

The role of clusters in stimulating breakthrough innovation in enterprises

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Abstract. The subject of this article is the role of clusters in increasing breakthrough innovation of their member enterprises. The aim of the article has been to investigate to what extent entering and operating within a cluster stimulates breakthrough innovation in enterprises. This aim has been achieved on the basis of comparative analysis of the number of patent applications of enterprises in 1990-2012, separately for the periods before and after the beginning of cooperation within the cluster. The study covered enterprises belonging to clusters in the Lower Silesia region (Poland). The results of the study suggest that there is no positive relationship between the enterprises being members of a cluster and their breakthrough innovation.

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INTRODUCTION

Since the formulation of endogenous growth theory, in light of which broadly understood knowledge was deemed critical for economic growth, economists and politicians have been increasingly interested in factors stimulating creation of new ideas. A special emphasis has been placed on generation of breakthrough innovations that are essential for the growth both of individual regions and the entire national economy.

At the same time, it has been increasingly emphasized that generating radical innovations by individual inventors in times of "knowledge overload" is becoming more and more difficult as in the course of their lives they are not able to acquire increasing amounts of knowledge necessary to make a "step forward" or innovation (Jones, 2009; Jones, 2010; Jones and Weinberg, 2011; Niklewicz-Pijaczyńska and Wachowska, 2012). Hence the process of innovation increasingly requires cooperation of highly specialized researchers (Wuchty *et al.*, 2007; Jones *et al.*, 2008; Ding *et al.*, 2009) with complementary areas of expertise.

One form of cooperation at the level of an enterprise is a cluster which is, broadly speaking, a geographic concentration of interconnected firms, specialized suppliers, service providers as well as firms operating in related industries and associated institutions, which compete but also cooperate with one another (Porter, 2001). Clusters can operate in various areas, i.e. they can include businesses, R&D and educational institutions, consulting institutions, information and promotion centers, industry associations and local government units (*Rozwój klastrów w regionie dolnośląskim*, 2008).

It is widely believed that cluster membership allows its participants to achieve a number of benefits, such as business costs reduction, public funding opportunities or entering new markets. An emphasis however is mostly placed on the potential of clusters as places in which diffusion of knowledge and, consequently, generation of innovations occur. From the point of view of development of the region as well as the entire economy, the latter benefit is especially important. It should be noted, however, that cluster membership benefits are not achieved *per se*. Achieving them depends on a number of factors that are sometimes region-specific.

Although there is large literature on the subject of clusters in Poland, most of it focuses on characterizing and describing particular joint initiatives undertaken by cluster members or providing examples of achievements resulting from their joint efforts. Other works assess the level of innovation of a cluster and its members, also against the background of other Polish clusters, but they fail to address whether the high level of innovation is a result of joint actions or simply the cluster has been created by innovative actors. Much less attention has been paid to studying the role of clusters in increasing the innovation of their members. In the few analyses that address this question, the importance of the cluster for an increase in innovation of its member enterprises is inferred on the basis of surveys addressed to its members rather than measurable data (Hołub-Iwan and Małachowska, 2008). Firstly, it is a subjective approach and secondly, it does not differentiate between an increase in breakthrough innovation and one that is incremental only.

Our empirical study is based on the analysis of the distribution of the number of patent applications over time in particular Lower Silesian clusters as a measure of breakthrough innovation of enterprises. Specifically, we compare the number of patent applications filed by particular enterprises belonging to Lower Silesian clusters before and after the beginning of cooperation within the cluster. The data on the number of applications come from the Polish Patent Office (PPO). According to our best knowledge this is the first study that uses the number of patent applications to infer about the innovation of enterprises belonging to clusters located in Poland.

Breakthrough innovations of particular enterprises have been measured by means of the number of patent applications rather than the number of patents received which are the usual measure of breakthrough innovation because patent applications better reflect innovative activity in the year of application than the number of patents in the year the patent was received. Until recently, having patent protection granted in Poland involved waiting for about 10 to 13 years and currently it is about 3 to 5 years. It means that the number of patents received e.g. in 2005 could in fact indicate the innovation of an enterprise in 1995. Our study, however, does not include patent applications for inventions that did not qualify for protection since they clearly show that the submitted idea did not have nature of breakthrough innovation. Only those patent applications have been included in the analysis in the case of which the applicant (1) has received patent protection, (2) is still waiting for the decision of PPO, (3) has received a decision of the expiration of exclusive right on formal grounds. Applications "pending decision" have been included due to the presumption that protection will be granted. Meanwhile, the inclusion of applications in the case of which the applicant has received decision of exclusive right expiration on formal grounds has been dictated by the inference that the merits alone of the submitted idea did meet the requirements to be considered an invention.

Measuring breakthrough innovation solely with the use of the number of patent applications without taking into account applications concerning e.g. utility models or trademarks is a certain limitation of the study but it results from preliminary evaluation; the results of preliminary analysis have shown that the number of applications pertaining to other objects of intellectual property is minimal. Another limitation of the study is exclusion of those breakthrough innovations of analyzed enterprises which on different grounds (e.g. choice of trade secret over patent protection) were not filed with PPO. Finally, it is also a limitation that inventions filed by enterprises with patent offices other than PPO have not been included. It may be assumed, however, that even if such applications existed, they would be mostly “duplicates” of applications to PPO.

Breakthrough innovations of enterprises in the period before their entering the cluster are analyzed from 1990 until the end of the year preceding the year of the establishment of the cluster, while subsequent innovative activity is studied in the period from the beginning of the year of the establishment of the cluster until the end of 2012. The beginning of the study period has been set at 1990 because it was a breakthrough year for Poland. In 1989-1990 transformation of the Polish economy from centrally planned to free market one began and adoption of a package of economic reforms, known as the Balcerowicz Plan, in 1990 is considered the beginning of the transformation. As a result of the reforms, many enterprises faced entirely new challenges and problems, also those related to R&D funding. This is why treating periods before and after 1989 as a whole could lead to false conclusions. The study is limited also by short duration of clusters, and consequently that of cluster membership of enterprises, as a result of which it is not possible to fully take into account the time lag necessary to observe positive effects of cooperation within the cluster.

The research has covered enterprises that were founding members and still belonged to Lower Silesian clusters at the end of 2012. Eliminated from the analysis have been enterprises which joined particular clusters at a later date than the date of cluster establishment as well as those which were founding members but withdrew from the cluster before the end of 2012. It has been dictated by the fact that in their case the period of membership in the cluster would be too short to permit drawing conclusions regarding an increase in their innovation. For the same reason, the research includes only those enterprises that were created until 2008 and continued to exist at the end of 2012. The duration of the clusters that were created after 2008 or ceased to operate before 2012 would be too short and make it impossible to conduct an analysis. Ultimately the research has covered 70 enterprises from 7 clusters.

Information regarding both clusters and founding and present members has been obtained from official websites of the clusters and as a result of contacts with representatives of individual clusters.

The remaining part of the paper is organized as follows. Chapter 2 reviews theoretical and empirical literature on the role of clusters in stimulating breakthrough innovation, indicates factors influencing the achievement of benefits from cluster membership in this regard as well as precisely defines breakthrough innovation. Our empirical findings have been shown in Chapters 3 and 4 and key conclusions of our analysis in Chapter 5.

1. THE ROLE OF CLUSTERS IN STIMULATING BREAKTHROUGH INNOVATIONS

Innovation is a highly desirable process from the knowledge economy perspective. However, since traditional ways of creating innovation appear to be insufficient to meet rapidly evolving market needs and expectations, new concepts continue to be created in this area. One of these is the concept of stimulating inventiveness through cluster initiatives. The idea of clusters is based on the assumption that creating a network of cooperation between entities associated within a cluster and consequently starting innovation processes shall lead to more efficient innovation.

Potential of geographically and industry- centered entities was reflected upon, among the others, by A. Hirschman and F. Perroux, however the term “cluster” was not yet in use at that time. G. Myrdal (Myrdal, 1957) also addressed problems of spatial regional development and saw on the one hand the benefits resulting from concentration, similarly to A. Hirschman and F. Perroux, but on the other hand also the problem of a drain on the development potential of peripheral regions it created (Perroux, 1955, pp. 307-320; Hirschman, 1958, pp. 51-52). Meanwhile, P. Krugman argues that spatially concentrated entities achieve benefits resulting from geographical proximity of their business partners, reduction in transaction and transport costs, operating in monopolistic competition environment, knowledge diffusion and intellectual capital concentration as well as creation of internal market with large capacity (Krugman 1991, pp. 483-499).

With time, cluster initiatives began to be associated mainly with the stimulation of innovation, which while created inside the cluster subsequently diffused beyond its borders. Such function of the cluster is referred to by flexible production agglomerations theory of A. Scott, who considers the activity core to be a metropolis (or even technopolis) that brings together high technology enterprises and thus shows high levels of production innovation and flexibility. Cooperation, knowledge spillovers and spatial concentration lead to reduction in transaction costs on the one hand and on the other hand they stimulate innovation through the constant presence of competition (Scott, 1998). M. Storper, in turn, emphasizes that the basis for economic development is formed by the melting pot of three ingredients: (1) consistent organizational system based on cooperation and specialization, (2) geographic concentration and (3) technological (breakthrough) innovation (Storper, 1997).

The cluster hence plays the role of the driver of technological progress and economic development of regions (but not necessarily of the national economy since strong differences between potentials of particular regions and polarization of their incomes prevent the implementation of convergence theory) (Stackelberg and Hahne, 1998). At the same time, they constitute a paradoxical phenomenon from the perspective of market economies whose inherent feature is competition. While entities associated within the cluster continue to compete with one another, they do so to the extent to which they can achieve synergy (especially in the area of research and development cooperation).

The emphasis on the special meaning of cluster initiatives for innovation has been reflected in contemporary definitions of cluster and even in distinguishing its particular type – innovation cluster. Such a concept has been introduced by the European Commission and means “groupings of independent undertakings – innovative start-ups, small, medium and large undertakings as well as research organisations – operating in a particular sector and region and designed to stimulate innovative activity by promoting intensive interactions, sharing of facilities and exchange of knowledge and expertise and by contributing effectively to technology transfer, networking and information dissemination among the undertakings in the cluster” (*Community Framework for State Aid for Research and Development and Innovation*, 2006). Introduction of innovation as an important component of the definition of cluster accompanied by ceding of powers to create clusters to the regional level resulted in clusters becoming a symbol of decentralization of innovation policies which had proved ineffective in many dimensions when implemented on a top and central level. It has been also an expression of the belief that it is the region with its institutional framework, internal network intensity and external cooperative and information linkages that is the true source of new ideas and solutions (Christopoulos, 2001).

Today one of the most important functions of the cluster is generation and commercialization of innovations, especially those which are a priority for the economy, i.e. breakthrough innovations (first mover advantages). In literature this term denotes market introduction of products, services or technologies that are absolute novelty. They are radical and change the perception of goods as well as radically verify the needs of their users (Niklewicz-Pijaczyńska, 2013, p. 337). C. M. Christensen calls them “disruptive technolo-

gies” (Christensen, 2010). They pose a challenge for competitors and consumers alike, requiring continuous learning (Lehman and Winer, 2004). K. B. Dahlin and D. M. Behrenes, in turn, identify radical innovations with contemporary understanding of the concept of invention. They argue that being a breakthrough results from the technical side of an innovation that meets three criteria: novelty, uniqueness and setting of future technological trends (Dahlin and Behrenes, 2005). In contrast to these, incremental innovation is a mere modification or evolution of the product or service present on the market.

Do therefore clusters that combine cooperation and openness of innovation processes stimulate breakthrough innovation of their members?

The experiences of Silicon Valley and other clusters worldwide show that such a form of cooperation may be conducive to breakthrough innovation, whereby the positive effect will not spontaneously occur due only to the fact of the establishment of a cluster; its success depends on many factors.

First of all, particular members of the cluster, or at least some of them, must possess valuable knowledge. Otherwise, the network within the cluster will lead to diffusion of imitative processes rather than breakthrough ideas, if any knowledge at all. Moreover, particular members of the cluster must possess complementary knowledge because otherwise involvement in joint efforts will not be very effective in terms of inventiveness improvement. Finally, cluster members, especially those which are the richest in valuable knowledge, must have willingness to share it.

Presence of close social relationships between the members of a cluster is important, too, because they also shape processes of knowledge transfer and learning. Close social relationships are admittedly facilitated by geographic proximity between particular members of the cluster but they are not enough to create new interpersonal bonds. However, both are equally likely to influence knowledge flows (Amin and Cohendet, 2004).

It is also recommended that there be a technological gap between the members of a cluster though it is difficult to clearly determine how large it should be. On the one hand, occurrence of this gap creates an opportunity for the diffusion of knowledge, but on the other hand, if there is too much distance between the members of the cluster, it may even prevent acquisition and adaptation of ideas. Generally, it may be said that the larger the capacities of particular members of the cluster to absorb external knowledge, the larger may be the technological gap between them. The ability to absorb external know-how, meanwhile, is largely influenced by the education and expertise of the staff, i.e. the quality of human capital of particular members of the cluster.

Innovative ideas stem not only from internal interactions in the cluster but also from linkages between cluster members and external entities (Bathelt et al. 2004; Maskell et al., 2006; Morrison et al., 2013). Therefore, if enterprises belonging to the cluster want to achieve long-term benefits in the form of improved innovation, they must acquire knowledge also from third parties. They may do so by locating their subsidiaries abroad (Wachowska, 2010), engaging in research and development activities within consortia with partners not belonging to the cluster, hiring employees from competitors not belonging to the cluster (Agrawal et al., 2006; Azoulay et al. 2011) or participating in international professional meetings, e.g. exhibitions (Maskell et al., 2006). The ability to use external sources of knowledge, however, depends also on general absorptive capacity of the enterprise. The larger it is, the more likely to occur are external linkages and transferring of external knowledge (Giuliani and Bell, 2005). However, it should be kept in mind that too many external linkages can result in knowledge overflow and subsequent “information fatigue syndrome”, paralysis of analytical capacity and increased nervousness (Bathelt et al., 2004), all which is no longer beneficial for innovative capacity. A similar effect is caused by the cluster having too many members.

2. BREAKTHROUGH INNOVATION IN LOWER SILESIA CLUSTERS. RESEARCH RESULTS

Only three of the seven analyzed Lower Silesian clusters recorded an increase in the number of patent applications from the moment of their establishment. These are (1) NutriBioMed Cluster, (2) ICT Cluster – Knowledge and Innovation Community for Information and Communication Technology (ICT) and (3) Lower Silesia Eco-Energetic Cluster EEI – Energy, Ecology, Innovation (EEI).

The enterprises from the NutriBioMed Cluster filed a total of 18 applications with PPO within the first 5 years from the establishment of the cluster, i.e. in 2008-2012, which was an average of 3.6 inventions per year (see *Figure 1*). Compared with the 5-year period immediately preceding the establishment of the cluster, i.e. in 2003-2007, when the total number of patent applications had been 11, i.e. an average of 2.2 inventions per year, it was an increase of 63.6%. Moreover, in comparison with the entire period beginning in 1990 and preceding the establishment of the cluster, the enterprises belonging to the NutriBioMed Cluster also improved on their inventiveness with an increase of 5.88% from 17 to 18 patent applications. It means that within the 5 years of operation of the cluster the enterprises generated a total of more inventions than within the 18 years when they had not been members of the cluster.

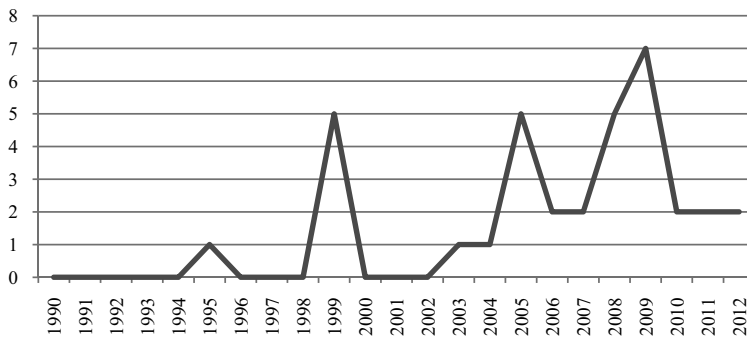


Figure 1. Total number of patent applications filed by enterprises from NutriBioMed Cluster in 1990-2012

Source: Own work and calculations, based on Polish Patent Office data, www.uprp.pl.

While the enterprises from this cluster together achieved benefits in the form of increased number of patent applications, considered separately only 50% of those enterprises which did generate inventions managed to achieve results in this regard within the first 5 years of operation of the cluster as compared with the five-year period preceding the establishment of the cluster.

The enterprises from the ICT Cluster recorded an even greater percentage increase in the number of patent applications (see *Figure 2*). Within the 6 first years of operation of the cluster, i.e. in 2007-2012, they filed a total of 8 applications with PPO, i.e. an average of 1.3333 inventions per year while they filed only one application within the 6 years immediately preceding the establishment of the cluster, i.e. in 2001-2005, which is an average of 0.1666 inventions per year (an increase of 700%). In the case of the ICT Cluster, similarly to the NutriBioMed Cluster, the enterprises together achieved more in terms of breakthrough innovation within mere 6 years of operation within the cluster than they had done within the 17 years (from 1990) preceding the year of the establishment of the cluster. They filed only 2 applications in 1990-2006 while in 2007-2012 they filed as many as 8 applications (an increase of 400%).

In the case of this cluster, the common success was individually shared by all the enterprises which could boast of generating any inventions at all.

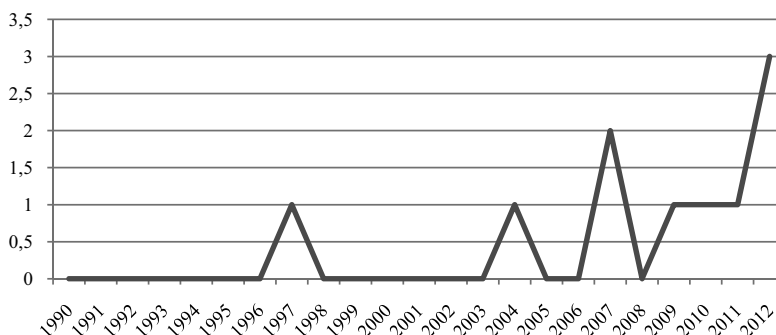


Figure 2. Total number of patent applications filed by enterprises from ICT Cluster in 1990-2012

Source: Own work and calculations, based on Polish Patent Office data, www.uprp.pl.

A similar increase in patent applications occurred in the EEI Cluster (see *Figure3*). Within the first 7 years following the establishment of the cluster, i.e. in 2006-2012, the enterprises filed 700% more applications (a total of 8 and an average of 1.1428 inventions per year) as compared with both the 7 years immediately preceding the establishment of the cluster, i.e. in 1999-2005, and the entire period preceding the establishment of the cluster (a total of 1).

Similarly to the enterprises from the ICT Cluster, also in this case all enterprises possessing any patent applications recorded an increase in their number after they had entered the cluster.

For all the three above-mentioned clusters, the long-term trend (1990-2012) in the number of patent applications is growing, which gives reason to hope that the results of these clusters in terms of their breakthrough innovation will continue to improve in the future.

On the other hand, however, it must be noted that in the case of all the three above-mentioned clusters the number of patent applications is small due to which drawing conclusions – and especially making predictions about future – may be subject to error. Moreover, the innovation of the EEI cluster actually relies on one enterprise only. It means that if this enterprise withdrew from the cluster it would mean deteriorating performance of the entire cluster. The situation is similar in the case of the ICT Cluster whose innovation – despite its many enterprises – is based on as few as two enterprises. In this case, the situation of the NutriBioMed Cluster is definitely better as the number of its patent applications is distributed over 7 enterprises even though its progress in the number of patent applications is much smaller than in the case of the other two clusters (see *Table 1*).

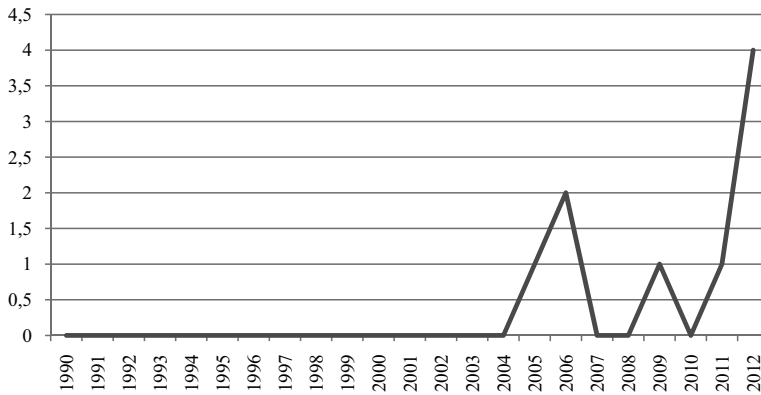


Figure 3. Total number of patent applications filed by enterprises from EEI Cluster in 1990-2012

Source: Own work and calculations, based on Polish Patent Office data, www.uprp.pl.

Another two of the clusters covered by the analysis, i.e. Lower Silesian Mineral Resources Cluster and Innovative Cluster for Energy Use and Generation in Mega- and Nano-scale (Mega and Nano Energy) recorded a decrease in the number of applications filed with PPO from the moment of their establishment, with enterprises from the latter having been affected more severely.

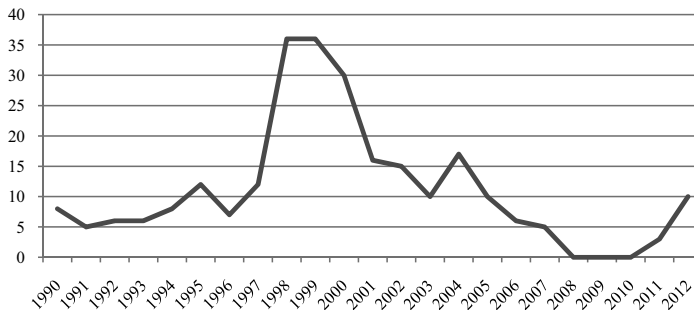


Figure 4. Total number of patents filed by enterprises from Mega and Nano Energy Cluster in 1990-2012

Source: Own work and calculations, based on Polish Patent Office data, www.uprp.pl.

Within the first 6 years following the establishment of the Mega and Nano Energy Cluster, i.e. in 2007-2012, its enterprises generated a total of 18 patent applications (an average of 3.0 applications per year), which was a decrease of 76.62% compared with 74 applications (an average of 12.333 applications per year) (see *Figure 4*). Meanwhile, in comparison with the entire period preceding the establishment of the cluster, beginning in 1990, the enterprises belonging to the cluster filed together 92.5% fewer applications. It means at the same time that the long-term trend in patent applications is decreasing which usually gives little hope for its reversal, albeit the number of filed applications began to strongly increase in 2010.

It is beneficial for the Mega and Nano Energy Cluster in terms of improving on its innovation that the number of patent applications prepared within the cluster is distributed over four enterprises (see *Table 1*).

The enterprises from the Mineral Resources Cluster shared the fate of the enterprises from the Mega and Nano Energy Cluster but in their case the number of patent applications decreased by 44.4% from 27 (an average of 3.857 applications per year) in 1999-2005 to 15 (an average of 2.142 applications per year) in 2006-2012. Compared with 1990-2005 the total number of applications filed by the enterprises decreased by as many as 66.7% from 45 to 15 inventions.

Contrary to the Mega and Nano Energy Cluster, however, the long-term trend (1990-2012) in the number of filed inventions is growing and particularly strong from 2010. Moreover, in spite of the fact that the enterprises together generate a smaller part of inventions starting from 2006, considered separately 50% of the enterprises from the cluster managed to reverse the trend.

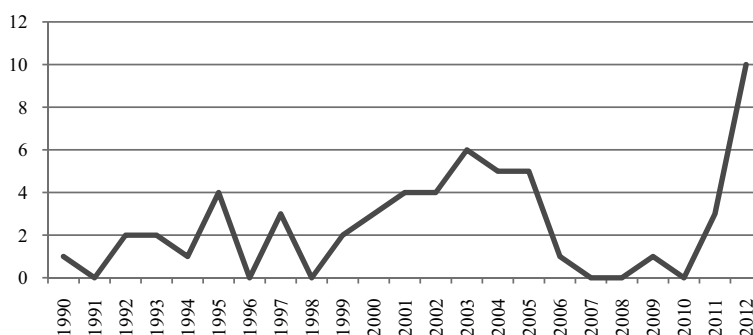


Figure 5. Total number of patent applications filed by enterprises from Mineral Resources Cluster in 1990-2012

Source: Own work and calculations based on Polish Patent Office data, www.uprp.pl.

In the case of two of the seven analyzed clusters—Lower Silesian Cluster of Renewable Energy and Side Cluster – one can hardly speak of any increase or decrease in the number of filed patent applications since the enterprises from the first cluster had no applications throughout the entire period covered by the analysis (1990-2012) and the latter had only one application in 2011. In the case of these clusters, therefore, one can hardly speak of any relationship between membership in the cluster and breakthrough innovation of its member enterprises.

3. INDIVIDUAL ACHIEVEMENTS OF ENTERPRISES FROM LOWER SILESIA CLUSTERS. RESEARCH RESULTS

Only 19 of the 70 enterprises covered by the analysis have had any experience in generating inventions, i.e. they can boast of at least one patent application within the entire research period (1990-2012). It is partly due to the nature of their business which in a way does not permit generating inventions (e.g. accounting services) and partly due to their low levels of innovation.

Among the 19 enterprises with an invention generating experience, 10 enterprises (over 52%) increased their number of patent applications in the early years of operation of the cluster as compared with the analogous period preceding the establishment of the cluster. It is worth noting that as many as 5 of those 10 enterprises began to innovate only after entering the cluster. Another 6 (over 31%) of the 19 enterprises covered by the study recorded a deterioration in performance in this regard and innovation levels of 3 enterprises (over 15%) remained unchanged (see *Table 1*).

Table 1

Number of patent applications filed by enterprises with inventive experience
belonging to Lower Silesian clusters in 1999-2012

Enterprise	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NutriBioMed Cluster														
BIOCHEFA Farmaceutyczny Zakład Naukowo-Produkcyjny	x	x	x	x	0	0	3	1	2	1	3	1	0	0
P. W. FUTURUM Sp. z o.o.	x	x	x	x	0	0	0	1	0	3	1	0	1	0
Zakłady Jajczarskie OVOPOL Sp. z o.o.	x	x	x	x	0	0	2	0	0	0	0	0	0	0
POMONA Enterprise LTD Sp. z o.o.	x	x	x	x	1	0	0	0	0	0	0	0	0	1
P.H.P.U. TRANSVET Sp. z o.o.	x	x	x	x	0	0	0	0	0	0	1	1	0	0
TECHNOX Firma Technologiczna Tadeusz Trziszka	x	x	x	x	0	0	0	0	0	0	2	0	1	0
Finepharm Sp. z o.o.	x	x	x	x	0	0	0	0	0	0	0	0	0	1
TRONINA Przedsiębiorstwo Handlowo-Wdrożeniowe	x	x	x	x	0	1	0	0	0	1	0	0	0	0
ICT Cluster														
WASKO S.A.	x	x	0	0	0	1	0	0	0	0	0	0	0	3
SMT Software S.A.	x	x	0	0	0	0	0	0	0	0	1	0	0	0
Transition Technologies S.A.	x	x	0	0	0	0	0	0	2	0	0	1	1	0
EEI Cluster														
Ładziński Zakłady Metalowe	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Metalerg Sp. J.	0	0	0	0	0	0	1	2	0	0	1	0	0	4
Mega and Nano Energy Cluster														
ABB Sp. Z o.o. Warszawa	x	x	11	9	4	7	4	5	0	0	0	0	1	1
ZBUS Combustion Sp. z o.o. in Główno	x	x	0	1	0	5	1	1	5	0	0	0	1	0
KGHM Cuprum CBR Sp. z o.o.	x	x	4	4	5	5	3	0	0	0	0	0	1	9
Elektrownia Turów S.A.	x	x	0	0	0	0	0	0	0	0	0	0	0	0
KGHM Polska Miedź S.A.	x	x	1	1	1	0	2	0	0	0	0	0	0	0
Mineral Resources Cluster														
KGHM ECOREN S.A.	0	0	0	0	1	0	0	1	0	0	1	0	2	1
KGHM Cuprum CBR Sp. z o.o. (also in the Mega and Nano Energy Cluster)	2	3	4	4	5	5	3	0	0	0	0	0	1	9

Source: Own calculation based on Polish Patent Office data, www.uprp.pl.

Taking into account only the above 19 enterprises, the above results should be considered good. However, when all the enterprises belonging to the 7 clusters covered by the analysis are taken into account, individual performances of the enterprises in terms of innovation do not look as good. Only 10 of the 70 enterprises increased the number of filed applications following the beginning of cooperation within the cluster, which in this case means that only 14.28% of the enterprises increased their breakthrough innovation.

CONCLUSIONS

In literature on clusters, a number of benefits of cluster membership are rather commonly indicated. It is also repeatedly argued that clusters are an effective driver of innovation in enterprises. Meanwhile, our analysis of the data on the number of patent applications filed by enterprises concentrated within the seven investigated Lower Silesian clusters does not provide any definite support for this belief.

Taking into account the total effect of all the enterprises belonging to the cluster, only three clusters improved on their breakthrough innovation as measured by the number of their patent applications. Innovation levels of another two clusters remained unchanged and in the case of two clusters they even deteriorated. It means that as many as four of the seven clusters covered by the analysis failed to achieve benefits in the form of increased levels of breakthrough innovation after the beginning of cooperation within the cluster.

Individual performance of the enterprises in terms of breakthrough innovation does not look any better. Among the seventy enterprises belonging to the Lower Silesian clusters only ten enterprises managed to increase the number of inventions they generated and filed as patent applications, which constitutes only 14.28% of all the enterprises. In the case of six enterprises, the level of breakthrough innovation even decreased (8.6% of all the enterprises). The level of innovation of the remaining 54 enterprises remained unchanged with only three enterprises being able to boast of any experience with regard to inventiveness. It means that as many as 51 of all the enterprises under study had not created any invention and their becoming member of the cluster changed nothing in this regard.

In conclusion, although some enterprises improved on their breakthrough innovation after the beginning of cooperation within the cluster, the results of the study do not show any positive relationship between an enterprise being a member of the cluster and its level of breakthrough innovation.

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