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Developing technologically innovative industrial infrastructural facilities for their better efficiency: case study of technology parks in Russia

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Abstract

The article discusses an approach to forming a model for evaluating the efficiency of a typical technologically innovative industrial infrastructural facility using a nonparametric modelling. The study models and measures the efficiency of technologically innovative industrial infrastructure (case study of technology parks in Russia) by using a data envelope analysis (DEA) method. Facilities are identified as efficient or inefficient from the standpoint of the DEA methodology, and the evaluation results are compared with the results obtained in the Technopark National Ranking. The article also presents recommendations for making technologically innovative industrial infrastructural facilities more efficient in accordance with the results of the modelling; it substantiates the mechanism of ensuring the competitiveness of technologically innovative industrial infrastructural facilities of the same type, based on the technical efficiency achieved by a facility, as a result of solving an optimization problem using the shell data analysis method.

Keywords: technologically innovative industrial infrastructure, development of innovative infrastructure, technical efficiency, data envelope analysis

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Развитие Объектов Производственно-Технологической Инновационной Инфраструктуры с Целью Повышения Эффективности Их Функционирования на Примере Технологических Парков России

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Аннотация

Статья затрагивает вопросы разработки подхода к формированию модели оценки эффективности типового объекта производственно-технологической инновационной инфраструктуры посредством непараметрического моделирования. В рамках исследования смоделирована и оценена эффективность производственно-технологической инновационной инфраструктуры (на примере технологических парков России) посредством метода оболочечного анализа данных (Data Envelopment Analysis, DEA), выявлены эффективные и неэффективные объекты с точки зрения методологии DEA; результаты оценки сравнены с результатами, полученными в рамках расчета Национального рейтинга технопарков. Автором предложены методические рекомендации по развитию объектов производственно-технологической инновационной инфраструктуры с целью повышения эффективности их функционирования с учетом результатов моделирования; обоснован механизм обеспечения конкурентоспособности объектов производственно-технологической инновационной инфраструктуры одного вида, основанный на достижении объектом технической эффективности в рамках решения оптимизационной задачи посредством метода оболочечного анализа данных.

Ключевые слова: производственно-технологическая инновационная инфраструктура, развитие инновационной инфраструктуры, техническая эффективность, Data Envelopment Analysis, метод анализа оболочки данных

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1. Introduction

The gradually forming dependence of economic development on institutional conditions and the larger roles of investment and new technology in accelerating economic growth have led to an innovative economy based on the formation and development of national and regional innovation systems wherein various innovative infrastructural facilities are growing and spreading. According to Article 2 of Federal Law No. 127-FZ of 23.08.1996 "On Science and State Scientific and Technical Policy", innovation infrastructure is a set of organizations that contribute to the implementation of innovative projects, including through providing managerial, logistical, financial, information, personnel, consulting, and organizational services.

Technological industrial infrastructure provides innovative production facilities with access to an industrial environment and is a type of infrastructure for innovative activity (Khanchuk and Semke, 2016). Technological industrial infrastructure for innovative activity includes innovation and technology centres, technoparks, innovation and industrial parks, technology clusters, technology and innovation zones, centres for the collective use of technology, business incubators, engineering centres, cluster development centres, special economic zones, science cities, advanced development territories, spinouts, internal ventures, and innovative development zones (Chistyakova, 2018; Zemtsov, 2011).

Innovative infrastructural facilities, which are increasing in number and type, often have subtle differences, which aggravates the problem of their systematization and the design of programmes for their development. Moreover, in literature, in practice, and in the reports of regulatory authorities, authors often highlight the insufficient efficiency of innovative infrastructure. No complete evaluation of the efficiency of (most) types of production and technologically innovative infrastructure has been presented since most facilities have been in operation for a relatively short time and are significantly diverse; further, there are either no methods for evaluating their efficiency or these methods have significant shortcomings.

This study puts forward recommendations for the development of technologically innovative industrial infrastructural facilities (using an example of technoparks) in order to increase their efficiency. The objectives of the study were to develop a methodological approach to building a model for evaluating the efficiency of an technologically innovative industrial infrastructural facility; test the model for evaluating the efficiency of technologically innovative industrial infrastructural facilities by using the example of technology parks in Russia; identify efficient and inefficient technoparks by using the proposed methodology; verify the adequacy of the model for application; and offer methodological recommendations for the development of technologically innovative industrial infrastructural facilities in order to increase their efficiency.

2. Literature review

An innovation system imposes favourable conditions for economic growth, increasing the competitiveness of enterprises. Among other things, the interaction of players results in the innovative development of regions. Considering modern integration, efficient ways of operating innovation systems should be searched for in order to develop these systems (Solomatina and Slavnetskova, 2017).

Today, the competitiveness of a region's economy depends not only on innovation but also on organizational changes that contribute to commercial results – as well as on market techniques implementing and promoting innovation, which often justifies the formation of technologically innovative industrial infrastructure in a region (Akhmetshin et al., 2017; Rodionov et al., 2019).

Infrastructure develops as part of an evolutionary process, responding to the transformations and advances of economic systems. The model of infrastructural support in a regional economic system is in direct relationship with structural changes in economic systems, with the vector of infrastructural support being chosen when creating an environment that ensures competitiveness (Kalenskaya, 2015).

Innovation policy tools should be selected to address the specific problems and goals of an innovation system, as well as the peculiarities of administrative structures. The result of an investment policy depends on how well innovation policy tools are defined, adapted, and correlated with the goals and problems of the innovation system (Borrás and Edquist, 2013).

The researchers note that there is currently no comprehensive system for monitoring and evaluating innovation infrastructure in Russia. Moreover, there is a problem of inconsistency of the actual activities infrastructural innovation facilities are engaged in and the stated goals of creating an environment that stimulates innovation (Barinova et al., 2014).

Among the main scientific approaches to assessing the efficiency of technologically innovative industrial infrastructure, the following are worth highlighting:

- evaluating efficiency in a component analysis based on available indicators (assessing the contribution of each component to the total variance) (Latkin and Kharchenkova, 2019);

- using benchmarking technologies (Rodionov et al., 2012);

- evaluating the infrastructure by measuring innovation, with a set of evaluation criteria being selected for a specific research task. Such criteria can be economic efficiency, scalability, compatibility with infrastructure, problem-solving in specific industries, compatibility with regulatory requirements, degree of novelty, etc. (Bhattacharyya et al., 2017);

- making evaluations based on determining the attractiveness of innovative infrastructural facilities for potential residents and investors (Tkachenko and Meteleva, 2019);

- evaluating the impact of the infrastructure on levels of entrepreneurship/startup activity (Audretsch et al., 2015); and

- studying the functional dependencies of innovation production and innovation activity of the region (Acs et al., 2002).

Researchers outside Russia have noted that the development of technologically innovative industrial infrastructural facilities should be based on forming development strategies, defining the technological areas of specialization of the region, building the infrastructure (Yim, 2014), and improving communications within the facilities (Blasini, 2020).

Strategies for the development of innovative infrastructural facilities are influenced by the digital transformation of regions (Polyakov and Stepanova, 2020), comprehensive assessment of the level of economic security of the region given the innovative component (Zaytsev et al., 2021) evaluation of the structural capital of the innovative infrastructural facilities (Babkin et al., 2022).

In most scientific approaches to evaluating the efficiency of innovative infrastructure, the infrastructure is analysed as a subsystem of the regional innovation system. The basic principles of evaluation rely on the availability of information as well as an integrated approach (based on the analysis of a group of indicators/evaluation areas).

The comprehensiveness of an evaluation, which is often represented by multifactorial/multi-criteria models, is preconditioned by the variety of activities of the infrastructural facility and by the versatility of types of infrastructural facilities. Thus, the researchers propose to evaluate the efficiency of a regional innovation system (in the context of the dynamics of innovative development indicators) by considering the development indicators of the innovative infrastructure; we suggest that the efficiency of infrastructural facilities themselves be evaluated in various areas of activity, with the attractiveness of the facilities for investors being taken into account.

Given the specifics of technologically innovative industrial infrastructural facilities described above, it seems that existing approaches are not sufficiently uniform in assessing their efficiency, nor can they adequately assess shortcomings in the operation of these facilities. In this study, we are suggesting that innovative infrastructural facilities be evaluated in the context of their technical efficiency.

3. Materials and methods

In the literature, authors mainly distinguish technical from allocative efficiency. According to T.C. Koopmans (1951), a manufacturer achieves technical efficiency if it is technologically impossible to increase any output and/or to reduce any input without simultaneously reducing other outputs and/or increasing other inputs.

Technical efficiency characterizes the ability of a decision-making unit (DMU) to efficiently use available resources. It is always aimed at minimizing resource costs or maximizing outputs with the available resources.

Facilities within a technologically innovative industrial infrastructure are typically characterized by similar structures, modes of operation, and management. For our research, it seems appropriate to study the technical efficiency of innovative infrastructural facilities, since the totality of facilities of the same type is represented by a homogeneous sample that functions with limited resources and is characterized by approximately the same indicators responsible for the output.

It is proposed to measure the efficiency of technologically innovative industrial infrastructural facilities using a data envelope analysis (DEA) method. This method has proven itself in measuring the efficiency of homogeneous facilities.

DEA models have been successfully used in the scientific environment to assess the efficiency of a regional innovation system (Zemtsov and Kotsemir, 2019; Rudskaya, 2017), innovation activity as a whole (Feng et al., 2021), individual technologies in the production of equipment (Jie et al., 2012), and the efficiency of environmental innovation (Yang et al., 2022) and to measure the stimulating effect of tax incentives on the innovative activity of enterprises (He, 2021).

The DEA methodology defines the "efficiency of operation" of facilities in terms of the efficiency of converting input parameters into output ones. DEA is a nonparametric evaluation method and can be used to measure the technical efficiency of facilities. Nonparametric evaluation models are characterized by the fact that their structure is determined by actual data, while the nature and number of parameters can be flexible. The DEA method is distribution-free, that is, it can be used independently of the nature of the data distribution. In the DEA methodology, the results of the determined efficiency coefficients do not depend on the nature of the data distribution; it is suitable for calculating the desired coefficients without suggestions about distributions, but the results will correspond to those obtained through standard multidimensional analysis.

The DEA method is also chosen due to the need to measure the efficiency of facilities by comparing a significant number of indicators that can be expressed in various units of measurement. In addition, DEA allows one not to test hypotheses about the relationships of the indicators, since the parameters can be selected by the researcher based on the measurement goals and the specifics of the facilities.

Given the specifics of the objects being evaluated, a number of indicators must be included in the evaluation that are difficult to directly relate to resources or outputs. In particular, DEA can take into account variables that are external to the facility (such parameters are difficult to manage in the short term). In our case, such specific variables may be the areal characteristics of the property complex of the innovative infrastructural facility (land plots/buildings/premises) or the capacity of energy supply facilities.

The basis of the DEA method is the construction of the efficiency boundary, which is an analogue of the production function (Alimkhanova and Mitsel, 2019). The production function determines the maximum output of goods that can be produced from a given number of input parameters (resources) when using a technology. The production boundary, or the efficiency boundary, is determined in the case that several types of products are made. In this case, the facilities that show the maximum output from a fixed number of input factors will be recognized as efficient: their points in the input–output space will be at the efficiency boundary. The points at the efficiency boundary will correspond to the facilities that function inefficiently in terms of converting input parameters into output. At the same time, the degree of inefficiency of facilities will vary depending on how distant the point is from the efficiency boundary. Use of the DEA method is suitable for determining a efficiency limit that is not known in practice.

Again, the DEA methodology defines the efficiency of operating facilities in terms of the efficiency of input parameters converted into output. There are quite a few DEA models. They are usually categorized according to the following criteria (Lissitsa and Babiéceva, 2003):

- type of production function (partially linear, partially nonlinear or partially linear-logarithmic – a partially linear function is considered in research studies as a simplified normal case);

- orientation of the model (focused on resources or outputs, or a model without orientation); and

- returns to scale (constant or variable).

Researchers choose the model independently, taking into account the objectives of evaluating efficiency, the type of data analysed, the number of parameters responsible for inputs and outputs, the limitations of the model, returns to scale, etc.

To analyse the efficiency of technology parks, we choose the basic DEA model (i.e. CCR, standing for the first letters of the creators' names: Charnes, Cooper, Rhodes). This model measures the efficiency of the DMU by combining input and output parameters into scalar input and output indicators. This model corresponds to a partially linear view of the production function.

The model also assumes the presence of constant returns to scale (CRS), so the values of the output variables change proportionally in accordance with the magnitude of technical efficiency. The input parameters remain unchanged. For the purposes of our study, it is assumed that it is necessary to set permanent returns to scale, which implies a potentially infinite growth of indicators responsible for the output.

Thus, DEA efficiency is the ratio of the sum of weighted output indicators to the sum of weighted input indicators (Formula 1).

$$Efficiency = \frac{\sum \text{weighted output indicators}}{\sum \text{weighted input indicators}}. \quad (1)$$

The advantage of the DEA method is that there is no need to set weights in advance, since the weights will be determined automatically as the linear programming problem is solved to maximize the ratio of outputs to inputs.

A distinctive feature of the DEA model is that the result of the evaluation is relative rather than absolute efficiency; the result indicates the efficiency of a DMU in relation to other DMUs named in the sample to be evaluated. For the purposes of our research study, this feature is an advantage, as we want to compare the efficiency of facilities of the same type. The DEA method allows one to determine the most efficient infrastructural facilities among facilities of the same type, with a measure of inefficiency being determined for all the rest.

Given that the final set of indicators for evaluating various types of technologically innovative industrial infrastructure may differ slightly based on the specifics of facilities (for example, the input indicator for technology parks may be floor area, while the property complex of SEZs and industrial parks is represented mainly by undeveloped land plots), further building of the model for measuring the efficiency of infrastructural facilities will be proposed by the authors using an example of technology parks (technoparks) in Russia.

The next step in building the DEA model is to determine a set of input and output indicators and collect data on them. We use data from statistical reports on Russian technoparks (with due regard to the rankings by the Association of Clusters, Technoparks and SEZs of Russia) as data for the analysis. Thus, the DMU whose efficiency is evaluated is a Russian technopark. The indicators for evaluating technoparks are chosen given the specifics of their operation, the features of the property complex, and the need to evaluate the infrastructural facility together with its management company.

Technoparks as innovative infrastructural facilities are engaged in activities aimed at creating favourable conditions for residents to carry out scientific, technical, and innovative activities. A technopark houses and ensures the development of innovative companies that are its residents. The property complex of a technopark is represented by a complex of real estate objects with premises for various purposes (production, offices, administrative spaces, etc.).

The current functioning of technoparks is inseparable from the activities of their management company. In the past, we found that the management companies of technologically innovative industrial infrastructural facilities show various economic results and are often loss-making.

Table 1 presents the data on the input and output indicators selected for evaluation.

Taking into account the fact that, objectively, there is a time interval between the formation of inputs and outputs of technoparks, statistical reporting of 2017 and 2020, respectively, is used as data. Because the specifics of the functioning of technoparks, the Association of Clusters, Technoparks and SEZs of Russia justifies a time interval of 3 years, during which the outputs of a technological park are formed, the authors also chose a time lag equal to 3 years.

Table 1. Input and output parameters of the model

Inputs (2017)	Outputs (2020)
1. Number of residents **(Residents)**, units	1. Total amount of tax and customs deductions of residents, **(Deductions to Budget)**, million rubles
2. Floor area of premises, **(Premises)**, thousand square meters	2. Residents' total revenue, **(Revenue)**, million rubles
3. Total investments by residents, **(Investments)**, million rubles	3. Number of intellectual property objects registered by residents, **(R&D Outputs)**, units
4. Residents' R&D costs, **(R&D Costs)**, million rubles	4. Total exports of products from technopark residents, **(Exports)**, million rubles
5. Investments in technopark infrastructure, **(Public Funds)**, million rubles	5. Average revenue of the management company, **(Revenue of MC)**, million rubles
6. Investments in technopark infrastructure, **(Non-Public Funds)**, million rubles	

Source: compiled by the authors.

The Open Source DEA analysis package was used for the calculations.[1]

4. Results and Discussion

Table 2 presents the results of the calculations for the selected output model.

Table 2. DEA results

DMU Name	Efficiency Value	Efficiency
SIGMA. Novosibirsk Technopark	0.116749673	No
High Technology Park, KhMAO-Yugra	0.159961673	No
High Technology Park in the Republic of Mordovia	0.187029155	No
Moscow Technopolis	0.230380186	No

[1]Open Source DEA. URL: https://opensourcedea.org/

DMU Name	Efficiency Value	Efficiency
Scientific Technology Park of Novosibirsk Akademgorodok	0.243049062	No
Nanotechnology Center “Tekhnospark”	0.317588322	No
Sarov Technopark	0.332998344	No
Mosgormash Technopark	0.362845452	No
Center for Nanotechnology and Nanomaterial in the Republic of Mordovia	0.386907389	No
Lipetsk Technopark	0.513586331	No
Yakutia Technopark	0.670842295	No
West Siberian Innovation Center	0.793345412	No
High Technology Park “Zhigulevskaya Dolina”	0.997106825	No
Electropolis Industrial Technopark	1	Yes
Idea Innovation-Industrial Technopark	1	Yes
IKSEl Industrial Technopark	1	Yes
Polus Technopark	1	Yes
Mayak Technopark	1	Yes
Strogino Technopark	1	Yes
Kalibr Technopark	1	Yes
Elma Technopark	1	Yes
High Technology Park “IT Park”	1	Yes
Ankudinovka High Technology Park	1	Yes
St. Petersburg Technopark	1	Yes
Istok Technopark	1	Yes
Yablochkov Technopark	1	Yes
Kuzbass Technopark	1	Yes
Rameev High Technology Park	1	Yes
Kosmos-Neft-Gas Technopark	1	Yes
High Technology Park of Sverdlovsk Oblast	1	Yes
Idea-Yugo-Vostok Innovative Technology Park	1	Yes
Ulyanovsk Nanocenter (ULNANOTECH)	1	Yes
Podolie Technopark	1	Yes
Slava Technopark	1	Yes
Contact Technopark	1	Yes

Source: compiled by the authors

Thus, according to the results of the DEA, 22 technoparks are within the border of efficiency (i.e. they are efficient; the value of their technical efficiency = 1) in the methodology we use. Thirteen technology parks do not seem to function efficiently. Figure 1 shows the remoteness of each from the border of efficiency.

The West Siberian Innovation Center is closest to achieving technical efficiency (efficiency value 0.8). The developing technoparks with efficiency indicators of 0.5–0.8 are the Yakutia Technopark and the Lipetsk Technopark. The remaining technoparks show relatively low levels of technical efficiency (<0.5).

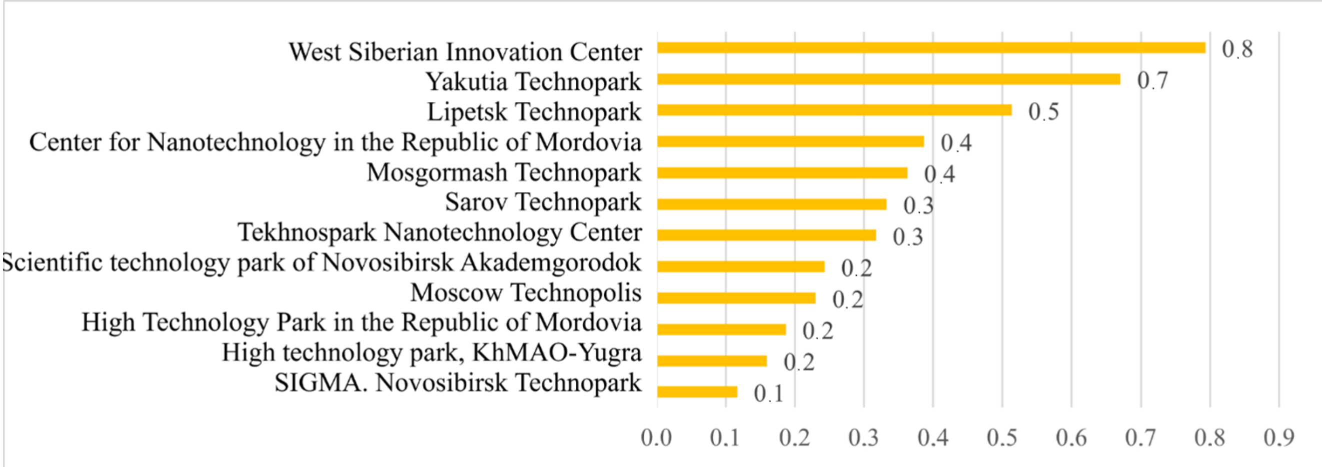

Figure 1. Remoteness of technology parks from the efficiency boundary

Table 3 presents a comparison of the efficiency evaluation results of the Russian technoparks obtained by the Association of Clusters, Technoparks and SEZs of Russia as part of the National Rankings of Technoparks for 2019-2020 and the results obtained by the DEA method.

The technoparks whose efficiency evaluation results differ significantly are highlighted in the table.

Table 3. Comparing the evaluation of the efficiency of Russian technoparks

Technopark	National Ranking of Russia Technoparks 2019–2020		DEA	
	Efficiency, %	Efficiency Level	Efficiency Value	Level (authors' interpretation)
SIGMA. Novosibirsk Technopark	98.53%	Moderately high	0.1	Weak
High Technology Park, KhMAO-Yugra	111.91%	Highest	0.2	Weak
High Technology Park in the Republic of Mordovia	100.62%	High	0.2	Weak
Moscow Technopolis	124.77%	Highest	0.2	Weak
Scientific Technology Park of Novosibirsk Akademgorodok	99.77%	Moderately high	0.2	Weak
Nanotechnology Center "Tekhnospark"	166.30%	Highest	0.3	Weak
Sarov Technopark	92.84%	Moderately high	0.3	Weak
Mosgormash Technopark	82.48%	Sufficient	0.4	Weak
Center for Nanotechnology and Nanomaterial in the Republic of Mordovia	102.61%	High	0.4	Weak
Lipetsk Technopark	78.85%	Sufficient	0.5	Developing
Yakutia Technopark	92.55%	Moderately high	0,7	Developing
West Siberian Innovation Center	90.28%	Moderately high	0,8	Developed

Technopark	National Ranking of Russia Technoparks 2019–2020		DEA	
	Efficiency, %	Efficiency Level	Efficiency Value	Level (authors' interpretation)
High Technology Park "Zhigulevskaya Dolina"	118.03%	Highest	1	Efficient
Electropolis Industrial Technopark	90.54%	Moderately high	1	Efficient
Idea Innovation-Industrial Technopark	110.73%	Highest	1	Efficient
IKSEl Industrial Technopark	57.90%	Sufficient	1	Efficient
Polus Technopark	125.60%	Highest	1	Efficient
Mayak Technopark	56.67%	Sufficient	1	Efficient
Strogino Technopark	117.20%	Highest	1	Efficient
Kalibr Technopark	111.48%	Highest	1	Efficient
Elma Technopark	135.49%	Highest	1	Efficient
High Technology Park "IT Park"	107.23%	High	1	Efficient
Ankudinovka High Technology Park	88.66%	Sufficient	1	Efficient
St. Petersburg Technopark	102.17%	High	1	Efficient
Istok Technopark	82.02%	Sufficient	1	Efficient
Yablochkov Technopark	75.12%	Sufficient	1	Efficient
Kuzbass Technopark	82.21%	Sufficient	1	Efficient
Rameev High Technology Park	96.64%	Moderately high	1	Efficient
Kosmos-Neft-Gas Technopark	73.55%	Sufficient	1	Efficient
High Technology Park of Sverdlovsk Oblast	138.66%	Highest	1	Efficient
Idea-Yugo-Vostok Innovative Technology Park	52.78%	Sufficient	1	Efficient
Ulyanovsk Nanocenter (ULNANOTECH)	104.74%	High	1	Efficient
Podolie Technopark	64.80%	Sufficient	1	Efficient
Slava Technopark	134.24%	Highest	1	Efficient
Contact Technopark	78.12%	Sufficient	1	Efficient

Source: compiled by the authors

Thus, significant differences in efficiency were revealed in relation to 18 technoparks out of 35.

The reliability of the model we propose for evaluating the efficiency of innovative infrastructural facilities should be verified. Thus, it seems reasonable to confirm the significance of the factors selected for the model and their impact on the outcome.

Researchers have identified several ways to justify the factors selected for DEA models (Nataraja and Johnson, 2011). They include: the Pastor test, which can be used to assess the significance of the input variables selected for the analysis by evaluating the model when they are excluded from it (Pastor et al., 2002); regression models; principal component analysis (factor analysis); and bootstrap analysis.

To establish the significance of the selected variables, we built multiple regression models. Since regression analysis is sensitive to the type of data distribution, we normalized the distribution of the source data (by logarithm) and checked the normality of the distribution based on the analysis of descriptive statistics using SPSS.

The results obtained from the regression models show that all the independent variables selected for the efficiency assessment model are significant for it. Therefore, the presented model is adequate and applicable for taking measures to evaluate the efficiency of technologically innovative industrial infrastructural facilities and to put forward recommendations for their more efficient operation and development.

Researchers often consider the impact of innovative infrastructure on the competitiveness of a region's economy (Rodionov and Sedov, 2013). However, thanks to the many types of innovative infrastructure now in use, there is competition for residents and investment between them. This is evident, among other things, in the blurring of fundamental differences between technologically innovative industrial infrastructural facilities, which, in fact, grant their residents access to a production environment, providing them with space and infrastructure.

The advantages of the DEA method include the ability to determine the target values of inputs and outputs for each technopark whose efficiency is determined as insufficient and to allow the former to achieve technical efficiency. Better efficiency of technologically innovative industrial infrastructural facilities and their increased competitiveness (among facilities of the same type) can be ensured with higher technical efficiency.

Projecting the point of an inefficient facility onto the efficiency boundary relies on the basic position of the DEA methodology, according to which if there are DMUs that manufacture a certain quantity of products from a limited number of factors, then an inefficient DMU can use the same number of factors of production to make the same quantity of product. Thus, the competitiveness of technologically innovative industrial infrastructural facilities can be formed if their technical efficiency is ensured among infrastructural facilities of this type (Figure 2).

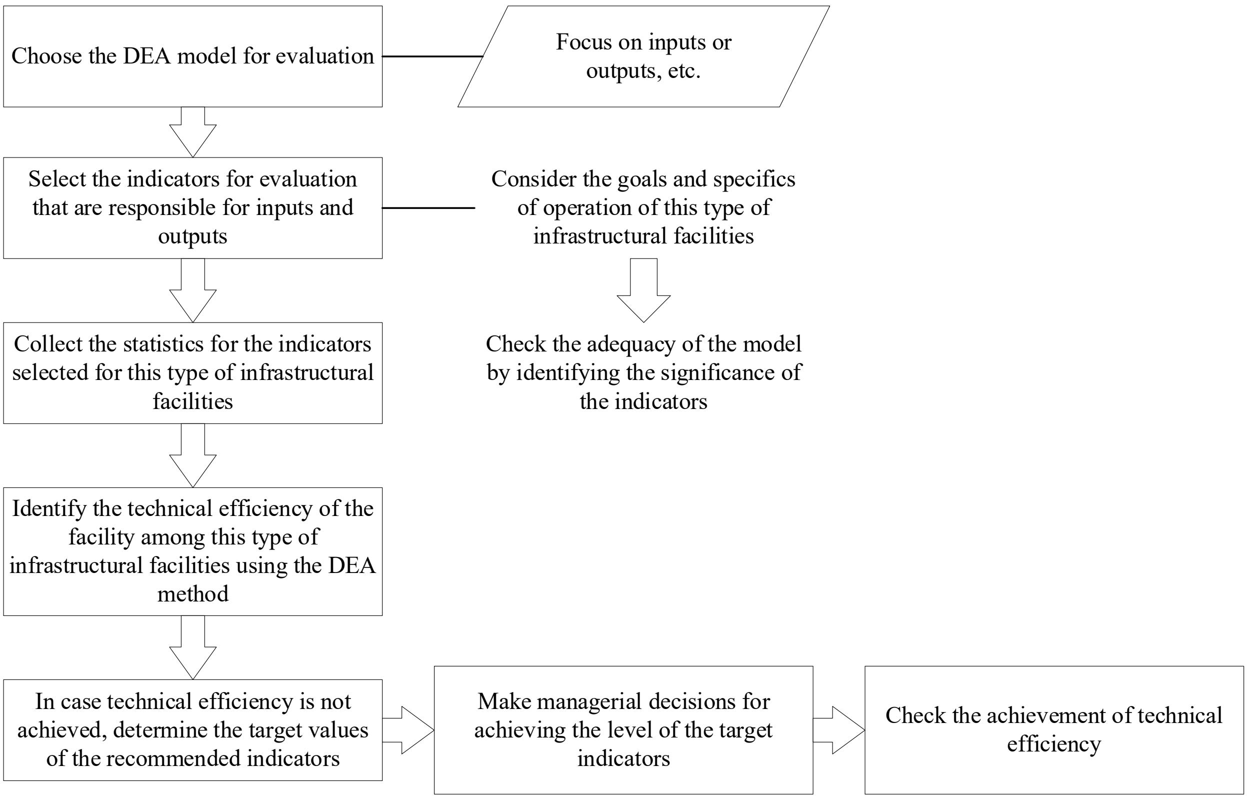

Figure 2. Forming the competitiveness of technologically innovative industrial infrastructural facilities of a single type by ensuring technical efficiency

According to the analysis, it can be stated that the efficiency of innovative infrastructural facilities can be influenced both by public authorities (which take part in funding the construction of engineering, transport, and other infrastructural facilities, grant incentives via legal regulation, etc.) and by the innovative infrastructural facility itself through the management company, which ensures the attraction of residents to the territory of the facility, management of the property complex, and the provision of various kinds of services to residents aimed at improved the results of innovation and economic activity.

Let us consider the methodological model for developing innovative infrastructural facilities by making them more efficient (Figure 3).

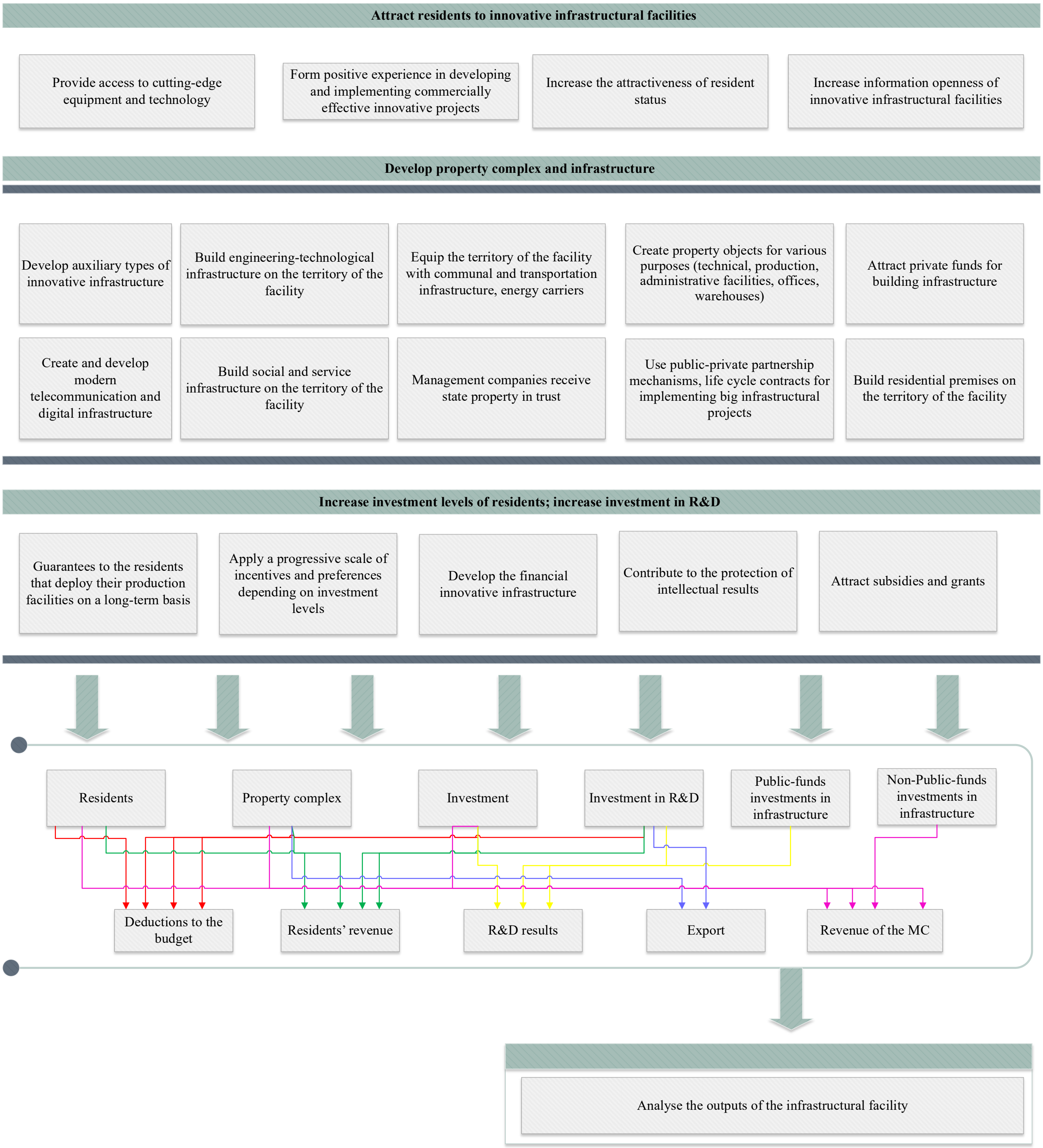

Figure 3. Methodological model for developing innovative infrastructural facilities and increasing their efficiency with key outputs

The presented model reflects the previously established links between the variables and contributes to improved efficiency of infrastructural facilities by using their key inputs.

Let us take a closer look and put forward methodological recommendations to management bodies (management companies, authorized public authorities) for developing the main areas of innovative infrastructural facilities.

Actions aimed at attracting residents to technologically innovative industrial infrastructural facilities.

1. Provide access to cutting-edge equipment and technology.

The attractiveness of an innovative infrastructural facility for residents is primarily ensured by the possibility of using the expensive innovative devices, equipment, modern telecommunications, and digital technology needed in research and development.

Thus, in order to attract residents, the management company of an innovative infrastructural facility should:

- provide residents with access to high-quality, advanced engineering and other technical infrastructure necessary for the organization of the production process (on favourable terms);

- provide access to modern telecommunications and digital infrastructure;

- ensure stability of the residents' business conditions; and

- develop different kinds of services rendered to residents and give them privileged conditions.

2. Form positive experience in the development and implementation of commercially efficient innovative projects in order to attract innovative industrial companies as residents.

3. Increase the attractiveness of resident status by providing various kinds of incentives (tax, customs, property). It is possible to consider the issue of exemption from individual payments for a period of 3 years or for the management company to provide residents with additional incentives, apart from those defined by the legislation for the type of facility.

4. Increase the information openness of innovative infrastructural facilities.

It is necessary to create and develop geoinformation systems containing comprehensive information about the design and functioning of innovative infrastructural facilities.

It also seems that attracting residents will be facilitated by holding various conferences, competitions for non-residents, advertising, congress and exhibition activities, implementing educational programmes, etc.

Actions aimed at developing the property complex and infrastructure of technologically innovative industrial infrastructure.

1. Develop different types of related innovative infrastructure in facilities in order to provide residents with a full range of services (engineering centres, spinouts, collective use centres, cluster development centres, prototyping centres, business incubators, accelerators, etc.) and develop consulting innovative infrastructure (organizations providing services on the problems of intellectual property, standardization, licensing, etc.).

2. Provide the best engineering possible on the territory of the facility, including housing and communal services, transport infrastructure, energy carriers, and real estate objects that can serve various purposes (technical, industrial, and administrative buildings, offices, warehouses).

3. Build social and service infrastructure on the territory of the facility.

4. Build residential premises on the territory of the facility.

5. Use public–private partnership mechanisms and life cycle contracts for large infrastructure projects.

6. Allot state property to management companies in trust.

7. Increase the percentage of used area in the facility and optimize maintenance costs of the property complex.

8. Increase the profitability of public funds invested in the infrastructure of facilities by attracting more investments per 1 ruble of public investments.

9. Ensure the output of products with a big share of value added by combining projects into technological chains.

10. Engage external investors in building infrastructure by increasing the attractiveness of work with residents of infrastructural facilities (lower logistics costs when goods are received from manufacturers, no customs barriers in work with residents, etc.).

Investors can be large companies interested in acquiring high-quality innovative products from the residents of facilities. In this case, investors will be sought by the management company, which can work actively in the information field: present the residents' products, search for long-term sales channels, and promote innovative products made at the facility.

Large residents can also take part in funding the building of infrastructure. According to the decision of the management company, the costs they incur can be partially reimbursed by providing them with additional incentives and services.

Actions aimed at increasing investment in industrial and technological innovative infrastructural facilities on the part of residents for acquiring and creating fixed assets, for building and reconstruction (expansion, modernization), etc.

1. Provide guarantees preserving the lease conditions of residents that deploy their production facilities on a long-term basis at the facility.

2. Apply a progressive scale of incentives and preferences depending on investment level.

3. Develop the financial innovative infrastructure, including various foundations: venture, insurance, public, investment foundations; attract leasing companies, banking and other credit organizations, business angels, and other development institutions to finance projects.

Actions aimed at increasing investments in R&D.

1. Assist in protecting the results of intellectual activity by co-financing residents' costs of maintaining patents, and help them protect R&D results outside the Russian Federation in countries chosen by the right holder (legal assistance and co-financing of costs).

2. Develop venture financing mechanisms for promising innovative projects and production facilities, including for the terms of co-financing of projects by the management company.

3. Attract subsidies (for reimbursing some R&D costs, some costs related to paying interest on loans, etc.) and grants.

In short, the methodological model is aimed at developing innovative infrastructural facilities by encouraging measures for the formation and use of the key inputs of these facilities. We refer to residents, the property complex of the facilities, investments in R&D, and investing public and non-public funds in the engineering, transport, social, and other infrastructure of such facilities.

It seems that implementation of the proposed methodological model can provide innovative infrastructural facilities with the inputs necessary to increase outputs.

5. Conclusion

This study proves that its model is appropriate for investigating the technical efficiency of innovative infrastructural facilities, as the totality of facilities of the same type is represented by a homogeneous sample that functions with certain limited inputs and is characterized by similar indicators responsible for the outputs.

According to the analysis, the efficiency of an innovative infrastructural facility is influenced both by public authorities and by the facility through its management company.

The main results of the study are as follows:

1. The study proposes and justifies the choice of a model for analysing the efficiency of technologically innovative industrial infrastructural facilities. It substantiates a set of input and output indicators for evaluating the efficiency of technology parks in Russia, given the specifics of their functioning as well as the distinctions of their property complexes.

2. The study evaluates the efficiency of technology parks in Russia by using the DEA method. It compares the efficiency of Russian technoparks as evaluated by the Association of Clusters, Technoparks and SEZ of Russia in the National Rankings of Technoparks for 2019–2020 with the results obtained by the DEA method. The reliability of the proposed model is confirmed with the significance of the selected factors and the influence of each on the output, which is supported by the regression models we built.

3. The study puts forward recommendations for improving the competitiveness of technologically innovative industrial infrastructural facilities and thus ensuring their technical efficiency among innovative infrastructural facilities of the same type.

4. Based on the analysis and the relationships identified between the variables, we propose a methodological model for developing innovative infrastructural facilities based on improving their efficiency with key inputs. We point out the main measures aimed at attracting residents to facilities, developing the property complex, and increasing the volume of investments made by residents and the volume of investments in R&D.

Our methodological model for the development of innovative infrastructural facilities is aimed at developing these facilities through measures for their formation and use of main inputs. The model reflects the relationships between the variables previously set in the study. The results of the study can be used in the practical activities of the management bodies of innovative infrastructural facilities as well as by specialized public authorities pursuing state policy in the formation and development of innovative infrastructural facilities.

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