	133	10.8
Competitors or other firms in firm sector	412	17.4	101	8.2
R&D sector*	276	11.6	65	5.3
Other sources**	667	28.1	136	11.1

*including consultants, commercial lab. private and government, universities and higher education institutions
**Conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations

In innovation strategy, occasional innovators focus on process innovation while persistent ones focus on product innovation. 47.2% of occasional innovators develop process innovation and 24.2% develop product innovations by themselves or within the group they belong to. Meanwhile, for persistent innovators, the figures are 59.9% and 64.3%, respectively. 11.6% of occasional innovators which develop process innovations and 2.2% which develop product innovations cooperate with other firms (in the case of persistent innovators, the figures are 15.1% and 8.2% respectively).

Summing up, the two groups of innovators differ in knowledge sources they used and in innovation strategies they introduced: persistent innovators are externally oriented (use of network) and focus on product innovation while occasional innovators focus on process innovation.

Table 3. Frequency of firms' perception of barriers to innovations according to descriptive variables (% of firms meeting at least one barrier) in 2006

	Permanent		Occasional	
	No of firms	% of persistent population	No of firms	% of occasion population
a) Lack of funds within firm or group	1394	58.8	713	58.0
b)Lack of finance from sources outside your firm	1220	51.5	656	53.4
c) Innovation costs too high	1591	67.1	786	64.0
d) Lack of qualified personnel	803	33.9	437	35.6
e) Lack of information on technology	634	26.7	392	31.9
f) Lack of information on markets	570	24.0	326	26.5
g) Difficulties in finding cooperation partners	657	27.7	416	33.8

	Permanent		Occasional	
	No of firms	% of persistent population	No of firms	% of occasion population
h) Market dominated by established firms	1025	43.2	520	42.3
i) Uncertain demand for innovative goods or services	1210	51.0	567	46.1
j) No need because of no demand for innovations	424	17.9	265	21.6
k) No need due to prior innovation	487	20.5	317	25.8

The frequency of perception of three financial innovation barrier items (a-c, Table 3) as both very important and important is largest among all barrier items. It is not surprising as financial problems are particularly acute in innovation activities due to some of their inherent characteristics (Hall 2002; Mohen et al. 2008). These barriers are perceived by every other firm in the panel. However it is worth underlining the excessive costs of innovation are perceived as a serious barrier even more often: in the case of persistent innovators, by 15.5 percentage points more than in case of lack of finance, while for occasional innovators the differences is 10.6 percentage points. The barrier items that follow above mentioned are market dominated by established firm, uncertain demand for innovative goods and lack of skills of employees. Occasional innovators more frequently than persistent ones perceive as important 7 out of 11 barrier items. More occasional innovators also recognise two reasons not to innovate: these are no need to innovate due to prior innovation and no demand for innovations. On the other hand, a large number of persistent innovators perceive the excessive innovation costs and uncertain demand for innovation products as significant impediments to innovation.

In sum, the two types of firms differ in the frequency of perception of innovation barrier items within a given set of barriers, but also in terms of sets of barriers. Two sets of barriers, knowledge and no need to innovate, are more strongly perceived by occasional innovators while market barriers are more strongly perceived by persistent ones. The lack of funds within firms or groups of firms is perceived as a barrier to innovation by every second firm in groups of innovators.

5. Testing for complementarities between barriers to innovation

We begin with an analysis of possible relationships between different barriers to innovation and study simple binary correlations between eleven barriers. To confirm the results of the above correlations, we use the Principal Component Analysis.

All barriers are positively correlated. The correlation matrix (Appendix Tables A2 and A3) allows us to group barriers to innovation for both persistent and occasional innovators. It shows that, first of all, the level of correlation of innovation barriers is highest within each of four sets of barriers selected by CIS, i.e. financial barriers (a-c), knowledge barriers (d-g), market barriers (h-i) and reasons not to innovate (j-k) rather than between them.

Secondly, in most cases the types of correlated pairs of barriers and the resulting groupings in persistent and occasional innovators are similar. For both types of innovators, the correlation between barriers related to financial factors, i.e. lack of funds within a firm or from external sources is high (0.599 for persistent and 0.609 for occasional innovators). The correlation between the excessive costs of innovation and the lack of finance within a firm (0.463 and 0.464 respectively) as well as the high costs of innovation and external funds (0.434 and 0.518) go hand in hand. The correlation between lack of skills and lack of information on technology is high (0.463 and 0.569). The lack of information on technology and lack of information on the market are highly correlated (0.587 and 0.623). The uncertain demand for innovative goods and the domination of the market by established firms go hand in hand (0.469 and 0.540).

However, there are also pairs of barriers that appear to be slightly correlated, such as “difficulties in finding cooperation partners” and the “domination of the market by established firms” (0.254 and 0.362) as well as “no need to introduce innovation due to prior innovation” and the “lack of information on markets” (0.271 and 0.233).

On the other hand, there are some differences in correlations between barriers perceived by persistent and occasional innovators. The lack of information on technology correlates strongly with the lack of information on markets in case of persistent innovators (0.587), while in the case of occasional innovators, it correlates strongly with the lack of skills (0.623). In the

case of persistent innovators, difficulties in finding a cooperation partner go hand in hand with the lack information on the market (0.438), while in the case of occasional innovators, it goes hand in hand with the lack of information on technology.

Thirdly, in the case of occasional innovators, the level of correlation is a bit higher than for persistent innovators.

To exclude the impact of third variables that may strongly impact the binary relationship reflected in the Pearson correlation and to confirm the correlation results, we employ Principal Component Analysis (PCA). Its purpose is to select groups of barriers that explain the variance in the responses to barriers, that is to select factors that underlie a larger sets of variables. PCA is introduced and utilized for persistent and occasional innovators separately. PCA (Table A.4 in Appendix) selects three groups of barriers to innovation that explain the modest 57.54% of the variance in the case of persistent innovators and 62.23% in the case of occasional ones. So the quality of adjustment provided by the three factors selected for both types of innovators is satisfactory.

In case of persistent innovators, the first factor accounts for a maximum variance of data: it explains 20.26% of variance. It gathers four factors: lack of qualified personnel, lack of information on technology, lack of information on markets, and difficulties in finding cooperation partners. As it refers to knowledge, it is interpreted as the 'knowledge factor'. The second factor accounts for the maximum variance that has not been accounted for by the first factor and explains 19.13% of variance. As it covers three financial barriers, it is interpreted as a 'financial factor'. In the third factor (explains 18.15% of variance), barriers related to the market dominate. It is interpreted as a market barrier.

In case of occasional innovators, the first factor covers knowledge barriers to innovation and explains 18.15% of variance. The second one contains not only financial barriers but also barriers stemming from market conditions: the dominance of established firms and the uncertain demand for innovative goods or services. It explains as much as 23.46% of variance. The third factor which explains 15.27% of variance is related with the occasional nature of the analyzed type of innovators. It reflects barriers stemming from an uncertain demand for innovative goods or services and no need to innovate because of lack of demand for innovations.

All in all, although for both populations: persistent and occasional innovators, the PCA confirms the binary correlation results, there are some differences in factors grouping between two populations of innovators (see Appendix, Table A.4). However the results of the above analysis are not fully in line with the groupings of Mohnen and Rosa (2002) or with Galia and Legros (2004) although they selected financial factors as well.

6. Results of testing for sensitivities to barriers to innovation

The section on correlations between innovation barriers gives only a preliminary idea on complementarities between them. In this section, we perform an econometric analysis and look at the correlations of the residuals where the individual effects are controlled by the presence of other variables reflecting firms' characteristics and knowledge sources. We show that the likelihood that a firm will perceive barriers to innovation is increased or reduced by the existence of given inputs or characteristic of firms. In other words we show the difference between two groups of innovators in the sensitivity to perception of innovation barriers conditional on the characteristics of firms and the innovation knowledge sources they explore.

6.1. Sensitivities to perception of innovation barriers conditional on firm characteristics

In this section we present commonalities and differences in sensitivities to the perception of barriers between persistent and occasional innovators conditional on firm's characteristics.

The negative (significant) coefficients (Table 4) suggest that large and/or medium sized innovators are less sensitive to most (but two: lack of market information and lack of demand for innovation products) innovation barriers than small ones. The sensitivity to perception of most innovation barriers of large innovators is lower than that of medium-sized. The smaller the firm, the larger probability of perceiving innovation barriers. On the other hand, although there are many common barriers that large and medium-sized firms of both groups of innovators are sensitive to, probability of perceiving them by persistent innovators is lower than in case of their occasional counterparts

Table 4. Sensitivity to perception of innovation barriers conditional on firms' characteristics

	Permanent		Occasional	
	Sensitivity to barriers		Sensitivity to barriers	
	increases	diminishes	increases	diminishes
Size of firms				
Large firms		Intern. finance (-0.56) Extern. finance (-0.42) Costs (-0.54) Skills (-0.37) Cooperation partner (-0.31) Dominant position (-0.34) Uncertain demand (-0.52)		Intern. finance (-0.31) Extern. finance (-0.22) Costs (-0.26) Skills (-0.45) Cooperation partner (-0.31) Techno. info. (-0.44)
Medium sized		Intern. finance (-0.31) Extern. finance (-0.22) Costs (-0.26) Skills (-0.19) Cooperation partner (-0.28) Dominant position (-0.25) Uncertain demand (-0.40) Prior innovation (-0.23)		Intern. finance (-0.20) Extern. finance (-0.60) Costs (-0.63) Dominant position (-0.29) Cooperation partner (-0.22) Techno.info. (-0.20)
Technology intensity of industries				
High Technology	Skills (0.31) Market info. (0.3) No demand (0.3)		No need (0.57)	Costs (-0.66)
Medium-high Technology	Skills (0.25) Market info. (0.16)	Uncertain demand (-0.17) No demand (-0.21)	Cooperation partner (0.22)	
Medium-low Technology	Cooperation partner (0.17)	Extern. finance (-0.19) Uncertain demand (-0.4) Dominant position (-0.2)		Extern. finance (-0.16) Costs (-0.22) No demand (-0.31)
Exports of innovation products as % of sales				
> 0% - 10%		Uncertain demand (-0.18)		
>10%	Skills (0.16)	Costs (-0.21) Dominant position (-.22) Uncertain demand (-0.4) No demand (-0.21)		Dominant position **(-1.25**).

Reference category are small firms. In parenthesis – coefficient of the probit model. Significant at 0.05 level.

The negative (significant) coefficients (Table 4) suggest that large and/or medium sized innovators are less sensitive to most (but two: lack of market information and lack of demand for innovation products) innovation barriers than small ones. The sensitivity to perception of most innovation barriers of large innovators is lower than that of medium-sized. The smaller the firm, the larger probability of perceiving innovation barriers. On the other hand, although there are many common barriers that large and medium-sized firms of both groups of innovators are sensitive to, probability of perceiving them by persistent innovators is lower than in case of their occasional counterparts.

On the one hand, in both groups of innovators the sensitivity to perception of innovation barriers in medium-low technology industries diminishes while in high technology industries– increases. The higher the technological intensity of an industry, the probability of perceiving of a greater number of barriers increases. On the other hand, there are quite large differences in sensitivity to perception of innovation barriers between persistent and occasional innovators operating in three different sectors. Persistent innovators belonging to high technology and medium- high technology industries are sensitive to perception of the same barriers which are different from their occasional counterparts. Persistent and occasional innovators operating in medium-low technology industries are sensitive to the perception of different barriers except for one (lack of external finance).

Exporters of innovation products are more prone to perceiving barriers to innovation than non-exporters. Population of persistent innovators where every second firm is engaged in the export of innovation products tend to perceive more barriers than occasional innovators who focus on domestic market. Secondly, the higher the share of innovative goods export, the more barriers are perceived. For example persistent innovators whose export share exceeds 10% perceive four barriers, while firms with an export share of less than 10% only perceive one barrier. Thirdly, the higher share of innovation goods' exports is accompanied by a drop in the sensitivity to perception of more barriers. A lower innovation intensity of export is accompanied by an increase in sensitivity to perception of barriers. Differences between two groups of innovators in export intensity of innovative products accompany differences in number of barriers that they are sensitive to. Fourthly, the dominant position of established firms on the domestic market is the only common barrier to which sensitivity to perception of barriers in both groups of innovators lowers. This is an only barrier perceived by occasional exporters of innovative products. However the probability of perceiving of this barrier by them drops very significantly and much stronger than in case of occasional innovators (see coefficient in Table 4).

Foreign versus domestic ownership of firms impacts the sensitivity to perception of innovation barriers. When compared to domestic firms, foreign-owned firms operating in Polish manufacturing have a decreasing sensitivity to the perception of innovation barriers in the case of almost all barriers. This is in line with the results of the analysis conducted by Immarino et al. (2007) on northern and central Italy. They show that foreign owned MNC tend to rate most obstacles to innovation as important or very important significantly less often

than domestic ones. In our population of firms there are differences in the drop in sensitivity to perception of innovation barriers of foreign owned innovators operating occasionally as compared to persistent ones. This sensitivity to perception of barriers of the foreign owned occasional innovators decreases more than in case of their persistent counterparts.

Summing up, the higher competitive environment, the more barriers are perceived by innovative firms. However the probability of the perceiving of them decreases. The export of innovative products acts as a factor that diminishes the sensitivities to the perception of innovation barriers. It also differentiates sensitivity to perception of barriers between persistent and occasional innovators. The larger the firm, the lower its sensitivity to the perception of barriers. However the likehood of perception of innovation barriers of large sized persistent innovators decreases more than that of their occasional counterparts. In respect to technology intensity, there are quite large differences in sensitivity to perception of innovation barriers between persistent and occasional innovators. Ownership matters for sensitivity to perception of innovation barriers as perception of barriers of foreign owned firms diminishes as compared to domestic owned firms. However, the probability of innovation barriers in occasionally innovating foreign owned firms is lower than that of their permanently innovating counterparts.

6.2. Sensitivities to perception of innovation barriers conditional on innovation inputs

The previous section has shown that firm characteristics matter for the assessment of sensitivity to the perception of innovation barriers. In this section we consider the impact of different types of knowledge sources on sensitivities to perception of innovation barriers: in-house R&D, forward linkages to customers, backward linkages to suppliers, horizontal linkages to competitors and linkages to R&D institutions while developing innovation. We start with internal source, that is in-house R&D.

As a proxy of firm involvement in R&D activities, we use the variable presenting the continuity of in-house R&D activities of firm.

Table 5. Sensitivity to barriers of innovation conditional on the continuity of internal R&D and the purchase of external intangible technology

	Permanent		Occasional	
	Sensitivity to barriers		Sensitivity to barriers	
	increases	diminishes	increases	Diminishes
Continuous R&D		Intern. finance (-0.22) Extern. finance (-0.31). Cooperation partner (-0.25). No demand (-0.21)		Market info. (-0.86)
R&D on occasion	Skills (0.13). Techno. info. (0.22) Market info. (0.18)			
Purchase of other intangible technology			Intern. finance (0.29) Extern. finance (0.2) Market inf0. (0.25) Uncertain demand (0.45) No demand (0.24)	

In case of R&D inputs, reference category are no-R&D firms. In case of purchase of other intangible technology reference category are firms that do not purchase this technology. In parenthesis – coefficient of the probit model. Significant at 0.05 level.

Table 5 presents differences in sensitivity to perception of innovation barriers between firms that based their innovation activities either on in-house R&D (continuous and non regularly) or on purchase of external intangible technology. In case of both groups of innovators, firms with continuous in-house R&D activities reveal more innovation barriers than those firms that non-regularly undertake in-house R&D. Continuous R&D activities decrease the sensitivity to perception of barriers while non-regular R&D activities increase this sensitivity. The continuous R&D of persistent innovators lowers the sensitivity to perception of three barriers: lack of finance within and outside firm and difficulties in finding cooperation partners, while in case of occasional innovators only one barrier: lack of market information. Non regular R&D increases the sensitivity to the perception of three barriers only in case of persistent innovators and does not reveal any barrier in the case of occasional innovators.

On the other hand, the rare involvement of occasional innovators in R&D activities accompanies the frequent purchase of external intangible technology. However in opposition to continuous R&D, the purchase of external technology increases the sensitivity to perception of financial barriers of occasional innovators. Although the purchase of other intangibles by occasional innovators seems to substitute for the R&D activities of persistent ones, there are differences in sensitivity to perception of innovation barrier between them.

Table 6. Sensitivity to barriers of innovation conditional on firms' partners in development of innovation products and process

Firms and institutions	Permanent		Occasional	
	Sensitivity to barriers			
	increases	diminishes	increases	Diminishes
Development of product innovation				
Within firm and group	Dominant position (0.17) Uncertain demand. (0.29)		Market info. (0.86) Dominant posit. (0.87)	
In cooperation	Costs (0.27) Dominant posit. (0.24) Uncert. demand (0.35)			Intern. finance (-0.80) No need (-0.99)
Domestic	Cost (0.63)	Cooperation partner (-0.88)	Costs (**1.88**) Dominant position (**2.1**)	
Foreign		Cost (-0.74) Cooperation partner (-0.84)		Extern. finance **(-1.41**)
Development of process innovation				
Within firm and group		No demand (-0.25)	Cost (0.74) Market info. (0.86)	
In cooperation			Techno.info. (0.61) Market info. (0.89) Dominant position (0.87)	
Domestic		Market info. (-0.49) No demand (-0.40)	Market info.(**1.02**) Dominant position (0.81)	
Foreign	Skills (0.38)		Cost (**1.05**) Dominant position (**1.41**)	

In case of within firms and group reference category are firms that do not introduced a given form of innovation (either product or process innovation) while in other cases - firms that do not cooperate or subcontract innovation while developing innovation. In parenthesis – coefficient of the probit model. Significant at 0.05 level.

The increase in sensitivity to perception of only 2 barriers: excessive costs of innovation and the dominant position of established firms in innovative goods market is common to both groups of innovators (Table 6). The differences between them concern as much as 6 barriers: lack of qualified personnel and difficulties in finding cooperation partner (revealed in the case of persistent innovators) and lack market information, lack of technology information and lack of finance within and outside firm (revealed in case of occasional innovators). Cooperation of while developing process innovation reveals much less innovation barriers than that of occasional innovators which developed process and product innovation. However in case of the latter innovators sensitivities to perception of barriers

increases much stronger than in case of the former innovators (Table 6). Different ways of developing product and process innovation, i.e. within a firm or in cooperation reveal a sensitivity to perception of different barriers of persistent as compared to occasional innovators.

Table 7. Sensitivity to barriers of innovation conditional on firms' cooperation in innovation activities

	Permanent		Occasional	
	Sensitivity to barriers		Sensitivity to barriers	
	increases	diminishes	increases	diminishes
Suppliers	Techno. info. (0.16) Cooperation partner (0.17)		Extern. finance (0.46)	Tech. inf. (-0.43) Market inf. (-045)
Customers	Skills (0.23) Dominant position (0.17)		Costs (0.65) Uncertain demand (0.59)	
Competitors	Extern. finance (0.19)			
R&D institutions	Dominant position (0.20) Uncertain demand (0.20) Prior demand (0.20)	Techno.info. (-0.16)		

Reference category are firms in case of which innovation is developed within firm or its group. In parenthesis – coefficient of the probit model. Significant at 0.05 level.

In both persistent and occasional innovators, cooperation in innovation activities usually increases sensitivities to the perception of innovation barriers. However this occurs more frequently in persistent innovators (Table 7). Considering that persistent innovators cooperate in innovation activities more frequently rather than occasional ones suggests that cooperation in innovation reveals more barrier items and the wider the cooperation, the more barriers are revealed.

Table 8. Sensitivity to perception of barriers of innovation conditional on firms' sources of market information for innovation activities

	Permanent		Occasional	
	Sensitivity to barriers		Sensitivity to barriers	
	increases	diminishes	increases	diminishes
Suppliers		Dominant posit. (-0,17) Uncert.demand (-0.26)		
Customers		No demand (-0.19)	Tech. inform. (0.33)	
Competitors	Cost (0.24) Uncert. demand (0.26) Dominant posit. (0.29)		Cost (0.85) Skills (0.43) Market inf. (0.37) Dominant position (0.38) Uncertain demand (0.56	
R&D institutions	No need (0.27)	Extern. finance (-0.21) Cost (-0.28)		

Reference category are firms in case of which innovation is developed within firm or its group. In parenthesis – coefficient of the probit model. Significant at 0.05 level.

The use of market information on innovation more frequently increases the probability of perception of innovation barriers. As persistent innovators are two to three times more likely to use market information (Table 2), their sensitivity to the perception of more barriers increases than in case of occasional ones (Table 8). Almost all market information sources reveal innovation barriers to persistent innovators. Summing up, the more market information on innovation is used, the more barriers are revealed and the sensitivity to more barriers increases. The more sources of information are used, the more barriers are revealed.

Summing up, differences in innovation strategy between persistent and occasional innovators accompany the differences in revealed barriers. Product development of persistent innovators results in the revealing of more barriers. Significantly fewer barriers are revealed when they develop process innovation. The opposite is true in the case of occasional innovators. More frequent cooperation in innovation activities of persistent innovators accompanies the perception of more barriers than in the case of occasional ones. Networking in innovation activities mainly increases the sensitivity to perception of innovation barriers. The more frequent cooperation and market information on innovation is used, the more barriers are revealed and sensitivity to the perception of them increases. However although occasional innovators are sensitive to the perception of fewer barriers than persistent ones, the sensitivity of occasional innovators increases more than the sensitivity to perception of innovation barriers of persistent innovators. The fewer barriers that are revealed, the stronger the increase in sensitivity to perception of them.

7. Results of testing for complementarities between innovation barriers

The section 4 on simple correlations between barriers to innovation gives only a preliminary idea of complementarities between them. In this section, we examine whether simple correlations are confirmed once we control for firms' characteristics and innovation inputs used. We estimate the correlation of disturbances, i.e. the correlations between barriers conditional on explanatory variables used in the paper.

Estimations of the correlation between barriers conditional on explanatory variables are shown in Tables A5 and A6. A comparison of Tables A2 and Table A5 as well as Table A3 and Table A6 shows that there are no differences in the calculations of simple correlations and that one takes into account the impact of exogenous variables: characteristics of firms and innovation inputs. That is the 'suggestive evidence of complementarity'. This concerns both persistent and occasional innovators. Section 6 shows that the operation of external variables differentiates the sensitivities to perception of innovation barriers between the two groups of innovators. However they do not change the relationship between barriers revealed in simple correlations, that is complementarities over barriers.

All pair-wise complementarities are significant after controlling for exogenous variables (Tables A5 and A6).

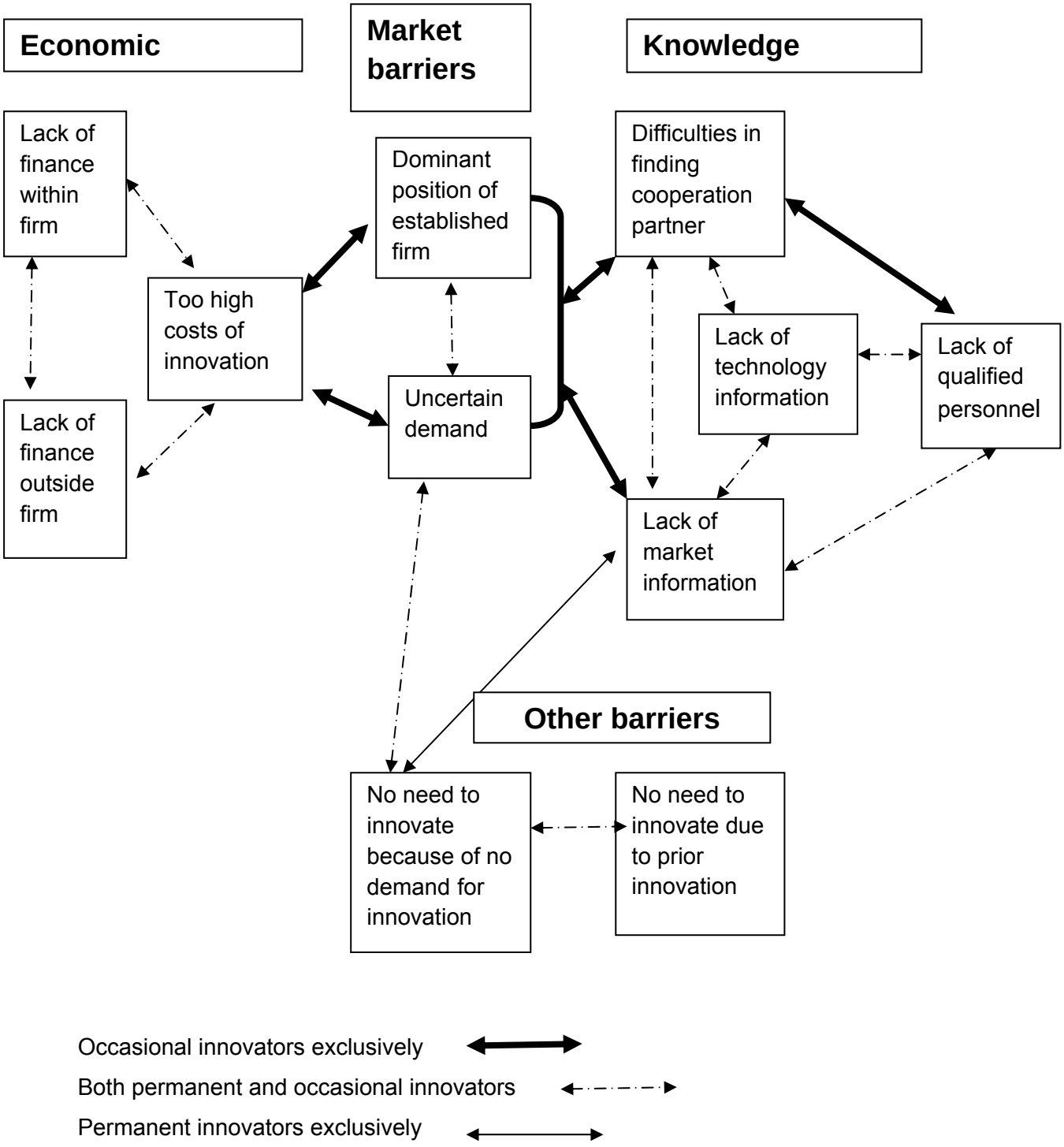
A large number of pair-wise complementarities of persistent and occasional innovators are within all sets of innovation barriers: financial, market and knowledge. In both groups of innovators the high costs of innovations and lack of finance both within the firm and outside it are highly complementary, i.e. they act together and reinforce each other. This means that the perception of costs barrier is increased by more whenever there are insufficient funds either within or outside the firm. The complementary character of the interdependence of these three barriers means that improvement in access to one of them (for example improvement in access either to external or to internal financing) decreases a firm's perception of other barriers (cost barrier). This suggests that improvements in access of firm to finance stimulate innovation.

In addition, four knowledge barriers are complementary in both groups of innovators. The lack of qualified personnel is highly complementary to lack of market and technology information and in the case of occasional innovators, it is also complementary to difficulties in finding cooperation partners. However the coefficient reflecting the level of complementarity of the latter barrier to skills barrier is lower than in the case of other barriers within the knowledge set of barriers. Whenever there is a lack of qualified employees, the access to market and technology information worsens even more (see coefficients reflecting level of complementarity in case of occasional innovators is higher than in case of persistent ones, see Table A4 and 5). At the same time the difficulties in finding cooperation partners increase even more. Insufficient information on technology and markets is perceived by more firms as a barrier whenever there is insufficient internal human capital. Therefore improvements in the skills of employees results in the improvement in access to information in both groups of innovators and increases the ability of firms to find cooperation partners (by occasional innovators).

In the case of a market set of barriers (a market of innovative goods dominated by established firms and an uncertain demand for innovative goods or services), there is one commonality and some differences in the pair-wise complementarities of barriers between persistent and occasional innovators. The dominant position of established firms and the uncertain demand for innovative goods go together in the case of both persistent and occasional innovators. This suggests that the structure of innovative products market has an impact on the innovation activities of other firms operating in demand side of this market.

It is worth mentioning that for occasional innovators, some barriers, for example the dominant position of established firms in the market of innovative goods, uncertain demand for innovative goods and lack of skills are complementary to more barriers than for persistent ones (graph 1). The first two barriers are worsened by the lack of market information and difficulties in finding cooperation partners. The cost barrier is complementary to more barriers in occasional innovators than in persistent innovators. In opposition to the latter, in the former, the domination of established firms in the innovative goods market by more worsens the too excessive cost of innovation. The latter barrier, the lack of market information and difficulties in finding cooperation partner barrier worsens the uncertain demand for innovation goods' barrier by more. Also the skills barrier worsen difficulties in finding cooperation partner by more in case of occasional innovators.

Graph 1. Differences in complementarities between barriers to innovation between two groups of innovators



The graph 1 presents differences in complementarities between barriers to innovation between two groups of innovators. In case of persistent innovators complementarities between barriers are within barrier sets. In case of occasional innovators they are also between barrier items belonging to different sets, that is between costs barrier (belonging to economic barriers set) and both dominant position of established firms and uncertain demand for innovation products (market barriers set) as well as knowledge barriers set.

Fourthly, the coefficients reflecting the level of complementarity of the all barriers are higher for occasional than persistent innovators. It suggests stronger complementarities between innovation barriers in case of former as compared to the latter innovators. The strongest complementarities for both groups of innovators concern complementarities between two financial barriers, two market barriers (the dominant position of established firms and uncertain demand), two barriers concerning lack of information and complementarities between lack of qualified personnel and both information barriers. It worth to mention that in case of occasional innovators the coefficient reflecting the level of complementarity of the skills barrier to other knowledge barriers is higher than in case of persistent innovators. It shows the important role of lack of skills of occasional innovators

Fifthly, it seems that a chain of complementarities between innovation barriers emerges (graph 1), which is in opposition to the innovation value chain concept (Roper et al. 2008). It starts from the lack of qualified personnel, to difficulties in finding cooperation partners, lack of market and technology information, to domination of established firms in the innovative goods market to cost barriers and to uncertain demand for innovative goods. So the first link of this chain, i.e. the lack of qualified personnel by more worsens the next three links (three knowledge barriers) and market barrier (the dominant position of established firms - suppliers of innovative goods) and altogether they worsen cost of innovation and uncertain demand of occasional innovators even more. The above-mentioned differences in complementarities between persistent and occasional innovators impact the less frequent innovation activities of the latter as compared to former innovators. More complementarities between barriers of occasional innovators reflect their weaknesses in innovation resources.

8. Summary and conclusions

Persistent and occasional innovators are quite similar in terms of firm size, ownership and technology intensity as well as in terms of frequency of perception of innovation barriers. However in terms of innovation activities and strategies, they differ quite considerably.

Innovation is a complex process which is influenced by many interrelated factors. As barriers hamper the operation of innovation factors, they are also interrelated. This raises the issue of complementarity among innovation barriers, i.e. when the operation of one barrier by more worsens the sensitivity to the perception of another one.

In both persistent and occasional innovators, three economic barriers, two market barriers and four knowledge barriers are complementary. For example, the lack of finance within a firm is highly complementary to the lack of finance outside a firm. Both barriers are highly complementary to the excessive cost of innovation. So the perception of the cost barrier increases by more whenever there are insufficient funds. However there are also important differences in complementarities between the two groups of innovators that impact the differentiation of the frequency of innovation activities between them.

Firstly, for persistent innovators, almost all barriers are complementary within barrier sets. In contrast, in occasional innovators, barrier items are complementary not only within all barrier sets but also across barrier sets. The cost barrier is complementary not only to other financial barriers (i.e., within the economic barrier set) but also to barriers belonging to the market barrier set (domination of established firms in the innovative goods market and uncertain demand for innovative goods). The market domination barrier (market barrier set) is also complementary to the lack of market information and difficulties in finding cooperation partners (belonging to the knowledge barrier set). The same concerns the uncertain demand for innovative goods barrier.

Secondly, in all cases, the complementarity of barriers is stronger in occasional innovators than in persistent innovators. This suggests that the interdependence of innovation barriers of occasional innovators is stronger than in the case of persistent innovators. As there are more pair-wise complementarities among barriers to innovation in occasional innovators,

barriers to innovation worsen the innovation activities of occasional innovators by more. This has an impact on differences in the frequency of innovation activities between the two groups of innovators and results in a diversification of innovators.

Thirdly, in the case of occasional innovators we observe that there is a kind of innovation barrier chain: from lack of qualified personnel to cost barriers. The first link of this chain worsens the next links: for example, lack of market information, difficulties in finding cooperation partners and lack of technology information together render the cost of innovation higher. We should keep in mind that not only is the frequency of perception of both cost and market domination barriers conditional to innovation inputs, one of the highest. The cost barrier is also complementary to an uncertain demand for innovative goods. The structure of the innovative goods market more is more likely to deter the innovation activities of occasional innovators than persistent innovators.

Fourthly, both barriers to innovation and complementarities between barriers reveal weaknesses in innovation capabilities and a strong dependence on the external sources of knowledge of occasional innovators.

An analysis of the differences in complementarity between innovation barriers of persistent and occasional innovators raises the issue of the interpretation of the barriers: as 'revealed' barriers (which obstruct firms' achievements in innovation activities) and as 'deterrent' barriers (which prevent firms from engaging in innovation activities) (D'Este et al. 2008). We observe that persistent innovators largely conform to a situation of 'revealed' barriers. The observed 'chain' and strength of complementarity between barriers and number of barriers that are complementary to one another suggests that some barriers of occasional innovators have a 'deterrent' character.

The evidence presented points towards a number of complementary relationships in innovation policy. As barriers to innovations are interdependent and reinforce one another, they should not be treated individually but should be tackled jointly. However as the share of innovative firms in Poland is very low, there are arguments which urge policymakers to consider problems with barriers to innovation encountered by occasional innovators. As occasional (intermediate) innovators are often in the process of transitioning between being non-innovators to persistent innovators and vice versa, some occasional innovators may become non-innovating firms, especially during periods of economic slowdown

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Appendix

A.1. Explanatory variables used in the analysis. Reference category is bolded

Group of variables	Variables	No. of variables in probit model
Firm size	**small**, medium, large	2
Technology intensity	**Low**, medium-low, medium-high, high technology	3
Exports of innovation products as % of sales	**no exporting**, exporting <10%, exporting >10%	2
R&D activity	**no R&D activity**, continuous R&D activity, R&D on occasion	2
Ownership	**domestic**, foreign	1
Purchase of other technology	**no purchase**, purchase	1
Development of new product	**not introduced a new product**, developed within firm and group, developed in cooperation, domestic institutions, foreign institutions	4
Development of new process	**not introduced a new process**, developed within firm or its group, developed in cooperation, domestic institutions, foreign institutions	4
Cooperation in innovation activities	**within firm or its group**, suppliers, customers, competitors, R&D institutions	4
Sources of market information	**within firm or its group**, suppliers, customers, competitors, R&D institutions, other	5
TOTAL		28

Table. A.2. Binary correlations between barrier to innovation. Persistent innovators

	Cost barriers			Knowledge barriers				Market barriers		Reason not to innovate	
	a)	b	c	d	e	f	g	h	i	j	k
a) Lack of funds within firms or group	1,000	0,599	0,463	0,187	0,140	0,152	0,139	0,219	0,217	0,109	0,081
b) Lack of finance from sources outsider your firm	**0,599**	1,000	0,434	0,183	0,186	0,170	0,177	0,220	0,198	0,118	0,127
c) Innovation costs too high	**0,463**	**0,434**	1,000	0,241	0,191	0,157	0,226	0,240	0,239	0,117	0,114
d) Lack of qualified personnel	0,187	0,183	0,241	1,000	0,463	0,357	0,277	0,226	0,162	0,205	0,161
e) Lack of information on technology	0,140	0,186	0,191	**0,463**	1,000	0,587	0,351	0,179	0,183	0,224	0,239
f) Lack of information on markets	0,152	0,170	0,157	**0,357**	**0,587**	1,000	0,438	0,253	0,271	0,271	0,351
g) Difficulties in finding cooperation partners	0,139	0,177	0,226	0,277	**0,351**	**0,438**	1,000	0,254	0,242	0,209	0,254
h) Market dominated by established firms	0,219	0,220	0,240	0,226	0,179	0,253	0,254	1,000	0,469	0,191	0,226

	Cost barriers			Knowledge barriers				Market barriers		Reason not to innovate	
	a)	b	c	d	e	f	g	h	i	j	k
i) Uncertain demand for innovative goods or services	0,217	0,198	0,239	0,162	0,183	0,271	0,242	**0,469**	1,000	0,198	0,334
j) No need because of no demand for innovations	0,109	0,118	0,117	0,205	0,224	0,271	0,209	0,191	0,198	1,000	0,509
k) No need to innovate due to prior innovation	0,081	0,127	0,114	0,161	0,239	**0,351**	0,254	0,226	0,334	**0,509**	1,000

Correlation coefficients bolded indicate higher than 0.35 values of correlation. All binary correlations are significant at the level α=0.001.

Table A.3. Binary correlations between barriers to innovation. Occasional innovators

	Cost barrier			Knowledge barrier				Market barrier		Reason not to innovate	
	a	b	c	d	e	f	g	h	i	j	k
a) Lack of funds within firms or group	1.000	0.609	0.464	0.298	0.195	0.225	0.251	0.305	0.325	0.082	0.097
b)Lack of finance from sources outsider your firm	**0.609**	1.000	0.518	0.259	0.231	0.262	0.294	0.324	0.290	0.082	0.171
c) Innovation costs too high	**0.464**	**0.518**	1.000	0.255	0.244	0.255	0.302	0.400	0.392	0.082	0.134
d) Lack of qualified personnel	0.298	0.259	0.255	1.000	0.569	0.508	0.389	0.261	0.248	0.173	0.224
e) Lack of information on technology	0.195	0.231	0.244	**0.569**	1.000	0.623	0.501	0.281	0.274	0.140	0.195
f Lack of information on markets	0.225	0.262	0.255	**0.508**	**0.623**	1.000	0.484	0.376	0.329	0.233	0.248
g) Difficulties In finding cooperation partners	0.251	0.294	0.302	**0.389**	**0.501**	**0.484**	1.000	0.362	0.398	0.181	0.242
h) Market dominated by established firms	0.305	0.324	**0.400**	0.261	0.281	**0.376**	**0.362**	1.000	0.540	0.169	0.238
i) Uncertain demand for innovative goods or services	0.325	0.290	**0.392**	0.248	0.274	**0.329**	**0.398**	**0.540**	1.000	0.195	0.307
j) No need because of no demand for innovations	0.082	0.082	0.082	0.173	0.140	0.233	0.181	0.169	0.195	1.000	0.492
k) No need due to prior innovation	0.097	0.171	0.134	0.224	0.195	0.248	0.242	0.238	**0.307**	**0.492**	1.000

Correlation coefficients bolded indicate higher than 0.35 values of correlation. All binary correlations are significant at the level α=0.001.

Table A.4. Factors selected in Principal Component Analysis

	Permanent			Occasional		
	Knowledge	Financial	Market	Knowledge	Financial and market	Not to innovate
a) Lack of funds within firms or group	,074	**,833**	,072	,120	**,790**	-,036
b)Lack of finance from sources outsider your firm	,121	**,799**	,086	,138	**,796**	,005
c) Innovation costs too high	,170	**,722**	,107	,158	**,766**	,039
d) Lack of qualified personnel	**,692**	,197	,036	**,749**	,177	,069
e) Lack of information on technology	**,839**	,077	,085	**,868**	,102	,041
f Lack of information on markets	**,755**	,040	,294	**,795**	,162	,181
g) Difficulties in finding cooperation partners	**,569**	,129	,272	**,641**	,283	,188
h) Market dominated by established firms	,103	,323	**,571**	,282	**,542**	,308
i) Uncertain demand for innovative goods or services	,056	,279	**,675**	,247	**,533**	,394
j) No need because of no demand for innovations	,215	-,047	**,660**	,095	,000	**,823**
k) No need due to prior innovation	,209	-,061	**,765**	,141	,096	**,822**
Variance (&)	20,264	19,131	18,146	23,608	23,458	15,267
Cumulative variance	20,264	39,395	57,541	23,608	46,966	62,233

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Table A5. Matrix for the correlations of disturbances – obstacles to persistent innovators

	Fin.int	Fin.ext	Costs	Skills	Tech.inf	Mark.inf	Cooper	Monopol	Uncl dem	No dem	No need
Fin.int	1.0000										
Fin.ext	0.5757	1.0000									
Cost	0.4398	0.4095	1.0000								
Skills	0.1591	0.1589	0.2238	1.0000							
Tech.inf	0.1185	0.1753	0.1848	0.4657	1.0000						
Mark.inf	0.1305	0.1611	0.1486	0.3500	0.5839	1.0000					
Cooper	0.1070	0.1574	0.2111	0.2667	0.3450	0.4341	1.0000				
Monopol	0.1847	0.1878	0.2054	0.2114	0.1687	0.2382	0.2443	1.0000			
Uncl.dem	0.1764	0.1632	0.2032	0.1545	0.1796	0.2635	0.2374	0.4350	1.0000		
No dem	0.0976	0.1150	0.1174	0.2094	0.2309	0.2761	0.2097	0.1867	0.1933	1.0000	
No need	0.0683	0.1264	0.1111	0.1626	0.2407	0.3520	0.2558	0.2292	0.3361	0.5181	1.0000

(p=0.0011)

All coefficients are significant on level 0.001 (p<0.001) expect (bara, bark) where p=0.0011

Table A6. Matrix for the correlations of disturbances – obstacles to occasional innovators

	Fin.int	Fin.ext	Cost	Skills	Tech.inf	Mark.inf	Coop	Monopol	Unc.dem	No dem	No need
Fin.int	1.0000										
Fin.ext	0.5872	1.0000									
Costs	0.4532	0.4911	1.0000								
Skills	0.2923	0.2461	0.2437	1.0000							
Tech.inf	0.1723	0.2112	0.2233	0.5624	1.0000						
Mark.inf	0.2142	0.2487	0.2307	0.5030	0.6134	1.0000					
Coop	0.2133	0.2659	0.2834	0.3866	0.4960	0.4916	1.0000				
Monopol	0.2744	0.2970	0.3632	0.2534	0.2632	0.3584	0.3489	1.0000			
Unc.dem	0.2967	0.2716	0.3752	0.2455	0.2617	0.3127	0.3753	0.5240	1.0000		
No dem	0.0821	0.0885	0.1022	0.1765	0.1389	0.2428	0.1757	0.1682	0.1987	1.0000	
	(p=0.2071)(p=0.0209)(p=0.0030)										
No need	0.0933	0.1672	0.1409	0.2299	0.1098	0.2442	0.2431	0.2362	0.3034	0.4861	1.0000
	(p=0.0033)										

All coefficients are significant on level 0.001 ($p<0.001$) expect (bara, barj) where $p=0.2071$, (bara, bark) where $p=0.0033$, ((barb, barj) where $p=0.0209$, (barc, barj) where $p=0.0030$.