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HOW TO MEASURE THE EFFECTIVENESS OF TECHNOLOGY PARKS? THE CASE OF POLAND

Summary: In a knowledge-based economy, the human capital that is capable of innovative thinking and entrepreneurial action is the factor responsible for the creation of prosperity. Technology parks are an example of a high concentration of innovative human capital. In the past five years several new park initiatives have been established in Poland. In some large cities such as Poznan and Wroclaw, there is already a kind of fashion for technology parks. These initiatives are called technology parks, research and business parks. The activities of parks should be development measured, for example, by employment growth in the regions, and the innovativeness of companies. Technology parks are from an organizational and conceptual point of view the most advanced innovation centers in Poland. Entrepreneurs, representatives of the scientific sector, business environment institutions as well as regional authorities expect of them a permanent, intensive development, which translates into the development of the environment in which they operate. The main aim of this paper is a multidimensional comparative analysis of the spatial diversity of the development of technology parks in Poland. For the study of spatial differentiation in the development of technology parks in Poland a taxonomic measure of development z_i was used, which was based on the statistical information collected during the study "Benchmarking of technology parks in Poland – 2012 edition". The statistical information of the 19 technology parks selected for the study was analyzed. The multi-dimensional comparative analysis in the study of technology parks shows that the phase of growth of parks does not always translate directly into the position they occupy in the taxonomic hierarchy.

Keywords: technology parks, effectiveness, multi-dimensional analysis

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1. Introduction

Industrial and technology parks should be places which, due to the concentration of firms from just one or similar sectors and the supporting science and research

facilities, are able to develop quickly. Although the first technology parks were created in Poland in the mid-nineties, it was this type of co-financing projects from European Union funds, that led to their rapid development. Technology parks in Poland are located particularly in large cities such as Wrocław, Poznań and Gdańsk. The weaker regions with less developed urban centers which are in transition deviated from their industrial roots, and technology parks do not exist there or are in the embryonic phase such as in the Lubuskie region. A significant differentiation in the level of development of technology parks in Poland is apparent. In view of the fact that these parks are mainly financed from public funds, there is a need to assess the efficiency of their operations and to identify the main problems of their development and the risks associated with the allocation of public funds in this area.

The main goal of this work is a multi-dimensional assessment of the level of differentiation of the development of technology parks in Poland and an indication of the factors affecting the efficiency of the system. The following aspects were considered:

1. Diversity, multifaceted and differentiation operation of technology parks in Poland also requires a comprehensive approach to study the effectiveness of their operation.

2. The efficiency of the operation of parks cannot be measured only on the basis of their infrastructural facilities and financial performance. It is necessary to link the effectiveness of the park with its functions.

For the study of the differentiation in the development of technology parks in Poland a taxonomic measure of development zi was used, which was based on the statistical information collected during the study ”Benchmarking of technology parks in Poland – 2012 edition”.

2. Effectiveness of technology parks – some research

The study of the effectiveness of technology parks based on different concepts of development requires compliance of the used methods (quantitative and qualitative) with their functions, which often evolve over time. The location of the technology park is also important, the development of regions and cities depends not only on the size of the national income, but also on its source. Knowledge of the economy is a factor in the welfare of human capital capable of innovative thinking and entrepreneurial action [Matusiak 2011].

Differences in approach to the factors describing the competitiveness of regions and cities have evolved from a more general level in the direction of specialization, including both factors related to the quality of human capital and economic potential. The main changes concern the increasingly observed duality of the labor market. From this point of view, among the new factors of competitiveness of regions and cities listed include [Sassen 2006, Parteka 2007]:

- instead of general human resources, the part of them that is capable of manufacturing and service activity permanently on the market;
- not so much the size of a scientific center in the vicinity, which is located in the technology park as its ability to generate innovation and absorb them;
- ability to mobilize capital and current unlike indicated, until recently, only the fact of ownership of financial capital, as such;
- willingness to make rapid changes in the economic profile and the variety and flexibility in the so-called specialization. Smart specialization, and not as yet indicated the stability of the development of cutting-edge sectors and specializations of the fixed region;
- economy based on virtual alliances group (cluster), small and medium-sized enterprises, in contrast to the industrial structure used, based on the large manufacturing companies cooperating with subcontractors.

In Poland, the potential for innovation, due to the structure of companies, is allocated mainly in small and medium-sized enterprises. Unfortunately a company of this size does not usually have the infrastructure or facilities for more research to implement new technology solutions more effectively. The solution in this regard may be the support of the business environment to facilitate access both to information as well as technical infrastructure, services and financial assistance – for example, by the possibility of using seed capital [Kowalak (ed.) 2010]. Technology parks are a good example of this type of support for small and medium-sized enterprises. In the past five years there have been several new initiatives of the parks in Poland, created by regional authorities, universities, and private owners. Each of the entities forming or co-participating in creating the park aims at different targets, including: the growth of entrepreneurship and employment in modern companies with high potential for innovation, for example in the case of regional authorities and the commercialization of knowledge and innovation, for example in higher education.

In this context there is a different way of approaching the effectiveness of the park. Differences in the approach to this type of problem can also be seen in Polish and European studies. European research is mainly aimed at developing such a methodology that would allow companies that have worked in the parks to assess their situation and position suited to the needs of specific stakeholders – for example other regional authorities and others – in the event of having such potential customers. Due to the set of available indicators, each company can create its own set of variables showing the current situation and the results of such financial statements.

The aim of Polish research project of the Polish Agency for Enterprise Development ”Benchmarking of technology parks in Poland”, is rather a comparison of the rate and direction of development of parks in the same consideration to all parks in these criteria, the study involves two steps, whose aim is to determine the phase of the life cycle of the park and stage the appropriate essential benchmarking study.

Benchmarking is defined most commonly as a modern tool for managing an organization, the essence of which is to identify best practices in the business capable of achieving success in the industry and in the policy area. The identification of best practices is mainly through the analysis of internal and external processes in the organization. This is called benchmarking procedural or horizontal. Another form is the benchmark indicators, which compares similarities to each organization based on a set of highlighted indicators and the best result is used only as a reference point for other organizations. This form of benchmarking is used in the study carried out by the Polish Agency for Enterprise Development. Therefore a slightly different approach was used in this study. Table 1 shows the main differences between these Polish and European studies.

Table 1. Selected elements of the research methodology of the technological parks development of – Polish and European experience

European Studies Research	Polish Studies Research
1. The evaluation is conducted from the point of view of companies participating in the park. Assessment is subjected to the individual achievements of companies operating in the park.	1. Assessing mainly the managing of the park. Rating managing to that performed through the prism of business development in the park.
2. Rating the companies in the park made mainly from the perspective of the company's stakeholders including the city and the region, research centers, private investor, other tenants of the park.	2. Diverse range of research areas assessed, including the prospects of finance, stakeholders of internal processes, learning and development.
3. Ability to assess on the basis of a different set of indicators, selected from the proposed list.	3. The evaluation should cover all the indicators highlighted in the developed methodology study.
4. The choice of indicators allows for more individual approach, but does not provide matching opportunities.	4. Analysis of the same set of indicators allows comparisons to be made between the parks.

Source: own analysis based on: [Dąbrowska 2011; Hołub-Iwan, Olczak, Cheba 2012].

The methodology used in the European research, based on the selected set of indicators, is not aimed at conducting a comprehensive comparative analysis. However, the shortcoming of research conducted on the basis of Polish data, despite the rich set of variables analyzed, is to consider each feature separately, possibly two, in the selected statements presented in the form of maps of the strategic groups. Meanwhile, the comprehensive information about the position of the analyzed parks would provide a multi-dimensional comparative analysis based on all the variables considered as diagnostic.

An important element of the research work carried out by PARP is also to assess the impact of the parks' development on the environment in which they operate. The natural locations for parks are in an attractive and well-functioning urban

environment. Most of the technology parks in Poland are located close to large urban centers. A good location is one of the strongest assets of parks in Poland. This is confirmed by the results of the benchmarking framework, which evaluated the distance of parks, main roads railways, roads, the distance from large production facilities, the airport and the nearest university. The scope of points gained by the 19 parks participating in the study ranged from 21 to 25, with a maximum of 25 points. Noteworthy is the particularly high score for most of the parks in a good location in terms of distance to the nearest university. One of the main objectives of the operation of technology parks is, by the definition proposed by the International Association of Science Parks (IASP), expanding the wealth of their community, the promotion of a culture of innovation, the process of creation of innovative companies, to promote the transfer of knowledge and new technologies [Simmie 2001]. Of course, the effectiveness of the park in this area will be determined by its integral connection to the city center within which it operates.

The effectiveness of the technology park in this context to be included as standard in addition to describing the activity areas of parks, related to the development or possessing the potential infrastructure, and those areas that directly describe the relationship with the surrounding park. However, the factors determining the need to assess the operation of technology parks are [Dąbrowska 2011]:

1. The growing popularity of parks, forcing the need to assess the effectiveness of parks and their impact on economic development, including the development of urban centers which are located in the parks.

2. The growing investment earmarked for creating and development of the parks, forcing the need to confirm the credibility and provides chances and opportunities to achieve success.

3. Finding clear evidence and arguments relied on spend on such a project that could be presented to investors in order to confirm the validity and the possibility of achieving return on investment.

3. Methodology of research

The taxonomic measure of development z_i, has been used to study the development of diversity parks. We analyzed the statistical information collected during the investigation ”Benchmarking of technology parks in Poland – 2012 edition” of 19 technology parks selected for the study. In the first stage of research, the collected information was subjected to a preliminary analysis. From the set of potential diagnostic features we eliminated variables that do not meet the accepted criteria of formal and substantive. It is assumed that the final set of features should include variables [Zeliaś (ed.) 2000] with high spatial variability, with low correlating and an asymmetric distribution.

Hellwig’s parametric method was used for the purpose of the selection of the representatives of respective sets [Hellwig 1981]. After determining the matrix of

coefficients of correlation between respective variables belonging to the selected areas, all variables were divided into sets which included central variables together with satellite variables and the so-called isolated variables.

Finally, a set of 46 diagnostic features were selected for the final set of 22 variables. This collection, which became the basis for further empirical research created the following features:

1. Value of funds raised from the European Union (or as grants from other international organizations)/ revenue (%).
2. Investment expenditures of the park/total expenditure of the park (%).
3. Total revenue/park assets (%).
4. Total sales dynamic (% of growth).
5. Number of cooperating companies/ number of tenants.
6. Number of collaborating independent experts/ number of tenants.
7. Number of projects executed by a technology park in partnership with other institutions.
8. Park building area (m^2).
9. Number of tenants.
10. Number of spin-off companies/ number of newly created companies.
11. Number of start-up companies/number of newly created companies.
12. Ratio of used park building area (%).
13. Number of services provided to tenants during the last 12 months/number of tenants.
14. Overall rating of the institution managing the park given by tenants (park survey questionnaire).
15. Internet strategy (external evaluation on the basis of the website, the number of visits to the site, search relevancy in search engines, etc.).
16. Number of technological and innovative implementations by park tenants/ number of tenants.
17. Expenditure on ICT of the park/total sales (%).
18. Innovative companies/number of park tenants (%).
19. Park tenants engaged in R&D activity/number of park tenants (%).
20. Employees with a scientific degree of a PhD at least or an academic title/ total number of park employees (%).
21. Number of legally protected patents and trademarks/ number of tenants.
22. Number of scientific-industrial teams realizing research initiatives.

The scope of the variables used to determine the level of development of technology parks surveyed contains features describing on the one hand, the potential of the parks' infrastructure (building area, or the percentage level of its use), on the other hand focusing primarily on the indication of the potential of the parks in the possibility of developing co-operation with the environment (e.g. the number of industrial research groups pursuing scientific initiatives and the number of cooperating companies in terms of the number of tenants), and in assessing the

potential for innovation of the companies operating in the park (e.g. number of legally protected patents and trademarks in terms of the number or percentage of tenants – the share of innovative firms in the total number of the park's tenants). The data extracted both from the substantive criteria and formal statistical variables formed the basis of a comparison and classification of discrete spatial units (technology parks) into groups with similar levels of development.

For the study of the differentiation of the technology park's development, z_i – a taxonomic meter of development on the basis of standardized variables by transforming destimulants into stimulants was implemented. For this purpose the following formula was used [Nowak 1990]:

$$z_i = \frac{1}{K}\sum_{k=1}^{K} z_{ki},$$

where: z_i – value of a taxonomic measure of development for *i*-object; z_{ki} – standardized value of *k*-feature in *i*-object; K – number of features examined.

The arithmetic average of the measure determined in this way equals one. This enabled us to conduct the comparisons of the development of objects with multiple features. If the following inequality appears for the object examined: $z_i > 1$, then the object examined reaches a higher level of development than the average in the whole set of objects. In cases when $z_i < 1$, then the object examined reaches a lower level of development than the average in the set of the compared units [Nowak 1990].

4. Results of the empirical analysis

As a basis for the standardization of individual characteristics we assumed average values, determined on the basis of statistical information from the 13 analyzed technology parks. The division of parks into typological groups was preceded by an ability to gauge, the development of the designated group of units surveyed. We used for this purpose the formula proposed by A. Sokołowski as a discriminatory assessment of the properties of the variables determined by the formula [Sokołowski 1984]:

$$G = 1 - \sum_{i=1}^{N-1} \min_i \left\{ \frac{z_i - z_{i+1}}{R}, \quad \frac{1}{N-1} \right\}$$

where:

$R = \max_i \{z_i\} - \min_i \{z_i\}$,

N – number of objects.

Index G is standardized in such a way that:

$$0 \le G \le 1 - \frac{1}{N-1}.$$

High values indicate its great ability to gauge the development of the taxonomic group compared objects. Value Measure G, determining the ability of the measure to the development of the cities in the studied group was 0.61 (for G є <0; 0,94>, which means that the measure has a pretty good ability to divide parks typological groups. The facilities ordered by decreasing value of taxonomic measure of development are divided into groups with similar levels of development of the phenomenon under study. The study examined the set of all technological parks divided into four groups, including values of the measure with the development of the following ranges [Zeliaś 2004]:

- the first group of parks, for which $z_i \ge \overline{z} + S_z$,
- the second group of parks, for which $\overline{z} + S_z > z_i \ge \overline{z}$,
- the third group of parks, for which $\overline{z} > z_i \ge \overline{z} - S_z$,
- the fourth group of parks, for which $z_i < \overline{z} - S_z$.

The results of parks clustering are shown in Table 2.

Two technology parks included in the first typological group, characterized by a relatively small range of variation, are significantly different from the other analyzed parks. The second group includes six parks, where the level of variability of this group is also small, less than 8%. The most varied results were obtained with the third and fourth typological group. To the third group, with the results lower than the average in the study group, there were classified 8 parks, in which the level of variability stood at nearly 17%. However, in the fourth group consisting of three parks, the results obtained by the parks in this group are characterized by a higher level of variability in the range of 22%. The obtained results confirmed the parks' significant level of differentiation of their level of development.

Table 2. Classification technology parks by taxonomic measure of development in 2012

Group	A group of measurement value	Technology park		Descriptive characteristics	
		Number	Number of park	R*	Vs** (%)
1	1,4232 and more	2	Park 6, park 5	0,2256	9,14
2	<1;1,4232)	6	Park 8, park 14,park 19, park 16, park 7, park 9	0,2418	7,88
3	<0,5768;1)	8	Park 15, park 4, park 2, park 17, park 1, park 13, park 18, park 11	0,3793	16,86
4	below 0,5768	3	Park 12, park 10, park 3	0,1964	21,83

* R – interval, Vs – coefficient of variation.

Source: own analysis.

The results of this phase of the study are shown in Figure 1, the horizontal lines mark the division between the designated typological groups.

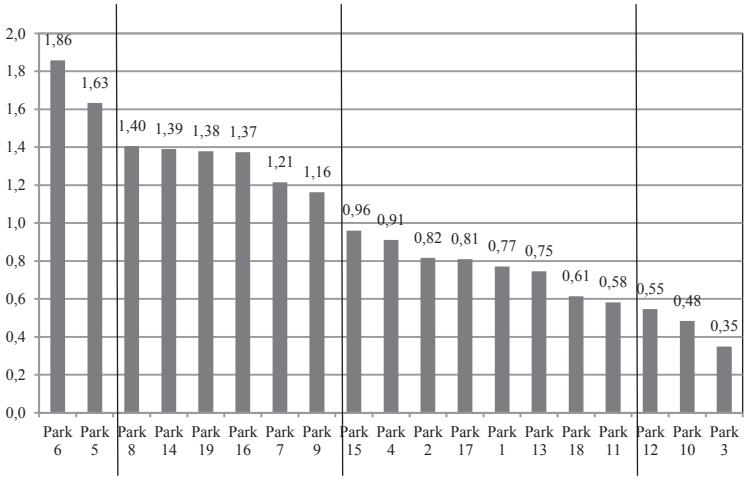

Fig. 1. Technology parks division into groups according to the taxonomic measure of development

Source: own calculations.

During the research, benchmarked parks were also classified into different phases of the life cycle, which were described by: the level of development of the organizational structure, the lifetime of the park, the level of use of the park, the number of types of services offered by the park, the park network connections at the national and international sourcing dynamics of tenants, number of network links between the tenants of the park. Theywere divided into the following five stages: the embryonic phase, the growth phase, the early maturity phase, the maturity phase, the late/stagnation phase. The results of grouping the parks are presented in Table 3. In the table, in addition to the development of the standardized measure information is also included about the group which is assigned to the park and the life cycle phase of the park is indicated.

Two parks that were in the first group are typological parks which during the benchmarking study were classified into the maturity phase and the phase of early maturity. In the second group of the six parks typologically classified in this group, only three of the parks are in the maturity stage and two parks are in a growth phase and one park is in the early stages of maturity. A similar situation can be observed in the case of the third group. In this group there were as many as four parks included in the maturity phase and two parks in the acute phase of maturity. Theoretically, it should be the case that parks which were included in the maturity phase, possibly the early phase of maturity, should have a higher taxonomic rank than the parks that are in the growth phase, before building their position and contacts with the environment

Table 3. Comparison of the results of the classification technology parks by taxonomic measure of development in 2012, with the phase of the life cycle of the park

Number of park	Life cycle phase of park	Taxonomic hierarchy	Number of park	Life cycle phase of park	Taxonomic hierarchy
Park 1	The maturity phase	13	Park 11	The early maturity phase	16
Park 2	The maturity phase	11	Park 12	The early maturity phase	17
Park 3	The growth phase	19	Park 13	The early maturity phase	14
Park 4	The growth phase	10	Park 14	The growth phase	4
Park 5	The early maturity phase	2	Park 15	The maturity phase	9
Park 6	The maturity phase	1	Park 16	The maturity phase	6
Park 7	The maturity phase	7	Park 17	The early maturity phase	12
Park 8	The growth phase	3	Park 18	The growth phase	15
Park 9	The maturity phase	8	Park 19	The early maturity phase	5
Park 10	The early maturity phase	18			

Source: own calculations.

and stakeholders in the park. Meanwhile, the multi-dimensional comparative analysis in the study of technology parks shows that the phases of the life cycle, which classify the parks do not always translate directly into the position they occupy in the taxonomic hierarchy.

5. Summary

Technology parks increasingly recognize the need for both the active acquisition of new tenants as well as their maintenance in the park. Contacts outside the parks, both with companies outside the parks as well as with representatives of science and research and development sector, are increasingly important.

Due to the wider spectrum of business parks and the intermingling of different areas of the business, a more comprehensive approach to evaluating the effectiveness of the technology park and considering the level of development of the park is necessary, not only from the point of view of the individual indicators, but also on the basis of a number of studies classified as diagnostic variables. A good solution in this case is the use of multivariate methods for comparative analysis, in this example, the taxonomic measure of development.

Measuring the effectiveness of technology parks is so important that the parks with a developed system of pre-incubators and incubators are one of the elements that describe the so-called modern metropolis of knowledge, or clusters of institutions, entrepreneurs and investors focused on functioning in the Knowledge-Based Economy [Parteka 2007].

Having an adequate infrastructure capacity is now a basic requirement and not an end in itself for technology parks. Although the parks continue to invest in expanding the assets held by them, in many cases, with the rapid growth observed in this regard, there is also growth in other areas of activity. This change in the proportion of weight given to achieving these objectives can provide not only an increase in the number of parks, but also in their development.

The observed increased activity of parks not only focused on expanding their resources infrastructure allows also the identification of future major courses of action affecting the parks' close ties with the environment, namely:

1. Creating lasting and mutual relationships with tenants of the park not only on the basis of the available infrastructural resources, but also by the high quality, variety and complexity of the services offered. The starting point is the modern infrastructure of the park and the possibility of its further development.

2. The increased activity of parks in many areas of activities requires the constant improvement of the quality of human capital. To meet the growing expectations of stakeholders of parks requires investment in specialized training for park employees, particularly those involving technical expertise. An opportunity to accelerate the transfer of knowledge and technology between universities, industry and business is investing in human capital as well as in the park, and what is more important is that not only administration of the park meets all the needs of the partners, it is also necessary to develop competencies in the field of innovation.

3. Therefore increasingly important is the quality of contact with the external environment, to which the parks are increasingly devoting their attention. The actions must be more precise and structured. This evokes the need to develop a comprehensive model of co-operation outside of the park identifying and bridging the existing systemic and institutional barriers which limit the use of networking opportunities.

4. Building a competitive advantage can only be based on a long-term innovation strategy. Despite the growing number of implementations of technology and innovation, patents and trademarks of the park's tenants, still such initiatives are not a very large margin business activities in the parks. It becomes necessary, therefore, to be aware of matching tenants, including an analysis of their potential to create a future of innovative solutions and advanced technologies.

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JAK MIERZYĆ EFEKTYWNOŚĆ FUNKCJONOWANIA PARKÓW TECHNOLOGICZNYCH? PRZYKŁAD POLSKI

Streszczenie: W gospodarce opartej na wiedzy czynnikiem budowania dobrobytu jest kapitał ludzki, zdolny do innowacyjnego myślenia i przedsiębiorczego działania. Przykładem dużej koncentracji innowacyjnego kapitału ludzkiego są parki technologiczne. W ciągu ostatnich pięciu lat w Polsce powstało kilkanaście nowych inicjatyw parkowych. W niektórych dużych miastach, takich jak: Poznań czy Wrocław, można już mówić o „modzie" na tworzenie parków. Inicjatywy te nazywane są parkami technologicznymi, naukowymi czy parkami biznesu. Efektem działań parków powinien być rozwój mierzony np. wzrostem zatrudnienia w regionach czy innowacyjnością przedsiębiorstw. Parki technologiczne to organizacyjnie i koncepcyjnie najbardziej rozwinięte ośrodki innowacji w Polsce. Przedsiębiorcy, przedstawiciele sektora nauki, instytucji otoczenia biznesu czy władz regionalnych oczekują od nich trwałego, intensywnego rozwoju, przekładającego się na rozwój otoczenia, w którym funkcjonują. Głównym celem pracy jest wielowymiarowa ocena przestrzennego zróżnicowania poziomu rozwoju parków technologicznych w Polsce oraz wskazanie czynników wpływających na efektywność ich funkcjonowania. Do badania przestrzennego zróżnicowania poziomu rozwoju parków technologicznych w Polsce zastosowano taksonomiczny miernik rozwoju z_i wyznaczony na podstawie informacji statystycznych zebranych w trakcie badania „Benchmarking parków technologicznych w Polsce – edycja 2012". Analizie poddano informacje statystyczne z 19 wybranych do badania parków. Przeprowadzona wielowymiarowa analiza porównawcza uczestniczących w badaniu parków technologicznych pokazała, że faza rozwoju parku nie zawsze przekłada się bezpośrednio na pozycję zajmowaną w rankingu.

Słowa kluczowe: parki technologiczne, efektywność funkcjonowania, wielowymiarowa analiza porównawcza.