Managerial Economics
2018, vol. 19, No. 2, pp. 227–249
http://dx.doi.org/10.7494/manage.2018.19.2.227

Małgorzata Wachowska*

Cluster as place of efficient diffusion of knowledge. Experiences of Lower Silesia

1. Introduction

It is widely believed that functioning within a cluster structure (broadly understood as a geographical concentration of interconnected entities that compete with one another but also cooperate (Porter, 2001) allows its members to achieve a number of benefits. These include a reduction in the costs, time, and risk of business operations (including R&D), the opportunity for obtaining public funds, or the possibility of gaining new sales markets. Above all, however, the potential of clusters is emphasized as places where the "combination of mind-power" and knowledge diffusion occur, which makes politicians perceive this form of cooperation between organizations as a tool for creating competitive advantages for a whole country.

Despite the widespread belief of the important role of clusters in the development of both the entities located within them as well as entire regions, the conclusions from many studies indicate that benefits in the form of the increased diffusion of know-how do not have to be achieved *per se*. Achieving them depends on a number of factors, such as the area of activity of the entities located in the cluster, the level of development of the cluster, the economic policy approach to supporting cluster initiatives (Yström and Aspenberg, 2017), the degree of the presence of R&D institutions in the cluster (Jankowska, Pietrzykowski, 2013; Mowery, Ziedonis, 2001), and the degree of domination of micro and small enterprises or even the specifics of values and behavioral patterns of the societies of the countries from which a specific cluster originates (Nishimura and Okamuro, 2011).

* University of Wroclaw, Faculty of Law, Administration and Economics, Institute of Economic Sciences, e-mail: malgorzata.wachowska@uwr.edu.pl.

The lack of conclusions as to the extent to which the functioning within a cluster has a stimulating effect on the efficiency of knowledge diffusion between its members also results from the lack of one knowledge diffusion measure possible for use under any conditions. This results from the fact that some researchers use more-direct measures of know-how diffusion, while others infer the occurrence of spillovers from more-direct indicators.

The most-direct measures of knowledge diffusion include all measures based on citations as well as surveys and direct interview data. In the case of citation-based measures, it is assumed that the citing party has used the concepts and ideas of the cited party; hence, knowledge flow has occurred from the citing entity to the cited one. Although frequently very subjective, the data and information obtained from direct interviews and surveys are somehow obviously treated as evidence for the occurrence of knowledge-transfer processes.

In the indirect approach, knowledge flow is measured from the perspective of the effects they cause. Since the circulation of know-how is expected to translate into an increase in productivity and innovation, many researchers consider total factor productivity or the number of inventions, patents, or other innovation indicators as measures of knowledge diffusion. Although widespread in the literature on the subject, it should be emphasized that such an approach has its opponents, who make a clear distinction between innovation processes and knowledge-transfer processes. Since a visible effect of knowledge exchange is also various kinds of joint "creations" (e.g., inventions jointly generated by different individuals or organizations), these are also used as measures of knowledge diffusion. It is worth emphasizing that joint works have an advantage over other indirect measures because they are associated with a greater probability that knowledge flow actually occurred. Unlike other indirect measures, joint works are associated with a greater degree of certainty that knowledge flow actually occurred.

Studies in which the problems of Polish clusters are addressed tend to be focused on the role they play in promoting competitiveness and innovation of their constituent enterprises. However, analyses that directly assess the effectiveness of cluster structures in stimulating the processes of knowledge diffusion are usually based on survey data. There is a lack of studies in which the scope of knowledge diffusion within the cluster is assessed on the basis of the number of citations; i.e., the *de facto* most-direct measure of know-how transfer. In this work, the author makes an attempt fill this gap.

This study contributes to the existing literature mainly through the use of patent citations[1] and the number of inventions created jointly by cluster participants to estimate the scale of knowledge diffusion within Polish clusters.

[1] Patent citations were used to estimate knowledge flow for the first time by Jaffe, Trajtenberg, and Henderson (1993).

The paper focuses on two objectives. The first of these is to examine to what extent those enterprises located in Lower Silesian clusters benefit in the form of knowledge diffusion from other cluster members and what factors stimulate the occurrence of these benefits. The second objective is to compare the results in terms of the effectiveness in promoting knowledge diffusion achieved by clusters from Lower Silesia with the achievements of the Aviation Valley from Podkarpackie Voivodeship, which is considered to be an excellent example of close cooperation between science and business as well as the activity of the enterprise sector in innovation processes in Poland. The comparative analysis of both voivodeships (one of which is considered a model to follow when it comes to R&D cooperation within the cluster) allows for a better assessment of the role of clusters from Lower Silesia in promoting the exchange of expertise and know-how.

For the purposes of this article, it is assumed that the measure of effectiveness of Lower Silesian clusters in stimulating the processes of knowledge diffusion among enterprises located in the clusters is the number of patent citations and number of joint inventions. In the study, our own conducted research has been focused on a quantitative and qualitative analysis of domestic and international patent applications filed by enterprises operating in the clusters covered by the study (in terms of the number of inventions they cited that belonged to entities located in the same cluster and the number of inventions created together with other entities from the same cluster).

2. Role of clusters from Poland in promoting diffusion of knowledge in light of literature research

From the perspective of modern economies, innovation is a particularly desirable process. However, due to the fact that traditional ways of creating innovation turn out to be insufficient, new types of institutional solutions have been created in this area. One of these is clusters created by geographical concentrations of independent entities from three different environments (referred to as the triple helix: business, research, and development) and the administration sector (Etzkowitz, Leydesdorff, 2000), which remain in the relationship of coopetition; i.e., competition and cooperation at the same time.

The success of clusters in increasing innovation activity is based primarily on the geographical proximity of the cluster members in the sense that it is important for the creation of close social relationships and promotes *face-to-face* contact. On the one hand, they are particularly important for acquiring tacit knowledge (Agrawal et al., 2006; Azoulay et al., 2011; Baptista, 2000; Bodas et al., 2013; Ceci, Iubati, 2012; Cooke, Wills, 1999; Oettl, Agrawal, 2008), and on the other hand,

they promote research cooperation, which results in a faster and more effective flow of knowledge (Marshall, 1920; Maskell, 2001) as well as the internalization of the effects of R & D (Spence 1984). Consequently, participation in a cluster not only stimulates innovation (Delgado et al., 2010; Delgado et al., 2014; Johnnessen, 2009) but also leads to an increase in the competitiveness and internationalization of cluster entities (Gorynia, Jankowska, 2007; Jankowska, Götz, 2016; Jankowska, Götz, 2017) and can also facilitate the transformation of business models towards Industry 4.0 (Götz, Jankowska, 2017). It follows from the above, therefore, that one of the most important benefits of cluster membership is the ability to draw on the knowledge of its participants; many of the other benefits are derived from this in a way.

Although there are voices saying that the reliance on localized knowledge can only lead to a "closure" of the cluster and a lack of new ideas, which can result in the closeness between cluster members becoming an obstacle in raising their innovation rather than being an advantage (Bathelt et al., 2004; Maskell et al., 2006; Morrison et al., 2013), these are aimed not so much at discouraging mutual knowledge sharing within a cluster but at emphasizing that it should not be limited only to the cluster members.

The potential of clusters in creating new knowledge has also been noticed in Poland, which would like to duplicate the success of other countries in the effective combination of business, universities, and government. As research results show, this has been partly successful, although the results of Polish clusters cannot be easily confronted with the achievements of the most well-known groupings in the world. First of all, the reason is that the first clusters in Poland began to form much later than in other regions of the world; hence, they are still in the embryonic phase.

Generally, as the results of most case studies, survey studies, or studies using the in-depth interview method show, participants of Polish clusters undertake cooperation with other cluster members (Główka, Jankowska, 2014; Gorynia, Jankowska, 2008; Jankowska, 2013; Jankowska et al., 2017), but it always takes a different form and is shaped on a different level in terms of its strength and frequency (Plawgo, 2014; Plawgo et al., 2013, p. 48); thus, both the potential of this cooperation in promoting knowledge-diffusion processes and the effectiveness of these processes are varied. Typically, cooperation within Polish clusters takes the form of cooperation of an organizational nature, under which companies sign joint purchase agreements, for example (Ratajczak-Mrozek, 2012). This is definitely less frequently undertaken in the area of innovation and technology (Hołub-Iwan, Małachowska, 2008, p. 58); therefore, enterprises are more willing to cooperate than to share their knowledge (Dyba, 2016). There are still problems

with initiating and building cooperation between entrepreneurs and R & D sector entities (Bembenek, 2016); this is associated with the circulation of the most specialized and tacit knowledge. It should also be emphasized that the majority of studies addressing the problems of intra-cluster cooperation do not compare the results achieved in this area by clusters with the results of other types of network organizations. A few of them, however, regard clusters as less effective sources of cooperation (Ratajczak-Mrozek, 2012).

Due to the fact that knowledge diffusion promotes innovation processes, the increase in innovation and competitiveness of entities is interpreted as evidence of the occurrence of spillovers. From this perspective, the contribution of clusters in stimulating innovation and competitiveness can also be, by implication, a contribution to promoting knowledge-transfer processes. The of studies on Polish clusters find a positive correlation between membership in a cluster and competitiveness (Jankowska et al., 2017), but others emphasize the fact that this does not directly result from cooperation (Gorynia, Jankowska, 2008). Due to the fact that innovation is determined by the processes of knowledge diffusion to a greater extent than competitiveness, it is more difficult to point out analyses that explicitly confirm the thesis that the geographical concentration of competitors stimulates innovation. The final conclusions also depend on what type of innovations are the subject of the research: whether those solving a technical problem (*de facto* inventions) or another type (e.g., new products, new organizational solutions, new forms of expansion, etc.). While coopetition within Polish clusters releases the innovative potential of enterprises in the latter case (Dąbrowska, 2014; Jankowska, 2013; Kowalski, 2012; Stanienda, 2014), this is not so obvious in the former (Kowalski, 2012; Niklewicz-Pijaczyńska, Wachowska, 2014).

3. Scope and method of research

The empirical research basically covers enterprises from two clusters: the NutriBioMed Cluster and the Innovative Cluster for Power Generation and Energy Utilization in Mega- and Nano-Scale (Mega Nano Energy Cluster). The main criteria for the selection of clusters for the sample was (primarily) the location of the majority of the key partners (as well as the founders) of the cluster in Lower Silesia and (secondarily) the above-average degree of total inventive activity of the participant enterprises of the cluster. Additionally, the analysis covered the Aviation Valley Cluster from Podkarpackie Voivodeship, whose achievements in promoting knowledge flow between its member enterprises constitute a reference point for the results achieved in this regard by the clusters from Lower Silesia.

Of all of the enterprises belonging to the three indicated clusters, only those that created the cluster and generated at least one invention throughout their entire lifetimes were selected for the research sample. Enterprises that joined the cluster structure at a later date are not included in the analysis. Such a procedure is aimed at the comparability of the results of individual enterprises located in the same cluster, especially from the perspective of two periods: "before" and "after" the creation of the cluster. Although the sample selection method used has consequences for the interpretation of the results, they seem insignificant as related to the clusters covered by the analysis. This is mainly due to the fact that the enterprises that are most successful in terms of inventiveness are at the same time key participants and founders of the cluster. There are, in fact, a few enterprises that can boast of inventions but find themselves outside the research sample. In the end, the research sample consisted of 18 enterprises, of which 8 formed the NutriBioMed Cluster, 5 the Mega Nano Energy Cluster, and 5 the Aviation Valley Cluster.

The analyzed enterprises from the NutriBioMed Cluster include the following: POMONA Company Sp. z o.o.; BIOCHEFA Farmaceutyczny Zakład Naukowo-Produkcyjny; Przedsiębiorstwo Wielobranżowe FUTURUM Sp. z o.o.; Zakłady Jajczarskie OVOPOL Sp. z o.o.; Przedsiębiorstwo Handlowo-Produkcyjno-Usługowe TRANSVET Sp. z o.o.; TECHNOX Sp. z o.o.; FINEPHARM S.A.; and TRONINA Przedsiębiorstwo Handlowo-Wdrożeniowe. The analyzed enterprises from the Mega Nano Energy Cluster include the following: Zakład Budowy Urządzeń Spalających ZBUS COMBUSTION Sp. z o.o.; ABB Sp. z o.o.; KGHM CUPRUM Sp. z o.o. Centrum Badawczo-Rozwojowe; Elektrownia TURÓW S.A.; and KGHM Polska Miedź S.A. Meanwhile, the enterprises from the Aviation Valley Cluster covered by the analysis include the following: Polskie Zakłady Lotnicze Sp. z o.o.; Wytwórnia Sprzętu Komunikacyjnego PZL-ŚWIDNIK S.A.; Wytwórnia Sprzętu Komunikacyjnego PZL-RZESZÓW S.A.[2]; Wytwórnia Sprzętu Komunikacyjnego PZL-KROSNO S.A.; and ULTRATECH Sp. z o.o.

This study utilized the method of quantitative and qualitative analysis of patent applications filed in the national and international procedure (PCT[3]) by enterprises belonging to the sample. The patent applications were analyzed first in terms of the number of inventions created by these enterprises in cooperation with other cluster members (both with entities within the sample and outside) and subsequently by the sources of cited knowledge (excluding self-citations at the level of the applicant); more specifically, in terms of the extent to which the enterprises in the sample refer in their patent applications to the knowledge or

[2] The current name is: Pratt & Whitney Rzeszów S.A.

[3] The *Patent* Cooperation Treaty.

achievements of other cluster members (both belonging and not belonging to the sample). In the end, 431 patent applications were analyzed, of which 323 belong to the enterprises from the Mega Nano Energy Cluster, 60 from the NutriBioMed Cluster, and 48 from the Aviation Valley Cluster; as the patent citations are concerned, only those applications have been analyzed thus far (in such cases, a description of the state of the art is disclosed[4]).

The data used in the analysis of the national applications was taken from the knowledge stock of the Polish Patent Office, and those used in the analysis of the international applications came from the resources of the World Intellectual Property Organization (WIPO).

The analysis has been made separately for two periods. The first one was for the years before the creation of the cluster; more precisely, the periods of up to 2007 for the enterprises from the NutriBioMed Cluster, up to 2006 from the Mega Nano Energy Cluster, and up to 2002 from the Aviation Valley Cluster. The second period was from the creation of each cluster up to 2017; i.e., the years of 2008–2017 for the NutriBioMed Cluster, 2007–2018 for the Mega Nano Energy Cluster, and 2003–2017 for the Aviation Valley Cluster.

4. Patent cooperation of enterprises located in Lower Silesian clusters: research results

The study of cooperation in the field of creating inventions and then filing them for patent protection covered clusters from Lower Silesia representing various industries. The area of activity of the NutriBioMed Cluster includes high technologies in food processing and biotechnological processes, nutraceuticals, and biomedical preparations, while the entities from the Mega Nano Energy Cluster deal with the development and implementation of innovative clean energy production technologies using various sources on the micro and macro scale as well as the improvement of the efficiency of its use. The clusters mentioned above differ not only in their areas of activity but also in the degree of inventive activity, although it should be emphasized that both are very good in this respect as compared to other Lower Silesian clusters.

[4] In some cases, only the information on the very fact of filing the invention for patent protection by a specific entity – including the number and date of application as well as other basic information – is given to the public, but the detailed description of the invention is not disclosed (including the description of the state of the art, in which references to the achievements of predecessors are found). There may be different reasons for this situation, with the still-unfinished patent procedure being the most common one for the national procedure.

Table 1

Number of patent applications from Lower Silesian clusters during periods before and after creation of cluster

Patent category	NutriBioMed Cluster				Mega Nano Energy Cluster			
	"before" cluster		"during" cluster		"before" cluster		"during" cluster	
	Qty.	[%]	Qty.	[%]	Qty.	[%]	Qty.	[%]
Total patent applications	23	100	37 (+61%)	100	276	100	47 (–83%)	100
Total joint applications, incl.:	13	–	17 (+31%)	–	16	–	10 (–38%)	–
• total with other cluster participants	10	43.48	13 (+30%)	35.14	6	2.17	1 (–84%)	2.13
• total with entities from outside	3	13.04	4 (+0%)	10.81	10	3.63	9 (–10%)	19.15
Total independent patent applications	10	43.48	20 (+100%)	54.05	260	94.2	37 (–86%)	78.72

Source: development and calculations based on own research

Up to 2017, the analyzed enterprises from the NutriBioMed Cluster generated a total of 60 inventions, while those from the Mega Nano Energy Cluster generated as many as 323 (Tab. 1). Despite these differences, the members of both clusters set the cooperation in the field of implementation and execution of projects as their main objective, with the emphasis on cooperation between science and economy as well as integration of the participants through the transfer of knowledge from academic centers to business units (*see* official websites of the clusters). Setting such priorities clearly indicates that the cooperation – owing to which the knowledge diffusion occurs – is considered by both clusters covered in the study as the key factor for the development, innovation, and competitiveness of the organizations.

It should be expected, therefore, that the entities forming the clusters mentioned above will undertake joint activities not only in the area of current minor initiatives but will, above all, combine their brainpower in order to create new breakthrough technical solutions (which undoubtedly include inventions). Unfortunately, the analysis of the patent documents of the member enterprises of the clusters mentioned above does not fully confirm these predictions, indicating that the entities continue to treat their cooperation with relative distrust (at least when it comes to cooperation in the field of creating inventions).

On the basis of the data and information from the Polish Patent Office and WIPO, it may be said that only slightly more than 2% of the inventions of the enterprises from the research sample in the Mega Nano Energy Cluster and slightly more than 35% in the NutriBioMed Cluster were created in cooperation with the other cluster members. Moreover, in the Mega Nano Energy Cluster, the number of these joint inventions decreased when compared to the period preceding the creation of the cluster in both absolute and percentage terms (Fig. 1, Fig. 2, Tab. 1).

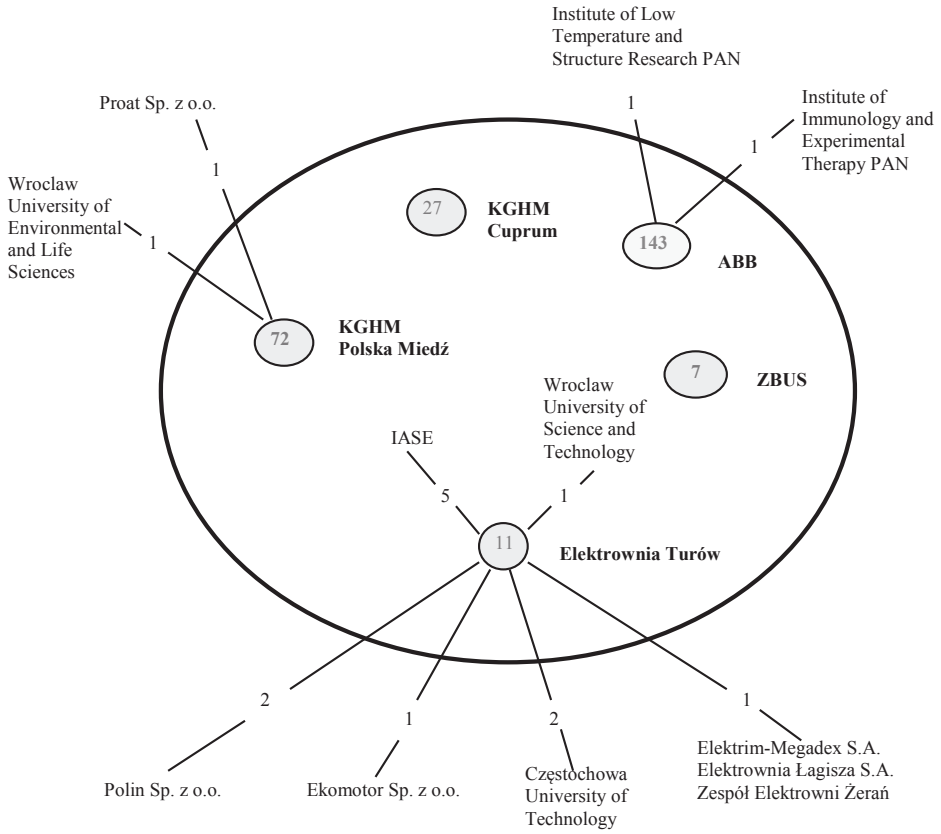

Figure 1. Joint patent applications of enterprises from Mega Nano Energy Cluster during period before creation of cluster

Legend: Numbers in circles indicate numbers of independent patent applications of enterprise; numbers between lines indicate numbers of applications filed jointly by entities connected by lines; inside large circle are all analyzed enterprises belonging to cluster as well as other cluster members with which patent cooperation was observed; outside large circle are entities not belonging to cluster

Source: developed on basis of own research

In fact, this means that the creation of the cluster not only failed to contribute to the intensification of the cooperation processes in the area of creating inventions, but the previously existing linkages between the enterprises currently forming the Mega Nano Energy Cluster and other existing cluster participants were also broken.

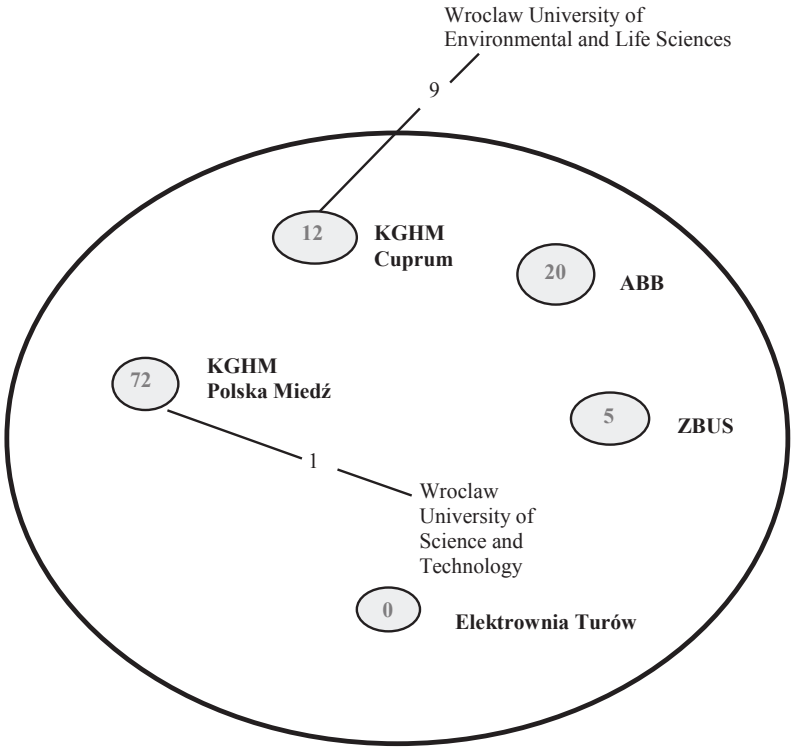

Figure 2. Joint patent applications of enterprises from Mega Nano Energy Cluster during period after creation of cluster

Legend: *see* Figure 1

Source: developed on basis of own research

While the enterprises from the Mega Nano Energy Cluster covered in the analysis had co-authored a total of 16 inventions during the period before the creation of the cluster (5.8% of the total number of inventions, including 6 with entities currently participating in the cluster – 2.17% of the total number of inventions), the total of co-authored inventions decreased to 10 during the subsequent

period (21.27% of the total number of inventions), including those generated with other cluster members (1 – accounting for just 2.13% of the total number of inventions) (Tab. 1). The decrease in the number of jointly created technical solutions results primarily from the general downward tendency in the inventive activity of the enterprises forming the cluster, which results, among others, from shorter time of functioning within the cluster than in the previous period. However, based on the obtained results in percentage terms, it is difficult to conclude that being a part of the cluster promotes knowledge-transfer processes.

Although the number of patent applications co-owned in the NutriBioMed Cluster is greater than that of the Mega Nano Energy Cluster (and it has additionally increased over time in absolute terms), it is also difficult to speak about the key role of cluster initiatives in facilitating knowledge flows in this case (measured by the number of joint inventions). This is due to the fact that, in relative terms, the enterprises from the NutriBioMed cluster showed less involvement in the joint inventive activity with other entities from the cluster than during the period when they did not constitute a formal grouping as of yet. Up to 2007, inventions co-authored with other cluster members accounted for slightly more than 43% of the total number of inventions, while during 2008–2017, this number was slightly above 35%. Similar to the case of the Mega Nano Energy Cluster, the bottom-up initiated cooperation in creating breakthrough innovations did not begin to visibly develop after these same entities decided to sign a formal cooperation agreement.

It should be emphasized, however, that the NutriBioMed Cluster demonstrates a greater potential for patent cooperation (unlike the Mega Nano Energy Cluster); with the creation of the cluster, the network of mutual connections between its participants grew (Figs. 3 and 4). While it was possible to observe ties connecting only two enterprises with two R&D entities during the period before the formation of the grouping, patent cooperation was undertaken by as many as five enterprises from the sample together with three academic centers and a technology park after the creation of the cluster.

Generally, with a relatively small degree of inventive activity of the enterprises belonging to the Lower Silesian clusters and, as a consequence, the small research sample consisting of only 13 enterprises from 2 clusters and a relatively small number of cases of jointly undertaken activities in the field of generating inventions by these enterprises, it is difficult to unambiguously indicate the factors that stimulate knowledge-diffusion processes within the cluster. Nevertheless, it seems that neither the size nor the degree of internationalization of the inventive output of these enterprises have any effect on the number of technical solutions jointly created by them and, thus, on the strength and scope of the knowledge diffusion within the cluster. For instance, among the enterprises from the Mega Nano Energy Cluster, the leader in undertaking R&D cooperation with other participants

of the cluster is Elektrownia Turów (with a relatively small number of inventions and not having a single PCT application), while the ABB company (which has the largest number of national and international applications) does not enter into any patent cooperation with entities from the same cluster. The case is similar in the NutriBioMed Cluster, in which, on the one hand, among enterprises engaging in joint R&D work there are both those which have international applications as well as those which do not have them at all, and on the other hand, among enterprises that have only independent patent applications there are also those which both have and do not have any PCT applications.

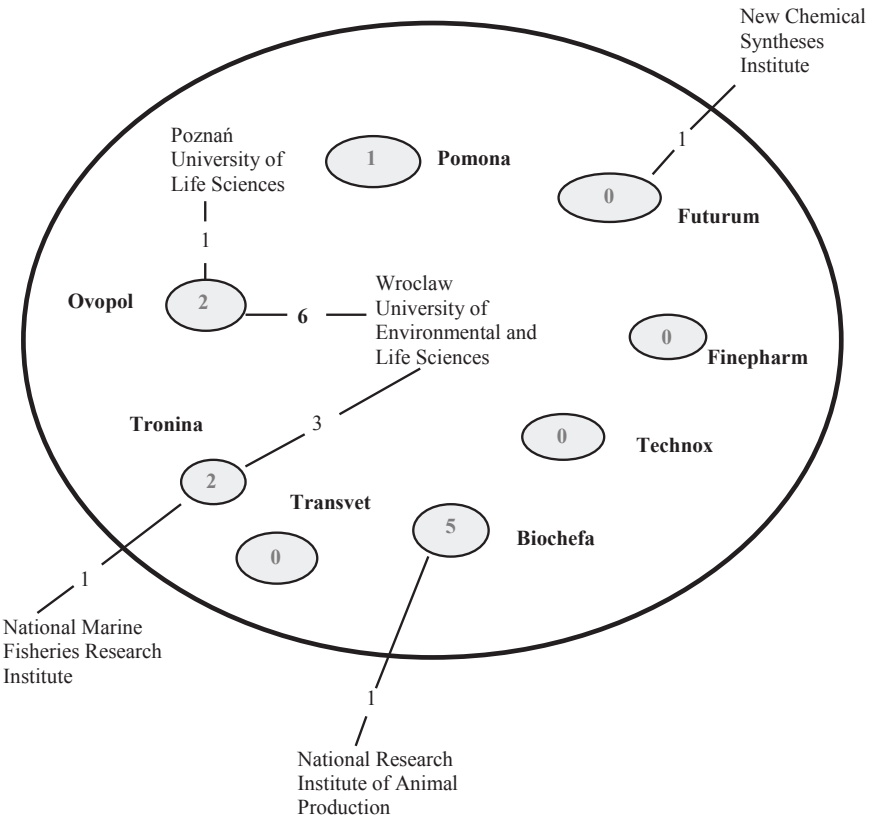

Figure 3. Joint patent applications of enterprises from NutriBioMed Cluster during period before creation of cluster

Legend: *see* Figure 1

Source: developed on basis of own research

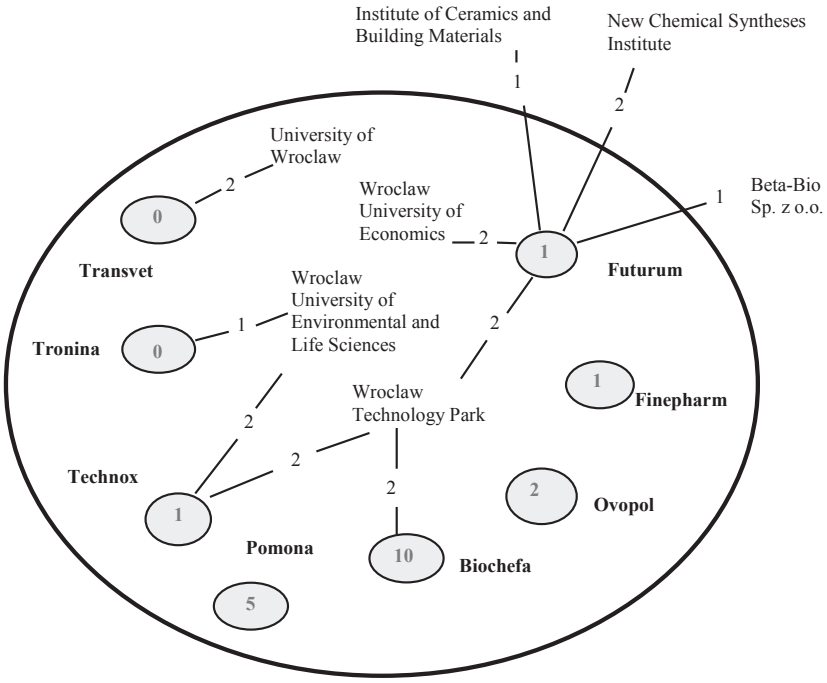

Figure 4. Joint patent applications of enterprises from NutriBioMed Cluster during period after creation of cluster

Legend: *see* Figure 1

Source: developed on basis of own research

5. Patent citations of enterprises from Lower Silesian clusters: research results

Just as the extent to which the enterprises covered by the study undertake patent cooperation with other cluster participants is small, the number of enterprises covered by the study that refer to the achievements of other cluster members in their patent applications is also small (with the enterprises from the NutriBioMed Cluster achieving better results in this respect).

The analysis of the national and international patent applications has shown that in the case of the enterprises from the NutriBioMed Cluster the number of cited inventions belonging to other cluster members increased (even significantly

in percentage terms) and also a network of mutual citations was initiated. Moreover, the enterprises began not only to refer to knowledge from the sphere of science but also to the achievements of the business sector. This is undoubtedly a signal that the knowledge flow between cluster members began to occur. Nevertheless, one should be careful about drawing final conclusions since the number of patent citations continues to be small and disproportionately smaller than the number of citations of know-how coming from outside the cluster (Figs. 5 and 6).

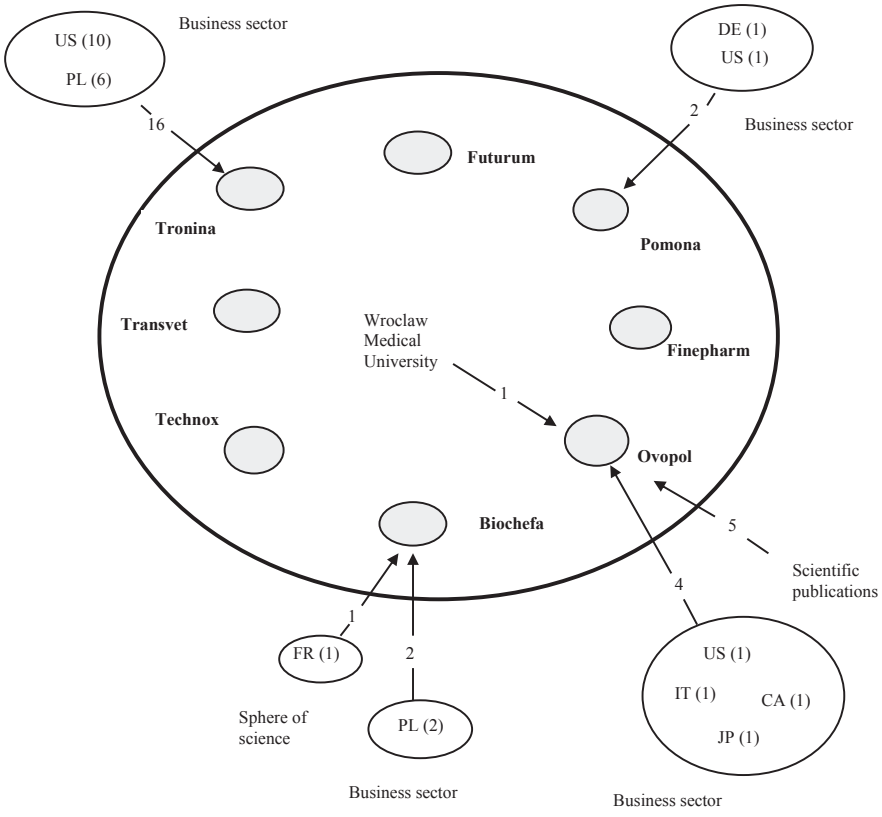

Figure 5. Patent citations of enterprises from NutriBioMed Cluster during period before creation of cluster

Legend: arrow shows direction of knowledge flow (from cited to citing entity); numbers in middles of arrows indicate number of citations; inside large circle are all analyzed enterprises belonging to cluster and other cluster entities that were source of knowledge for enterprises; outside large circle are entities not belonging to cluster.

Source: developed on basis of own research

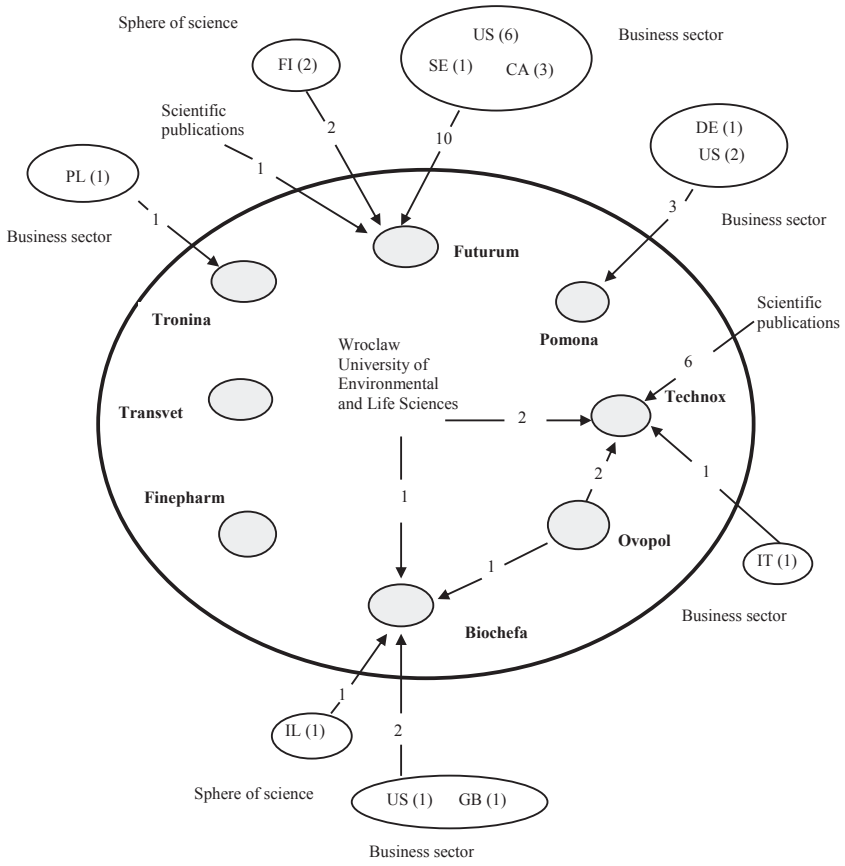

Figure 6. Patent citations of enterprises from NutriBioMed Cluster during period after creation of cluster

Legend: *see* Figure 5

Source: developed on basis of own research

During the period preceding the creation of the NutriBioMed Cluster, only one citation referred to knowledge created within the current cluster (3.2% of all citations), whereas the number of such citations increased to six after the initiation of formal cooperation (18.2% of all citations). In addition, before the creation of the cluster, only one enterprise had cited an invention of the academic center currently belonging to the cluster, whereas a total of two enterprises began to base their inventive activity on the knowledge created by their cluster partners during the subsequent period (both the other enterprises and the academic center).

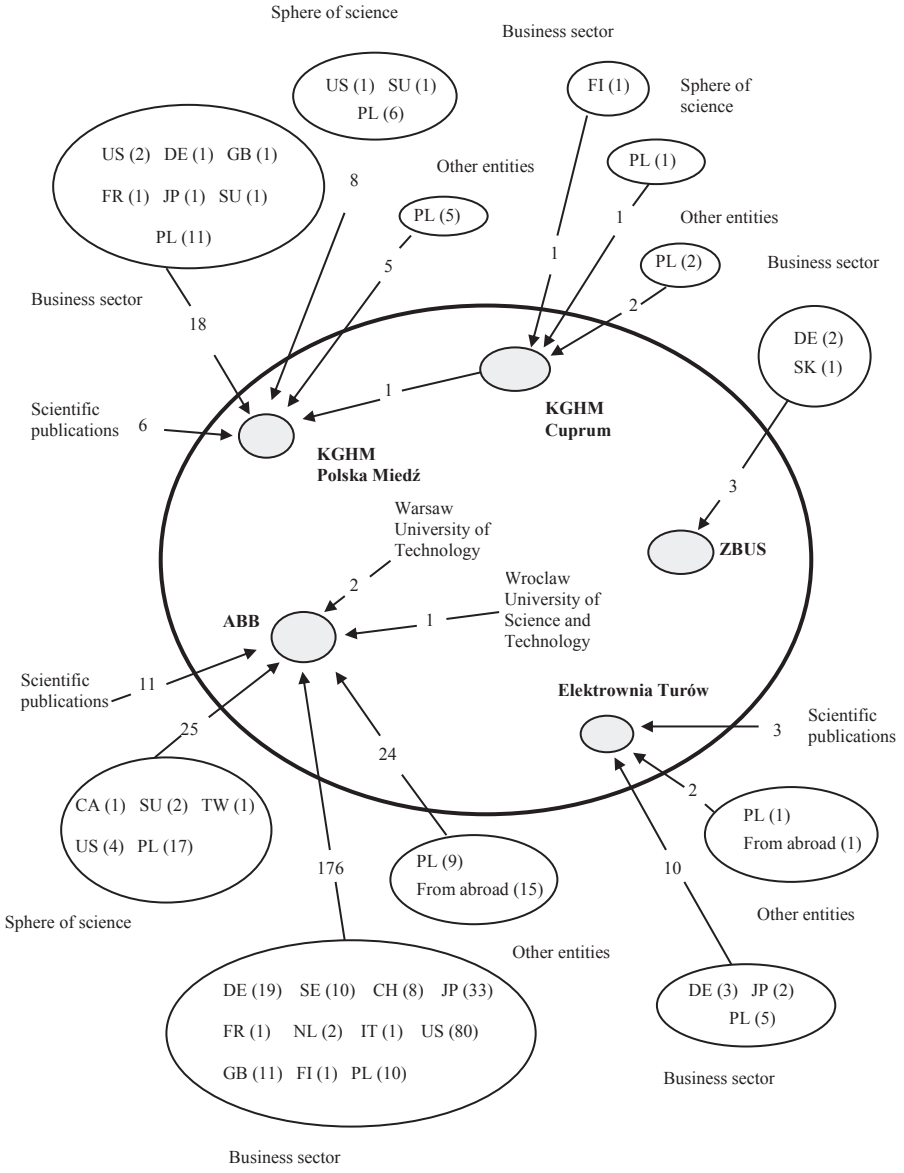

Figure 7. Patent citations of enterprises from Mega Nano Energy Cluster during period before creation of cluster

Legend: *see* Figure 5

Source: developed on basis of own research

Unfortunately, the results for the enterprises from the Mega Nano Energy Cluster are less optimistic than for the NutriBioMed Cluster. Although the enterprises from this cluster show very large absorption abilities (acquiring knowledge from around the world), they do not refer to technical solutions of entities with which they signed formal cooperation agreements in their patent applications. Surprisingly, they do not even use the know-how of the Wroclaw University of Science and Technology in generating inventions, which has enjoyed the status of a leader in terms of the number of patents obtained in Poland for years within the frames of the national procedure; however, they follow the patterns developed in national research units and academic centers not belonging to the cluster to a large extent (Figs. 7 and 8).

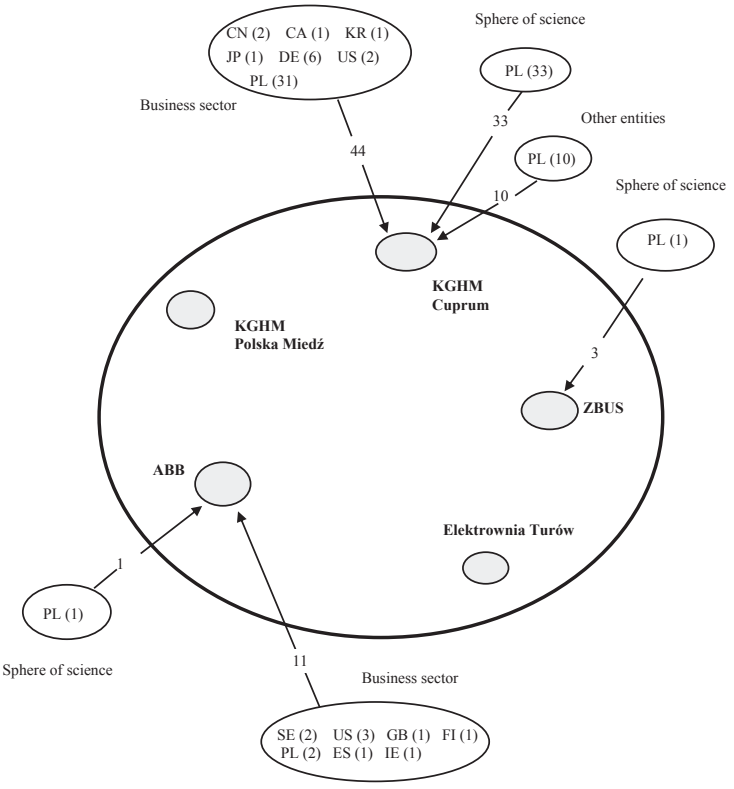

Figure 8. Patent citations of enterprises from Mega Nano Energy Cluster during period after creation of cluster

Legend: *see* Figure 5

Source: developed on basis of own research

To sum up, it may be concluded that, among the two Lower Silesian clusters, the enterprises from the Mega Nano Energy Cluster show a definitely larger inventive activity, both during the period preceding the creation of the cluster and at the time of the functioning of a formal grouping. Unlike the enterprises from the NutriBioMed Cluster, however, their inventive output has decreased over time. Moreover, despite the huge advantage they have over enterprises from the NutriBioMed cluster in terms of the number of inventions created, they show a smaller number of technical solutions created along with the other cluster members; therefore, it may be presumed that the strength and scope of their knowledge diffusion are smaller than within the NutriBioMed Cluster. And finally, they do not refer to the know-how of other cluster members in their patent applications during the lifetime of the cluster (which is contrary to the enterprises from the NutriBioMed Cluster); this also suggests that the scale of knowledge diffusion within the Mega Nano Energy Cluster is negligible.

6. Intra-cluster diffusion of knowledge: Lower Silesian clusters against background of Aviation Valley

The Aviation Valley is the most powerful Polish industrial cluster and, at the same time, "the only Eastern European cluster with such potential and growth" (Kulczycka, 2017). It is "(...) the pride of southeastern Poland. It is also a very beautiful example of cooperation between many Polish businesses and institutions whose purpose is joint success" (Stepaniuk, 2018).

The above statements are just two of many expressions referring to the success of the Aviation Valley that appear in scientific and journalistic literature. They are usually accompanied by "impressive" numbers showing the value of turnover, sales and exports as well as the size of employment and scale of investment of its members.

Despite the important role played by the Aviation Valley in the development of the entire Podkarpackie Voivodeship and the strong ties that connect its members, the enterprises covered by the study from this cluster demonstrate a small degree of patent cooperation; they do not undertake such cooperation with cluster partners at all and do not refer to their know-how in their patent applications either. This is true for both the period preceding the creation of the cluster and the years afterwards. Perhaps, therefore, this cooperation between the various entities of the Aviation Valley as well as their mutual exchange of knowledge and expertise do apply to the most valuable and most protected know-how of the enterprises.

In terms of the knowledge flow measured by the numbers of joint inventions and patent citations, the enterprises from the two Lower Silesian clusters covered by the study are better than the enterprises from the Aviation Valley. It should be assumed that the former achieve greater benefits in the form of the diffusion of precious know-how; although, as the data shows, the lack of cooperation in the field of creating inventions did not prevent the latter from achieving tangible successes. Nevertheless, developing joint innovative solutions could move them to a higher level of innovation that translate into even greater benefits.

7. Conclusions

It is widely believed that the key factor for the success of a cluster is the cooperation between its members, which results in the mutual exchange of knowledge and expertise. Although the members of the Lower Silesian clusters undertake a number of joint initiatives, there is still much to be done in the area of building and strengthening their cooperation in innovation.

The analysis of the national and international patent applications belonging to the enterprises from the NutriBioMed Cluster and Mega Nano Energy Cluster from Lower Silesia has shown that only a few enterprises undertake patent cooperation with the other entities from the cluster (albeit to a limited extent). The number of inventions co-authored with the partners from the cluster accounted for only 2.13% of the total number of all inventions of the enterprises in the case of the Mega Nano Energy Cluster and 35.14% in the case of the NutriBioMed Cluster. The result achieved by the enterprises from the NutriBioMed cluster could actually be regarded as satisfactory if not for the fact that this patent cooperation was more intensive during the period before the creation of the cluster. Namely, joint patent applications among the organizations currently belonging to the cluster accounted for 43.48% of the total inventive output of the enterprises at that time. This means that the signing of a formal cooperation agreement did not translate into a greater involvement of the enterprises in the joint inventive activity that would strengthen the knowledge-transfer processes. The enterprises from the Lower Silesian clusters not only do not acquire the valuable knowledge of their partners through direct contacts, but they also do so to a small extent by following their accomplishments (which is reflected in the small number of cited inventions belonging to the other cluster members). Of all the references of the enterprises from the NutriBioMed Cluster to other's knowledge, only six were citations of cluster members' know-how, while the enterprises from the Mega Nano Energy Cluster did not cite their cluster partners at all (with their

inventive activity based only on internal sources of knowledge or ones located outside the cluster).

Due to the small number of joint inventions and references to the knowledge of the other cluster members, it is difficult to identify the factors that stimulate knowledge flow within the cluster. It does not seem, however, that the size of the inventive output nor the degree of its internationalization are important here. On the other hand, it seems that the intensity of the knowledge transfers may depend on the number of R&D institutions in the cluster since the mutual exchange of knowledge is more intensive in the NutriBioMed Cluster (which has more of them) than in the Mega Nano Energy Cluster.

Although the research sample is too small for the results to be extended to the entire population of clusters, it seems that the potential of Polish clusters in promoting knowledge-diffusion processes is not sufficiently utilized. This is true not only for the analyzed clusters from Lower Silesia but also to the Aviation Valley, which is considered an enclave of innovation in Poland. The reason is that the enterprises from the Aviation Valley Cluster are even less interested in cooperation in the field of generating inventions and in referring to the know-how of their partners than the Lower Silesian clusters.

The most disturbing result of the study, however, is that the enterprises still do not see the benefits resulting from intra-cluster knowledge diffusion and regard cooperation with other cluster member as being of little importance or even risky from the point of view of innovation and competitiveness. This makes them approach it with suspicion, which makes it difficult for them to achieve benefits in the form of synergy effects.

The results of the analysis undertaken in this paper may be useful from the perspective of future studies, which could be extended to the entire population of Polish clusters. Then, it would be possible to better capture the relationship between the industry in which the clusters operate or the policies toward the clusters and the processes of knowledge diffusion, for example.

References

[1] Agrawal, A., Cockburn, I. and McHale, J. (2006) 'Gone but not forgotten: Knowledge flows, labor mobility, and enduring social relationships', *Journal of Economic Geography*, vol. 6, no. 5, pp. 571–591.

[2] Azoulay, P., Graff Zivin, J.S. and Sampat, B.N. (2011) 'The diffusion of scientific knowledge across time and space: Evidence from professional transitions for the superstars of medicine', NBER Working Paper Series, No. 16683.

[3] Baptista, R. (2000) 'Do innovation diffuse faster within geographical cluster?', *International Journal of Industrial Organization*, vol. 18, No. 3, pp. 515–535.

[4] Bathelt, H., Malmberg, A. and Maskell, P. (2004) 'Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation', *Progress in Human Geography*, vol. 28, No. 1, pp. 31–56.
[5] Bembenek, B. (2016) 'Współpraca strategiczna przedsiębiorców z sektorem badawczo-rozwojowym w polskich klastrach – współczesne wyzwanie w zarządzaniu klastrami', *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, No. 444, pp. 31–46.
[6] Bodas Freitas, I.M., Geuna, A. and Rossi, F. (2013) 'Finding the right partners: institutional and personal modes of governance of university-industry interactions', *Research Policy*, vol. 42, No. 1, pp. 50–62.
[7] Ceci, F. and Iubati, D. (2012) 'Personal relationships and innovation diffusion in SME networks: A content analysis approach', *Research Policy*, vol. 41, No. 3, pp. 565–579.
[8] Cooke, P. and Wills, D. (1999) Small Firms, Social Capital and the Enhancement of Business Performance Through Innovation Programmes', *Small Business Economics*, No. 13, pp. 219–234.
[9] Dąbrowska, A. (2014) 'Działania innowacyjne w strukturach klastrowych w świetle wyników badania', *Handel Wewnętrzny*, No. 3(350), pp. 41–53.
[10] Delgado, M., Porter, M.E. and Stern, S. (2010) 'Clusters and entrepreneurship', *Journal of Economic Geography*, vol. 10, No. 4, pp. 495–518.
[11] Delgado, M., Porter, M.E. and Stern, S. (2014) 'Clusters, convergence, and economic performance', *Research Policy*, No. 43, pp. 1785–1799.
[12] Dyba, W. (2016) 'Współpraca i przepływy wiedzy w organizacjach klastrowych w świetle polityki klastrowej UE – przykład badania relacji łączących przedsiębiorstwa z wykorzystaniem analizy sieciowej', *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego*, vol. 30, No. 1, pp. 124–142.
[13] Etzkowitz, H. and Leydesdorff, L. (2000) 'The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University-Industry-Government Relations', *Research Policy*, No. 29, pp. 109–123.
[14] Główka, C. and Jankowska, B. (2014) 'A cluster initiative as an effective instrument for building partnerships between business and research and development sector – the perspective of Polish micro-enterprises', in Towards greater economic competitiveness: Business clusters and cluster policy in Lithuania and Poland, Poznań 2014, pp. 97–113.
[15] Gorynia, M. and Jankowska, B. (2007) 'Wpływ klasterów na konkurencyjność i internacjonalizację przedsiębiorstw', *Gospodarka Narodowa*, No. 7/8, pp. 1–18.
[16] Gorynia, M. and Jankowska, B. (2008) 'Klastry a konkurencyjność i internacjonalizacja przedsiębiorstw Wielkopolski', *Gospodarka Narodowa*, No. 5–6, pp. 91–109.

[17] Götz, M. and Jankowska, B. (2017) 'Clusters and Industry 4.0 – do they fit together?', *European Planning Studies*, vol. 25, No. 9, pp. 1633–1653.
[18] Hołub-Iwan, J. and Małachowska, M. (2008) Rozwój klastrów w Polsce. Raport z badań, Fundacja Talent – Promocja – Postęp, Szczecin 2008.
[19] Jaffe, A.B., Trajtenberg, M. and Henderson, R. (1993) 'Geographic localization of knowledge spillovers as evidenced by patent citations', *Quarterly Journal of Economics*, No. 108(3), pp. 577–598.
[20] Jankowska, B. (2013) 'Coopetition as an attribute of clusters fostering innovativeness of enterprises – the case of one creative cluster', *International Journal of Business and Management Studies* 2013, vol. 5, No. 1, pp. 69–80.
[21] Jankowska, B. and Götz, M. (2016) 'Contrasting internationalisation intensity of business clusters – a study from a CEE country', EIBA International Annual Conference, Vienna 2016, pp. 1–31.
[22] Jankowska, B. and Götz, M. (2017) 'Internationalization intensity of clusters and their impact on firm internationalization: the case of Poland', *European Planning Studies*, vol. 25, No. 6, pp. 1–20.
[23] Jankowska, B., Götz, M. and Główka, C. (2017) 'Intra-Cluster Cooperation Enhancing SME's Competitiveness – The Role of Cluster Organization in Poland', *Journal of Regional Research*, No. 39, pp. 195–214.
[24] Jankowska, B. and Pietrzykowski, M. (2013) 'Clusters as absorbers and do users of knowledge', *The Poznań University of Economic Review*, No. 1, pp. 68–88.
[25] Johnnessen, J.A. (2009) 'A systemic approach to innovation: the interactive innovation model', *Kybernetes*, No. 38(1–2), pp. 158–176.
[26] Kulczycka, A. (2017) Dolina Lotnicza ma inwestycyjne żniwa. 11 nowych fabryk, *Gazeta Wyborcza*, 19.05.2017, [Online], Available: http://rzeszow.wyborcza.pl/rzeszow/7,34962,21831008,dolina-lotnicza-ma-inwestycyjne--zniwa-11-nowych-fabryk.html?disableRedirects=true [26 Feb 2018].
[27] Kowalski, A.M. (2012) The Impact of Industrial Clusters on the Innovativeness of Business Firms in Poland (July 13, 2012), European Business Research Conference Proceedings, [Online], Available: https://ssrn.com/abstract=2129190 or http://dx.doi.org/10.2139/ssrn.2129190 [26 Feb 2018].
[28] Marshall, A. (1920), Principles of economics, London.
[29] Maskell, P. (2001) 'Towards a Knowledge-based Theory of the Geographic Cluster', *Industrial and Corporate Change,* No. 10(4), pp. 921–943.
[30] Maskell, P., Bathelt, H. and Malmberg, A. (2006) 'Building global knowledge pipelines: The role of temporary clusters', *European Planning Studies*, vol. 14, No. 8, pp. 997–1013.
[31] Morrison, A., Rabelloti, R. and Zirulia, L. (2013) 'When Do Global Pipelines Enhance the Diffusion of Knowledge in Cluster?', *Economic Geography*, vol. 89, No. 1, pp. 77–96.

[32] Mowery, D. and Ziedonis, A.A. (2001), 'The geographic Reach of Market and Non-Market Channels of Technology Transfer: Comparing Citations and Licenses of University Patents', NBER Working Paper, No. 8568.
[33] Niklewicz-Pijaczyńska, M. and Wachowska, M. (2014) 'The role of clusters in stimulating breakthrough innovation in enterprises', *Journal of International Studies*, vol. 7, No. 1, pp. 58–69.
[34] Nishimura, J. and Okamuro, H. (2011) 'R&D productivity and the organization of cluster policy: An empirical evaluation of the Industrial Cluster Project in Japan', *Journal of Technology Transfer*, vol. 36, No. 2, pp. 117–144.
[35] Oettl, A. and Agrawal, A. (2008), 'International Labor Mobility and Knowledge Flow Externalities', *Journal of International Business Studies*, vol. 39, No. 8, pp. 1242–1260.
[36] Plawgo, B. (2014) 'Klastry – stan i perspektywy rozwoju w województwie podlaskim', Białostocka Fundacja Kształcenia Kadr, Białystok.
[37] Plawgo, B., Klimczuk-Kochańska, M. and Citkowski, M. (2013) Raport końcowy. Ewaluacja pt.: Jak zmieniają się klastry dzięki wsparciu z PO RPW?, Warszawa: Polska Agencja Rozwoju Przedsiębiorczości.
[38] Porter, M.E. (2001) Porter o konkurencji, Warszawa: PWE.
[39] Ratajczak-Mrozek, M. (2012), Klastry jako źródło nawiązywania współpracy przedsiębiorstw, *Zeszyty Naukowe Uniwersytetu Szczecińskiego*, No. 719, pp. 233–244.
[40] Spence, M. (1984) Cost reduction, competition, and industry performance, *Econometrica*, vol. 52, No 1, pp. 101–122.
[41] Stanienda, J. (2014) 'Znaczenie klastrów w innowacyjności przedsiębiorstw', *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie*, vol. 24, No. 1, pp. 189–200.
[42] Stepaniuk, W. (2018) Dolina Lotnicza – polski przykład biznesu na światową skalę, *Polski Przemysł. Portal Przemysłowy* 2012, [Online], Available: https://polskiprzemysl.com.pl/przemysl-lotniczy/dolina-lotnicza-klaster-lotniczy/ [26 Feb 2018].
[43] Yström, A. and Aspenberg, H. (2017) Open for innovation? Practices supporting collaboration in Swedish regional clusters, *International Journal of Innovation Management*, vol. 21, No. 5, pp. 1–28.