INTERNAL BARRIERS TO INTERNATIONAL R&D COOPERATION: THE CASE OF POLISH HIGH TECH FIRMS

JOANNA CYGLER, SYLWESTER WYKA

ABSTRACT

The article presents the results of research on internal barriers hindering international R&D cooperation by Polish enterprises from the high tech industry. Cooperation in the R&D area and the related joint innovation is important for the firms' development.

The aim of the research, conducted on a representative sample of 400 Polish enterprises from the high tech sector, was to analyse their perception of international cooperation and to identify and assess barriers to R&D cooperation. The research sample is representative of Polish enterprises operating in the high tech sector in Poland. The analysis of research results used a cluster analysis to allow the use of dendrograms to select clusters similar to each other due to the assessment of internal barriers, and a multidimensional correspondence analysis showing the relationships between the selected groups.

The research results show the moderation of Polish enterprises in establishing international cooperation and the most important internal barriers to establishing cooperation. The conducted analysis also shows differences in the perception of barriers depending on the size of enterprises (taking into account the size of employment and annual turnover). The research results will allow for a better understanding of the specificity of cooperation with Polish enterprises in the R&D area, taking into account the barriers they perceive and assess. They will also allow for the formation of strategic activities that will help to reduce barriers to international cooperation for Polish enterprises in the R&D area.

KEY WORDS

International cooperation, barriers to cooperation, high tech sectors, R&D.

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Introduction

The last five decades have been characterised by a significant increase in enterprises' interest in cooperation, especially in the R&D field. Hypercompetition processes (which have resulted in, among others, a significant increase in operating costs, short-term competitive advantage, increased aggression between com-

petitors (D'Aveni and Gunther 1995)) and globalisation of enterprises' activities (including R&D) have made cooperation an integral element of business development strategy, especially in the international dimension (Hong and Park, 2015; Namaki, 2017; OECD, 2001; Ricciardi 2014). Cooperation of enterprises generates significant benefits and increases their competitiveness (Porter, 1985: 57), among others, through open innovation (Cuplan, 2014), the possibility of acquiring new technological solutions or the faster and cheaper development of one's own technologies (OECD 2008). Despite the undeniable benefits of international technological cooperation, Polish enterprises are cautious about creating bi- and multi-lateral cooperative relations with foreign partners in the high tech sector. Enterprises encounter barriers to international cooperation in the field of R&D, which result from their deficits (e.g. lack of cooperation competence), and concerns about relations with a foreign partner. The aim of the article is to examine the significance of these barriers to Polish enterprises operating in the high tech sector. It also seems important to distinguish groups of enterprises that assessed the level of those barriers at a similar level, and to examine their common features. In research conducted in 2018 on a sample of more than 400 Polish enterprises operating in the high tech sector, only 61 declared such cooperation. Such a low number of Polish enterprises cooperating with foreign partners therefore acts as an impetus for examining barriers that are perceived at the organisational level and result from internal or relational conditions. To classify enterprises due to the similarity of barrier assessment, the research included the classification trees method; whereas to analyse the characteristics of clusters of enterprises (including the following variables: annual turnover, number of employees, and operations on foreign markets), correspondence was analysed. The main results of this research will be useful for managers to work out a formula for reducing these barriers and to gain benefits from R&D cooperation with foreign partners.

The article is organised as follows. The first section presents the theoretical background of inter-organisational cooperation using transaction costs theory, game theory and the resource-based approach. In the second section, the benefits of international R&D cooperation are introduced as the key success factor in contemporary business. The third section is devoted to a discussion of the internal barriers to international R&D cooperation. The next two sections discuss statistical data and the results of research. Conclusions are presented in the last section of this article.

1. The essence of cooperation – theoretical background

The essence of cooperation between enterprises is explained in several theoretical concepts, among which the most important are the transaction costs theory, game theory, and the resource-based approach.

According to the transaction costs theory, cooperation between enterprises is determined in many different ways: network connections (Thorelli, 1986), quasi-integration (Blois, 1972, Monteverde and Teece, 1982), non-standard trade agreements (Williamson, 1983), hybrid agreements (Borys and Jenison, 1989; Williamson, 1991), strategic alliances (Parkhe, 1993; Badaracco, 1991), and business groups (Granovetter, 1995).

In the transaction costs theory, cooperation is an intermediate form between market transactions (contract-based) and hierarchical structures (power-based, Hindmoor, 1998; Thompson, 2003). Each of

these extremes is burdened with specific transaction costs. Market transactions generate costs related to understanding and mastering newly created market situations, information qualifications and convincing a partner. On the other hand, hierarchical structures are threatened by bureaucratic costs: agency costs, avoidance, *free riding*, measurement and coordination. The sources of the above costs are asset specificity, the uncertainty and complexity of the environment, information limitations, continuity of transactions and bureaucratic costs (Williamson, 1991). Failures of hierarchical structures and market transactions force enterprises to choose intermediate cooperation structures (Ring and Van de Ven, 1989).

Cooperation limits the occurrence of opportunism by structuring the incentives to share information (know-how) and guarantee results, among others. Cooperation strengthens trust by following common moral values and norms (Child and Faulkner, 1998: 49), but also by imposing sanctions on cooperating organisations that violate the principles of cooperation, common values, and sabotage others' actions (Morgan and Hunt, 1994). The level of trust affects the stability of relations and the scope of cooperation, as well as the choice of their organisational form (Doney and Cannon, 1997; Rindfleisch, 2000). However, these relations require target assets that are protected by long-term contracts to be formed. Horizontal cooperation is characterised by a lower level of trust than vertical cooperation. This results from a higher level of the risk of opportunism, a lower level of interdependence and the strength of connections between the parties (Achrol, 1997; Rindleisch, 2000). Organisations will decide to cooperate when transactions require specific assets to be involved and be repetitive in nature (Williamson, 1983, 1991). Subsequently,

mutual involvement (i.e. through investments in specific assets) will bring about mutual dependence and the two-sided provision of services, and will reduce the tendency towards opportunistic activities as a consequence (Hill, 1990; Oerlemans and Meeus, 2001). Apart from the need to engage specific assets and the repeatability of transactions, uncertainty becomes a stimulus for cooperation, especially when there is a need to gain knowledge in the R&D field (Brockhoff, 1992).

Cooperation requires increased control and coordination of actions (Dyer, 1997; White and Lui 2005). Organisations decide to cooperate due to the possibilities of achieving common and individual goals (Lui and Ngo, 2005; Leavit and McKeown, 2013; King, 2007). Enterprises cooperate in an imperfect market situation, especially when they want to enter higher investment risk markets (Williamson, 1991). Cooperation with a partner who is already operating in the host country reduces the overall costs of entry and development on the market of a given country, and generates benefits resulting from the effects of synergy, scale, range and time (Buckley and Casson, 1976: 33; Teece, 1981; Witek-Hajduk, 2014: 79-92). The cooperation of enterprises in the international dimension generates benefits in each of the areas of an eclectic paradigm of international production (Dunning, 1995) through, for example, opportunities for R&D cooperation and increased competitiveness, the use of immobile local complementary assets (tangible and intangible, e.g. technology), the use of the comparative technological and organisational advantages of host countries, access to R&D, design engineering facilities, and better dissemination and interpretation of knowledge (Dunning, 1997).

Cooperation in game theory is considered a non-cooperative game (prisoner's

dilemma: Parkhe, 1993; Axelrod, 1984; Hart and Mas-Colell, 1997; Yi et al., 2005; Mayberry et al., 1992). Both parties are encouraged to cooperate with each other through repetitive movements (Cho, 2014), the predictability of players' reactions (the *tit for tat* strategy), and the shadow of the future (Axelrod, 1984: 126; Heide and Miner, 1992). The *tit for tat* strategy is based on the principles of mutuality, prompts parties to abandon opportunistic behaviours in the short term, and is clear and easy for players to identify (Thomson, 2003). During cooperation, players constantly analyse individual benefits in both the short and long term (Camera and Casari, 2009). The increased importance of subsequent moves (repetitive play) and payoffs (the shadow of the future) makes enterprises more willing to cooperate. Moreover, the payoff structure must encourage the parties to cooperate, such that the benefits of cooperation must be significant enough to limit the parties' motivation and engagement in competition (Rapoport, 1988), and the system of penalties will aggravate the players' fears of high sanctions for violation of the rules of cooperation (Rachlin et al., 2000; Wang and Yang, 2003).

In the resource-based approach, cooperation between enterprises is recognised as a condition for development and effective competition (Medcof, 2001). In case of the increased complexity of the environment, enterprises are increasingly often unable to create or acquire (more immaterial than material) resources, which are a source of a relatively lasting competitive advantage (Henderson and Cockburn, 1994; Chesa, 1996; Boultellier et al., 2000). Access to information is of great importance nowadays (Gulati, 1999, 2007; Borgatti 2003; McEvily and Marcus, 2005). In the case of high-tech sectors, cooperation to protect current and acquire new sources of information and knowl-edge (explicit and tacit) is a prerequisite for survival and development (Powell et al., 1996; Polanyi, 1966). Cooperation (bi- and multi-lateral) allows partners to share their resources (tangible and intangible) and to create new ones that become the basis for building a collective competitive advantage (Dyer and Singh, 1998; Dyer, 2000: 23-39). Stimulators of this advantage are relational rents that result from the mutualisation of resources and their specificity, as well as the possibility of using them in general resource management, which are the partners' responsibility (Lavie, 2006). Complementarity and scale relationships occur between these resource groups (Dyer et al., 2001). Relations in which partners pass on convergent resources benefit from the effect of scale, strengthening their position in the sector (Contractor and Lorange, 1988: 3-30). When enterprises decide to have cooperative relations due to the complementarity of their resources, the benefits of the synergy effect appear (Hitt et al., 2000). The resource approach indicates the possibility of increasing the enterprise's innovativeness (Danneels, 2002) through cooperative relations with other organisations, creating open innovation (OECD 2008; Cuplan, 2014). Open innovation is the effect of increasing the enterprise's possibility of acquiring and using external knowledge (Cohen and Levinthal, 1990), learning and developing cooperation competences (Hamel and Prahalad, 1994: 166; Ireland et al., 2002; Lavie, 2006) and, as a result, increasing competitiveness (Inkpen, 1997: 337-369). This is particularly important in the R&D field (Contractor and Lorange, 1988: 3-30; Poyago-Theotoky, 1997; Mothe and Quelin, 2001; Halawi et al., 2006) and in high tech sectors (ICT, automotive, aerospace, and biotechnology).

2. International R&D cooperation

Technological development is one of the factors which have a significant effect on the economic development of enterprises and countries. Schumpeter (1943) defined the development of new consumer goods, new production methods and new means of transport as an impulse to drive the "engine of capitalism". New technologies have become a stimulus for the development and modernisation of the economy (Toffler, 1971; Chesnais, 1986). Dicken (1992: 97) believes that technology is one of the most important factors underlying the processes of internationalisation, simultaneously emphasising global changes that facilitate the flow of information and the increasingly rapid spread of innovative technologies. The ongoing fourth industrial revolution (Bartodziej, 2017) and the related development of information technology (Schaeffer, 2017) is resulting in an even greater reduction of the influence of geographical distance (this process was initiated by the development of new means of transport, in particular air transport), and thus easier access to information and the faster spread of the concept of innovation. Along with these changes, companies that adapt their mode of operation to new environmental conditions have risen to prominence. The results of research on internationalisation processes taking place in these organisations did not match the previously formulated models of internationalisation of enterprises which define internationalisation as a long-term multi-stage process (Johanson and Wiedersheim-Paul, 1975; Johanson and Vahlne, 1977). These enterprises were characterised by very early internationalisation - they entered international markets immediately after or within a few years of starting business operations as born globals (Rennie, 1993). The phenomenon of born globals is described by Oviatt and McDougall (1994), who define them as enterprises that use their resources and connections to develop a competitive advantage and internationalise the organisation within a short period of time. In turn, Knight and Cavusgil (1996) list a number of factors that allowed for the development of born globals, i.e. the development of manufacturing techniques allowing companies to reduce production costs and increase the efficiency of unit and small lot production, an increase in the importance of niche markets, and the positive impact of IT development on the development of international cooperation.

One of the most important reasons for organisations to start R&D cooperation is to obtain an innovative product that allows them to gain a competitive advantage. Ditrich and Duysters (2007) use the example of Nokia to demonstrate how the extension of the R&D cooperation network allows companies to obtain innovative products. The process of undertaking cooperation in the field of research and development as an opportunity to access complementary material and non-material resources, which allow the organisation to obtain an innovative product, appears in numerous studies (Feller et al., 2013; Un et al., 2010; Wu, 2012). Time is an ever more scarce resource. The short life cycle of a product that characterises innovative markets and the shortened product development time forces enterprises to establish cooperation at the research and development stage (McGahan, 2004). However, the investment in research and development is subject to high risk and requires investment in specialised research equipment. Undertaking cooperation with research units or other entities allows companies to minimise this risk and optimise operating costs by limiting investments in material resources; additionally, cooperation at the research and development stage allows enterprises to

gain access to qualified staff, scarce intangible assets, and knowledge and innovative technologies (Franke and Piller, 2004).

Cooperation in the R&D field is characterised by a large flow of information and a high risk of failure (Dicken 1992). Despite the awareness of inconveniences, organisations undertaking R&D cooperation are focused on long-term relationships, and build cooperation based on mutual trust (Fritsch, 2003). In the course of research into actions taken in the field of R&D, Fritsch (2003) emphasises the importance of the environment in which a company operates. Organisations that have research institutions, business service providers and competitors in their environment are more willing to cooperate on research and development. The influence of the environment on the probability of undertaking research-development cooperation is also emphasised by Heider and De Pablos-Heredero (2012), emphasising the special role of the education system in providing properly educated staff (universities), technology transfer offices facilitating technology transfer from research institutions to enterprises, and science parks which facilitate the effective utilisation of the potential of cooperation between scientists and research units and industry representatives gathered therein.

3. Internal barriers to international cooperation in the R&D area

It is difficult to overestimate the importance of cooperation for enterprises in the R&D field in high tech sectors. Such cooperation has even become a necessity for enterprise development. International R&D activities generate benefits that cannot be achieved on a scale of one country, and they become a prerequisite for functioning in high tech sectors (Stuart, 2000). Despite the unquestionable benefits and enormous universality of establishing international cooperation in the field of R&D, enterprises point to barriers that make this cooperation more difficult. These barriers are related both to the lack of experience in internationalisation and in cooperation with particular emphasis on R&D activities. Barriers that stop enterprises from starting the process of internationalisation can be divided – due to the nature of their formation – into organisational, information, technological, and human resource barriers (Sharif, 1983). Mazurkiewicz and Poteralska (2015) propose a division into technological, organisational and legal, as well as systemic barriers.

Apart from the problem of the lack of resources and staff, many enterprises face the problem of the lack of competences required to manage the R&D process and implement the results of the work carried out (Rosenbusch et al., 2011). Another group of barriers to the internationalisation process are social, cultural, psychological and economic aspects (Bufon et al., 2014: 7; Wróblewski 2015). Despite the progressive homogenisation of markets, demand and business models on an international scale, the lack of soft competences is an obstacle to efficient international cooperation between enterprises. This has been confirmed through research by Kurowska-Pysz et al. (2018), which proves that the communication method between partners, availability of resources and potential to develop cooperation, asymmetry of potential benefits of cooperation, and differences in the individual interests of partners become significant obstacles to cross-border cooperation.

Barriers resulting from cultural differences are important at the stage of establishing cooperation with foreign partners, and the lack of awareness of their existence may already have a negative effect at the stage of negotiations with a foreign partner (Gestland, 2012: 25-28). The lack of aware-

ness of the existence of cultural barriers may result from the lack of previous experience in international cooperation or the lack of knowledge of the host country culture, adopted communication rules (rituals, language), and management styles which potential partners have (Fandrejewska and Wasilik, 2018). The use of this knowledge allows for limits to the negative effects of barriers resulting from cultural differences, adapting to the local recipient and maximising profits (Barkema et al., 1996; Gestland, 2012: 121-122).

R&D cooperation is closely related to the transfer of knowledge from previously implemented projects and research within the organisation (Ajmal and Koskinen, 2008). Research and development projects are often carried out by interdisciplinary, international teams. During such cooperation there are many barriers related to the flow of information and the principles of knowledge exchange between entities (e.g. division of rights to processes and effects of R&D cooperation). This results in an increase in opportunistic behaviour and a decreased level of confidence (Pan and Scarbrough, 1999). Enterprises often perceive their knowledge as a competitive advantage, which results in tight control of the information flow between cooperating companies, which in turn leads to communication barriers (Bartol and Srivastava, 2002). On the other hand, striving for excessive protection of knowledge and information against uncontrolled leakage causes distrust in the parties' behaviour, especially in R&D projects (Hexmoor et al., 2006; Goh and Hooper, 2009). As a result, employees of enterprises show less and less interest in working in mixed teams, sharing knowledge and co-creating new ones (Santos et al., 2012).

Additional barriers to R&D cooperation are excessive bureaucracy (Ladd and Ward, 2002), lack of support from the management team (Figallo and Rhine, 2002), and lack of clearly defined organisational strategy (Stoddart, 2001).

Previous research on barriers to international R&D cooperation was focused on their identification. However, the issue of whether these barriers are perceived by all types of enterprises in a similar way arises. Considering the gap in knowledge of the diversity of perception of international research and development cooperation barriers, we have tested the following hypothesis:

Hypothesis 1 (H1) *The assessments of barriers to international cooperation significantly differentiate enterprises operating in the high tech sector.*

Hypothesis 2 (H2) *The perceivability of barriers to international cooperation in the area of R&D is determined by the size of the enterprise, measured both by the number of employees and the annual turnover.*

4. Description of the research and the research sample

The aim of the empirical research was to identify barriers to international cooperation in various areas of activity, with particular emphasis on the R&D area. The research was conducted among 400 Polish enterprises in the high tech sector. The selection of the research sample resulted from the characteristics of the high tech sector, and above all the globalisation processes taking place therein, hypercompetition and increased expenditure on R&D. In industries belonging to the high tech sector (e.g. telecom industry, semiconductor industry, automotive industry, aerospace and aviation industries) cooperative relationships (including competition) are common (Cygler & Sroka; 2017; Cygler et al., 2018). The sample structure met the conditions of representativeness for the population of high tech enterprises in Poland. The selection of

the research sample was made in several stages. The high tech sector was defined in accordance with the OECD (2003) and the Polish Classification of Activities (PKD) classification, which is compatible with the OECD. The research was carried out in 2018. The data was collected directly, based on a survey.

Based on the preliminary stages of research, out of a sample of 400 enterprises, only 61 companies (15.25% of the respondents) cooperate or intend to cooperate with enterprises or institutions from other countries in the R&D field. Considering the universality of international cooperation (including R&D) of enterprises from other developed countries, the results obtained in these studies should be considered as in line with the economic reality in Poland (Amoroso et al. 2017). From the point of view of the undertaken research problem, the selected group will constitute a research object later in the article. Out of these 61 companies, 54% declare that international cooperation in the R&D field is currently taking place, 41% of companies undertook such cooperation in the past, and 18% plan to cooperate. It should

be noted that, in the analysed group of 61 enterprises, almost half of the respondents (49%) were enterprises that indicated current cooperation only, 1/3 of enterprises indicated only cooperation undertaken in the past and 10% indicated only planned cooperation. Only 5% of companies had experience in international cooperation in the past, are currently involved in such cooperation and plan to undertake such cooperation in the future, while 3% of companies undertook cooperation in the past and plan it in the future, but do not currently participate in such cooperation.

Taking into account the industry structure, the surveyed group includes enterprises from the electrical equipment industry (2), production of finished metal products (13) production of other devices (3), production of transport equipment (7), production of computer, electronic and optical equipment (6), telecommunications (1), IT and software (6), technical research and analysis, architecture and engineering (3), research and development (20). The structure of the surveyed enterprises according to PKD classification is presented in Figure 1.

Figure 1. The structure of the surveyed enterprises according to PKD
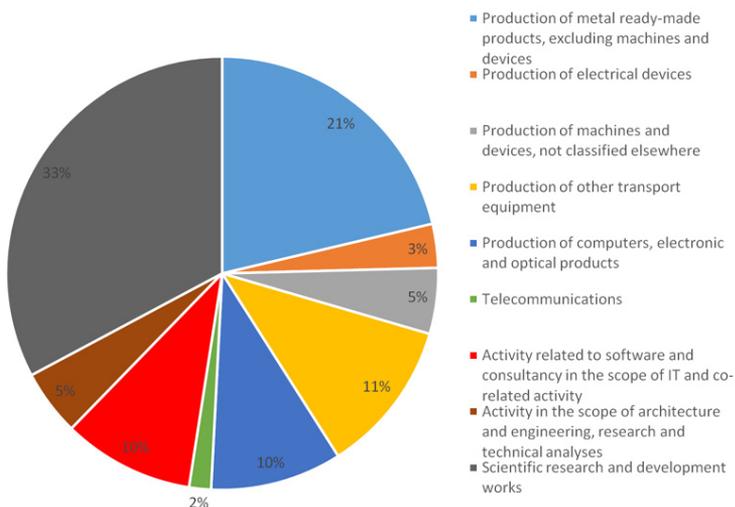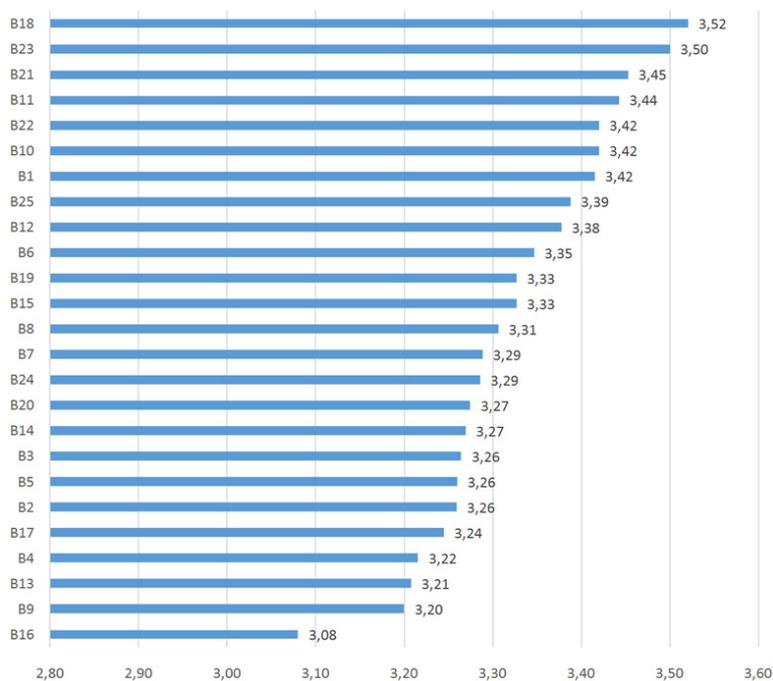

Source: Own elaboration.

5. Results and Discussion

Enterprises were asked to assess barriers to international cooperation in the field of R&D on a 5-point scale, where 1 meant that the barrier was of minimal importance, and 5 that the barrier was highly significant. Barriers were separated based on the literature analysis and based on interviews with managers of several dozen Polish companies and transnational corporations operating in the high tech sector. Individual assessments were used to calculate average ratings for individual barriers (in total, 25 micro-type barriers were assessed), which served to build a ranking of barriers from the most to the least obstructive to international cooperation between enterprises in the R&D area (Figure 2).

Figure 2. Ranking of internal barriers to international cooperation in the R&D area

Legend:

Markings:

B1   No need to cooperate with foreign entities
B2   Problem finding the right foreign partners
B3   Limited enterprise flexibility that does not allow for a quick response to changes imposed by the high-tech sector
B4   Negative experiences of other national enterprises in terms of international cooperation
B5   Negative experiences of an enterprise in terms of international cooperation in the past

B6   Negative experiences of enterprises in terms of cooperation with universities and research institutes in the country and/or abroad
B7   Fear of unlawful use of knowledge, information and technology
B8   Lack of sufficient knowledge and qualifications of employees
B9   Lack of research infrastructure required to carry out joint projects

B10　Lack of production infrastructure required to carry out joint projects

B11　Lack of adequate financial resources

B12　Insufficient brand/company recognition on the international market

B13　Insufficient brand/company recognition on the domestic market

B14　Inequalities in the area of resources and competences between partners

B15　Difficulties in the flow of information and communication with foreign partners

B16　Cultural and language barriers

B17　Differences in structures and management processes between partners

B18　Fear of losing independence and control over the company to a foreign partner

B19　Fear of losing the best employees after co-operation

B20　Fear of asymmetry of cooperation benefits (mainly resulting from the division of intellectual property rights of the project effect)

B21　Difficulties in estimating the potential costs and benefits of cooperation

B22　Insufficient knowledge of possible public support in Poland in the R&D area and internationalisation of activity

B23　Fear that support obtained from public funds in Poland in the R&D area and the internationalisation of activities will prove ineffective

B24　Lack of own decision-making

B25　Low frequency of direct contact with foreign partners

The entrepreneurs surveyed considered the following barriers the most obstructive to international cooperation in the area of R&D:

– Fear of losing independence and control over the company to a foreign partner,
– Fear that support obtained from public funds in Poland in the field of R&D and the internationalisation of activities will prove ineffective,
– Difficulties in estimating the potential costs and benefits of cooperation,
– Lack of adequate financial resources.

Entrepreneurs indicated the following as the least obstructive:

– Cultural and language barriers,
– Lack of research infrastructure required to carry out joint projects,
– Insufficient brand/company recognition on the domestic market.

However, barrier assessments were highly diverse among the entrepreneurs surveyed (coefficients of variation of ratings for each barrier exceeded 50%). Due to the heterogeneity of the assessments obtained, an attempt was made to divide the enterprises into groups with similar assessments of individual barriers. For this purpose, one of the methods of statistical multivariate analysis, namely cluster analysis, was used. This method is one of the so-called methods of interdependency analysis, which means that all variables in the analysis are treated as interdependent without separating dependent (effects) and independent variables (reasons) among them. Cluster analysis allows researchers to separate internally coherent groups of objects. The research was undertaken in four main stages: selection of variables and adoption of the method of determining similarities between objects (I), selection of the method of assigning given objects to a homogenous group (II), selection of the number of identified clusters (III) and interpretation and profiling of acquired clusters (IV). There are two cardinal approaches to grouping – hierarchical and non-hierarchical. In the hierarchical approach, we obtain a hierarchical structure of similarities between objects in the form of a tree, called a dendrogram (Ward, 1963). Based on this dendrogram (tree diagram), four clusters of enterprises were selected (Figure 3). In each of the clusters, enterprises were similar to each other due to the assessment of all 25 barriers.

Figure 3. Classification of enterprises due to the assessment of barriers using cluster analysis
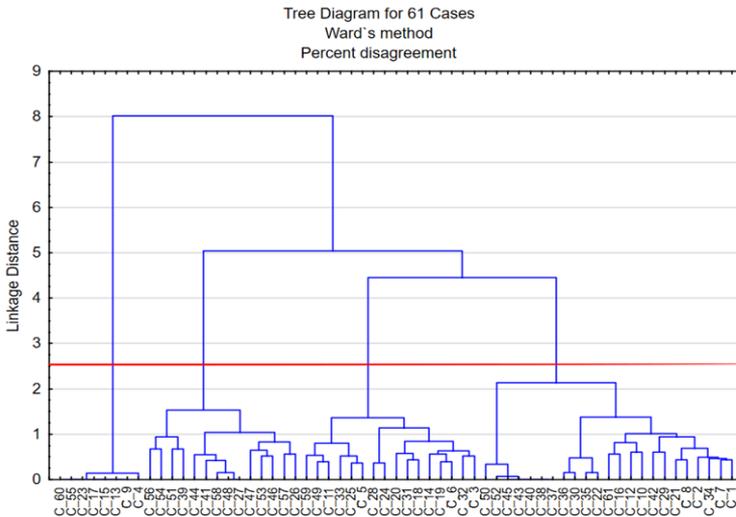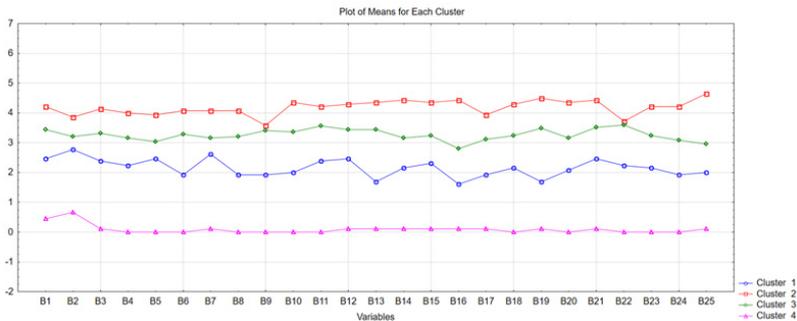

Source: Own elaboration.

The number of four clusters obtained using the tree diagram was used in the next cluster analysis method, i.e. in the k-means method.

For the set number of four clusters, a classification of enterprises for groups (clusters) that similarly assessed the barriers to international cooperation in the R&D area was made. Then, using the k-means method (as a non-hierarchical method), average levels of assessments of individual barriers in selected enterprise clusters were determined.

The k-means clustering method divides the entire set of different cases for the k different clusters possible. The algorithm of this method consists of moving objects between the indicated number of clusters to minimise intra-cluster variability and maximise variability between clusters.

The result of this method confirmed the correctness of enterprise grouping due to the similarity of assessments of barriers to international cooperation in the R&D area. In addition, the k-means analysis allowed the researchers to determine the average assessment of barriers in individual clusters (Figure 4).

Figure 4. Average assessment of barriers in individual clusters

Source: Own elaboration.

The cluster analysis made it possible to identify four clusters with similar assessments of barriers to international cooperation of enterprises in the R&D area. Cluster 1 consists of 13 companies (21% of the respondents) which assessed all barriers at a level below 3. This means that, according to these enterprises, the barriers assessed are not very troublesome when it comes to undertaking or conducting international operations. However, some of the barriers received a slightly higher rating in this cluster (they are more burdensome than others). These barriers include: the problem of finding the right foreign partners (B2), negative experiences of an enterprise in terms of international cooperation in the past (B5), fear of illegal use of knowledge, information and technology (B7), insufficient brand/company recognition on the international market (B12) and difficulties in estimating the potential costs and benefits of cooperation (B21).

Cluster 2 is comprised of 14 enterprises (23% of the respondents), which assessed the barriers to cooperation as far and away the most inconvenient compared to other clusters of enterprises. Only two barriers - lack of research infrastructure required to carry out joint projects (B9) and insufficient knowledge of the possible public support in Poland in the R&D area and internationalisation of activity (B22) – received a lower rating, making international cooperation more difficult in this cluster.

Cluster 3 is the largest, consisting of 25 enterprises (41% of the respondents). These organisations assess the troublesomeness of all barriers rather highly, and they are more difficult for international activities in the R&D area: no need to cooperate with foreign entities (B1), lack of research infrastructure required to carry out joint projects (B9) and finance (B11) in the company, insufficient knowledge of possible public support in Poland in the

R&D area and internationalisation of activity (B22).

Cluster 4 consists of only nine enterprises (15% of the respondents). These are companies for which none of the barriers are troublesome, and in many cases barriers do not exist at all. The results of the cluster analysis have shown a significant diversification of enterprises in the high tech sector in terms of the assessment of barriers to international cooperation in the R&D area, pointing to four relatively homogeneous groups.

This means that the H1 research hypothesis has been positively verified.

To characterise the selected clusters of enterprises, they were additionally analysed due to selected variables:

- Annual turnover (with the following variants: 100-500 thousand PLN, 500 thousand PLN - 1 million, 1 - 5 million PLN, 5 - 10 million PLN, 10-20 million PLN, 20- 50 million PLN, over 50 million PLN).
- Number of employees (with the following variants: 10-49 people, 50-249 people, 250 or more people).
- Activity on foreign markets (with the following options: yes, no).

To analyse the characteristics of clusters, taking into account the above-mentioned variables, the correspondence analysis was used. Correspondence analysis is a descriptive, exploratory technique of multivariate statistical analysis, allowing researchers to define the nature and structure of the relationship between qualitative variables, measured on nominal and ordinal scales. Correspondence analysis belongs to the group of incomplete taxonomic methods. This technique, as well as multidimensional scaling, principal component analysis of factor analysis, leads to an increase in the transparency of data and simplifies its interpretation, albeit at the expense of losing some of the information.

The use of statistics and charts specific to that method provides the researcher with easy, intuitive reasoning on the relationships between the analysed categories of variables.

Correspondence analysis is a multi-step procedure that starts from the arrangement of the data in the contingency table. The main aim of plotting the correspondence map is to reduce the number of analysed space dimensions (Greencare, 1984). In this process, the singular value decomposition (SVD) algorithm of the matrix decomposition is used with respect to specific values (Pres et al., 2007). Interpretation of the correspondence map allows the researcher to find diversity within the analysed variables profiles, as well as the co-occurrence of different categories. Using a multidimensional analysis of correspondence, a map of correspondence was obtained which shows the dependences between selected groups of enterprises that assess barriers to international cooperation in the R&D area (clusters) and other variables (Figure 5).

Figure 5. The correspondence map between clusters of enterprises and variables characterising enterprises due to size, turnover and activity on international markets
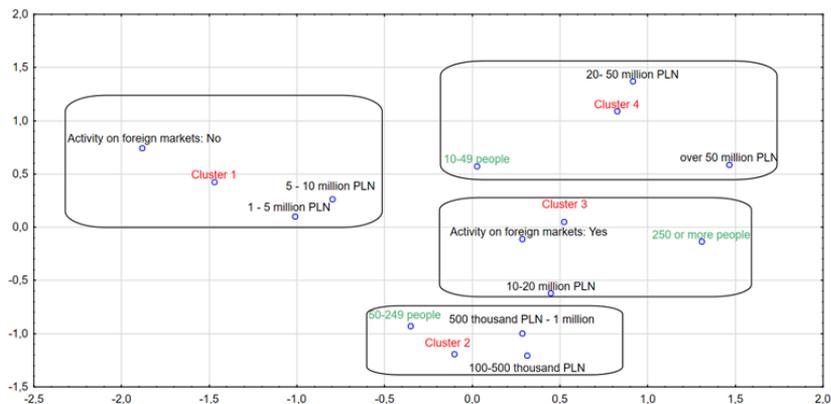
Source: Own elaboration.

Cluster 1, i.e. enterprises that are minimally affected by barriers to international cooperation, do not operate on foreign markets, and have annual turnover ranging from 1 to 5 million PLN or from 5 to 10 million PLN.

Cluster 2 consists of enterprises that are most strongly affected by barriers to international cooperation, often small enterprises (employing from 10 up to 49 people) with annual sales that are quite low, up to 1 million PLN.

Cluster 3 consists of enterprises that are strongly affected by barriers to cooperation and which are large enterprises (employing 250 or more people), operating on foreign markets, with a turnover of 10 up to 20 million PLN.

Cluster 4 includes enterprises that do not have barriers or those that are not affected by barriers. These are mostly medium-sized enterprises (employing from 50 up to 249 people) with the highest turnover (over 50 million PLN).

The correspondence analysis made it possible to clarify the characteristics of enterprises, creating clusters comprised of those which similarly assess barriers to international cooperation in the R&D area. Large enterprises with international experi-

ence are the least affected by barriers to cooperation, while small enterprises without much international experience are the most affected.

The correspondence analysis shows that the individual clusters of enterprises differ from each other in terms of the size of companies, both in terms of the number of employees and the level of annual turnover.

In two cases (clusters 1 and 3), experience (or lack thereof) of international activities was assessed as significant.

Therefore, it should be stated that enterprises from the high tech sector, which similarly assessed the barriers to international cooperation in the R&D area, are also characterised by similar size.

Therefore, the H2 research hypothesis has been confirmed.

Conclusions

Taking into account the results of analyses using both cluster analysis and correspondence analysis, it should be noted that there is a diversity of perception and assessment of barriers to international cooperation in the R&D area in the high tech sector depending on the company's characteristics. International cooperation in the R&D area becomes an inherent part of the development strategy of enterprises operating in the high tech sector.

The need to cooperate results mainly from globalisation processes in the high tech sector, the technological race (including the shortening of the life cycle of technologies and products), and hypercompetition. Cooperation allows companies to reduce operating costs due to the possibility of acquiring deficit strategic resources, among which intangible assets (knowledge, information, competences) are of key importance, creating a more sustainable and unique competitive advantage. International technology cooperation also reduces the costs resulting from business

relationships (increased trust, reduction of opportunism and uncertainty).

Despite the undeniable benefits of these relations, enterprises still perceive many barriers to this cooperation, which results in a certain reluctance to make the decision to cooperate with foreign partners in the R&D area. Polish companies from the high tech sector are a great example. The aim of the article was to analyse the perception and assessment of barriers to cooperation by Polish enterprises in the high tech sector.

This analysis is particularly important because Polish enterprises show moderate cooperative activity in the R&D area, as only 15.25% of the first research sample (representative of the high tech enterprise population in Poland) declared experience of international cooperation or the intention to begin doing so. The results of quantitative research (based on 61 Polish enterprises) allowed the researchers to verify the formulated hypotheses.

Our research contributes to the development of knowledge in several ways. First of all, though this research adopts a single-country approach, analysing Polish high tech companies gives us the opportunity to make a comparative analysis of the barriers to international cooperation in the R&D area in other high tech or technical sectors and in other countries.

At the same time, research results related to Polish companies' concerns about international cooperation in the R&D area will contribute to strategic actions of managers that are aimed at the effective reduction of these barriers, taking into account the experience of the companies surveyed depending on their characteristics. The perception and assessment of these barriers are not homogeneous, and the internal diversity of the analysed enterprises (in terms of both the high tech sector in which they operate and their size) is important for the assessment of these barriers.

The presented research has certain limitations. First of all, it concerns one country and a specific sector – albeit the sector is large, and the processes and phenomena occurring therein lead to its further extension to activities and technologies that did not exist or were not widely used until now. Therefore, there is a need for future research to fill this gap by extending the scope of research to include geographical and sectoral criteria. The research would then gain additional value in terms of cultural and industry factors. A wider approach to research would increase its attractiveness by dealing with the issues of diversification of barriers to international cooperation in the R&D area, depending on the country of origin of the enterprise and their influence on the decision to undertake technological cooperation with a partner from another country.

The research was carried out in 2018, which means that the collected data is static and has not been repeated. Therefore, it seems important to conduct cyclical research and verify the current results, and whether and to what extent the significance of particular barriers to international cooperation in the R&D area within the given sector and its particular industries has changed.

The perception of barriers by the surveyed enterprises seems important as well. The research was limited to identifying barriers and assessing its significance. However, its impact on the decision to undertake international cooperation activities has not been taken into account.

Considering the relatively small proportion of Polish enterprises from the high tech sector involved in international technology cooperation, knowledge of how strongly the analysed barriers affect decisions on joining alliances in the R&D area may turn out to be valuable for enterprises from other sectors and countries.

Another limitation concerns the research sample. Despite the initial relatively large number of analysed enterprises (400), the research was limited to 61 companies. Moreover, Polish enterprises were taken into account, excluding those in which foreign capital represents a majority share. It is therefore possible to increase the sample size to make the results more representative. Limiting the sample to Polish enterprises was done deliberately in order to examine what specific barriers limit Polish companies. The inclusion of enterprises operating in Poland but in which foreign capital represents a majority share would be important from the point of view of the comparative analysis of cooperative maturity on an international scale, and the perception of barriers.

The presented research has been limited to internal factors, i.e. directly related to the nature of the surveyed enterprises and to relations with foreign partners. The inclusion of factors related to sectoral specificity and macro factors, as well as a comparison of their significance and mutual relations, would undoubtedly increase the cognitive value of the research and conclusions of an application nature.

Despite the limitations presented, we hope that the results of the research and the conclusions drawn will allow interested parties to obtain a true picture of the sector being analysed. To the best of our knowledge, this research is unique on an international scale. The uniqueness results not only from the original nature of the problem and the characteristics of the surveyed enterprises, but also from direct research.

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