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GENERAL PRINCIPLES FOR MODELING THE MANUFACTURING PROCESSES OF INNOVATIVE PRODUCTS IN TECHNOPARKS

The article focuses on general principles of modeling the processes of manufacturing innovative products in technoparks. The necessity of applying economic-mathematical models and methods in the activity of innovative structures is substantiated. A system of indicators and criteria for assessing the performance and effective management of technoparks is developed. Based on this system, an information model of the technopark is proposed. A mathematical model of the general management of technoparks is proposed. An econometric model of manufacturing innovative products is developed. Based on a system of composite indicators and a composite index, a technique of comparative evaluation of innovative technology parks is proposed.

Keywords: *innovative economy, technopark, science and technology park, composite indicators system, economic-mathematical model, econometric model.*

Introduction

At present, economy is developing with the introduction of new technologies and innovations. Therefore, formation and application of scientific and technological innovation policy in the development of economy in advanced countries is one of the priorities. New economic development strategies are being developed to ensure the sustainability of the implemented economic policies and reforms. In Azerbaijan, in late 2016, the Strategic Road Maps (SRM) for the National Economy and Main Sectors of the Economy were prepared [1]. A total of 12 strategic roadmaps were adopted across 11 sectors of the national economy. The objective of these road maps is to improve the competitiveness and inclusiveness of the economy and the social welfare of the population.

SRMs include the Economic Development Strategy and Action Plan for 2016-2020, a long-term view for the period until 2025 and a targeted view of post-2025 period. Target view for post-2025 period will provide broad opportunities for the realization of human potential, the expansion of access to quality education, and the basis for the transition to effective and innovation-based economy. The competitive labor force – the main driving force of economy, regulation of labor market, application of high technologies, including intelligent devices and systems lead to the transition from the efficiency-based model to the innovation-based model of the economy.

Impact of innovative technologies to the development of newly emerging economies, the process of producing automated knowledge, "Internet control", remote control technologies, artificial intelligence and robotization, and the adaptation of advanced management technologies (bio, nano, information-communications, industry, finance, etc.) will be implemented.

Within the framework of SRM for the National Economic Prospects, it is estimated to provide macroeconomic stability, improve the structure of the economy, increase employment, stimulate a balanced regional development, expand business environment and strengthen the involvement of the private sector. The main objective of SRM for the development of Telecommunication and Information Technology, which is one of the 11 sectors covered by SRMs, is to develop and improve the ICT infrastructure for the effective functioning of the public sector, improvement of socio-economic life of population, digitization of health, education and finance, and intensification of potential of ICT industry of Azerbaijan.

In the innovation-oriented and knowledge-based economy, the launch of high-quality and competitive products in international and local markets, building clusters and high-tech parks that stimulate the development of startups and innovation enterprises are of the main goals. High-tech parks and scientific and technological innovation parks are key driving forces for the transition to the digital or innovative economy. Both in abovementioned official document and in the previous Development Concept "Azerbaijan 2020: Look into the Future" [2], including "National Strategy for the Development of Information Society in the Republic of Azerbaijan for 2014-2020" [3] set out the development of new management mechanisms for strengthening of education-science-production interaction, the establishment of innovation centers, technological complexes, techno-parks, business incubators and organization of their activity. In addition, the Law of the Republic of Azerbaijan "On Science" [4] covers the formation of knowledge-based intellectual society and economy, creation and development of scientific innovation subjects, science, education and entrepreneurship centers, funds, and building and developing innovation data banks.

Sustainable development and enhancement of competitiveness of innovate economy, expansion of innovation and high technology spheres based on contemporary scientific and technological achievements, and conducting research and development of modern technologies are supported by the Azerbaijani government. In this regard, the Sumgait Chemical Industrial Park, the High-Tech Park at the Ministry of Transport, Communication and High Technologies (HTP MTCHT), the Eco-Industrial Park in Balakhani, the Science and Technology Park at ANAS High Technology Park, agrarian and other high technology parks in the regions were established. All of this necessitates developing a common framework for the modeling of innovative production processes in technoparks, which are the key elements of the innovation structure in the information society.

Methodological basis for application of economic-mathematical models and methods for functioning of technoparks

Increasing the efficiency and innovation of technoparks includes raising the level of management, using innovation technologies, modern software and ICT; considering the development prospects of innovative products; applying intellectual systems; modernizing performance of technology park; developing and managing databases; building mobile management structure; increasing the role of human factor in the promotion of effectiveness, taking into account customer-oriented innovation services; using technological possibilities such as stimulation and forecasting, and so on.

Mathematical modeling tools are widely used to increase the efficiency of technology parks. Various Economic and Mathematical Models and Methods (EMMMs) are applied in technology parks. The development phases of economic-mathematical model in technopark are illustrated in Figure 1 [5].

Modeling process of technoparks comprises the following elements: research object; subject (researcher); and the tools expressing the relations between model, scope, and perceived object. Physical, graphic, and mathematical types of models are distinguished. Mathematical model of technoparks is a mathematical description of the processes going on within the research object. This description defines equations, tables, restriction conditions, graphs, and so on. Mathematical model variables consist of measurable and manageable variables and random variables.

The use of mathematical models and techniques in the operation of technoparks enables to get the mathematical description of the most important relationships of economic variables and objects. Economic-mathematical modeling is the mathematical writing (mathematical models) of economic processes or objects. The process of economic and mathematical modeling is based on a certain economic task. A mathematical model is built for this task. At the next stage, either the algorithm is developed or previously developed algorithm is used to analyze this model. If the model and algorithm are not sufficiently complex, an analytical study of the model may also be possible. Economic-mathematical models are theoretical-analytical and applied for their destination.

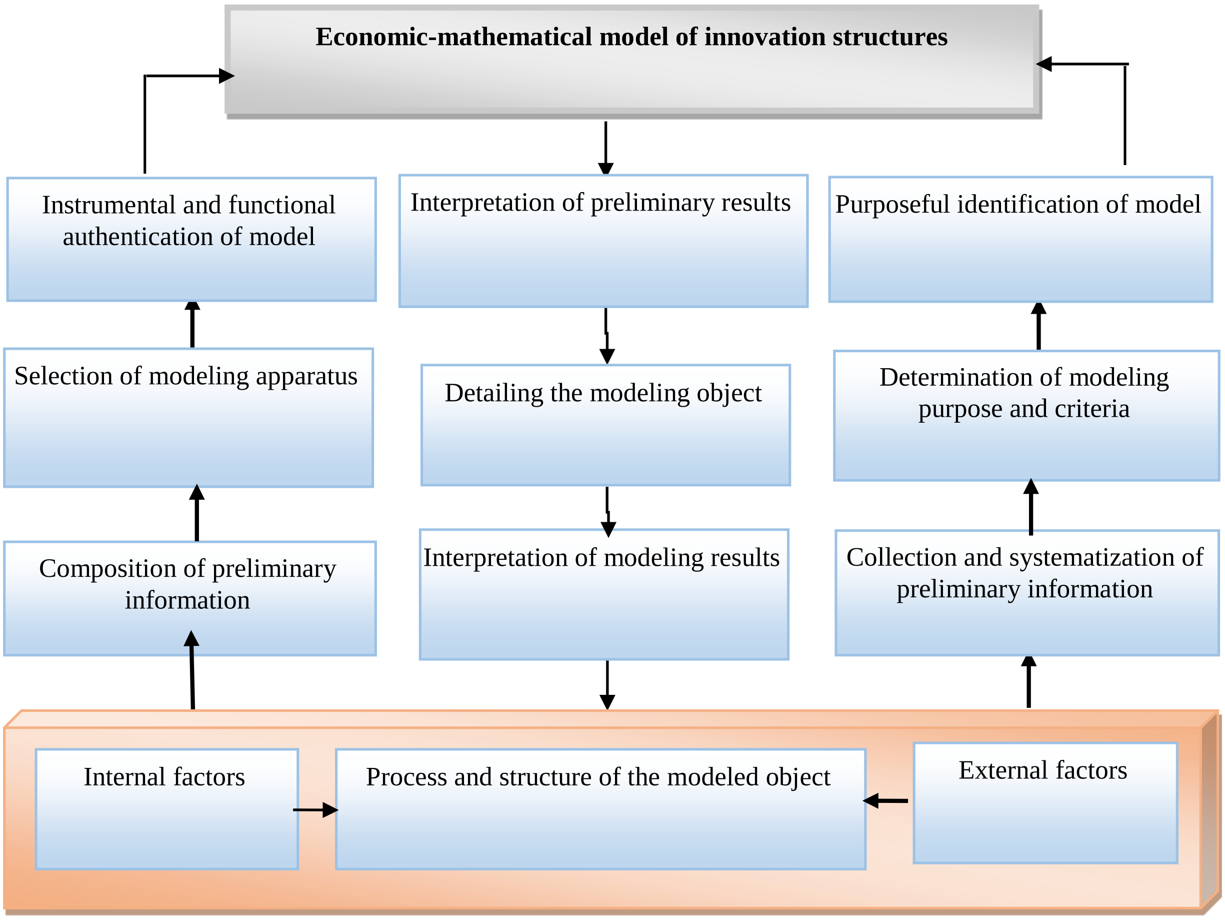

Figure 1. Development phases of economic-mathematical model of technopark

In technoparks, EMMs are classified into structural, non-structural and hybrid models [6-8].

Structural models are representing the connection between the structure of economy and its elements. In general, they consist of a system of non-linear equations. They provide better performance in medium and long-term forecasting. Low accuracy of forecasting in these models is considered to be one of its weaknesses.

Non-structural models have high accuracy in a short term; though often do not fit medium and long-term forecasting. It is difficult to take into account the change in macroeconomic indicators. Hybrid models in technology parks are built for joint use of structural and non-structural approaches. The spectrum of hybrid models is very broad. Hybrid models are a combination of two sub-models. The structural part is often medium and long-term, while non-structural part is used for short-term forecasting. EMM in technology parks can be classified by [9]:

1) aggregation degree of objects;
2) time factor;
3) application fields;
4) forms of mathematical dependencies;
5) types of mathematical tools (apparatus) and so forth.

According to application fields and types, EMM may refer to linear and non-linear programming, optimization methods, correlation-regression equations, probability theory, mathematical statistics, game theory, network and graph theory, input-output model, econometric model, mass service theory, imitation model, etc. In addition, for the presentation method, EMM can be classified as information models, verbal models, symbolic models, and computing models.

One of the main types of EMM in technoparks is econometric models. Correlation and regression analysis of economic indicators is the basis of econometric science. Econometrics studies the quantity and quality of economic events and processes through mathematical and statistical methods and models. As the major trends of modern economic analysis, econometrics studies the empirical methods of determining the legitimacy in economic processes. Econometrics is a science that is common for economics, mathematics, and statistics, and has distinctive features. The interaction of these sciences is described as in Figure 2.

Econometric models are used in the micro and macro levels of the economy. Their structure and verification is directly related to correlation and regression analysis of mathematical statistics.

The essence of correlation is to study interdependence and relations. The main task of correlation analysis is to identify the relationship between random variables and to assess the correlation degree. Regression analysis is the most commonly used method of econometrics. Its main task is to determine the form of dependency among variables. Regression analysis is a method of statistical analysis of the impact of one or more independent variables on other dependent variable.

Econometric modeling comprises the following basic steps [5, 6]:

1) phase of problem statement,
2) a prior phase,
3) modeling and parameterization phase,
4) information phase,
5) model identification phase,
6) model verification phase.

Econometric models build for analysis and forecasting are referred to regression models of single-equation, models of simultaneously given equations system, time series models, and so on.

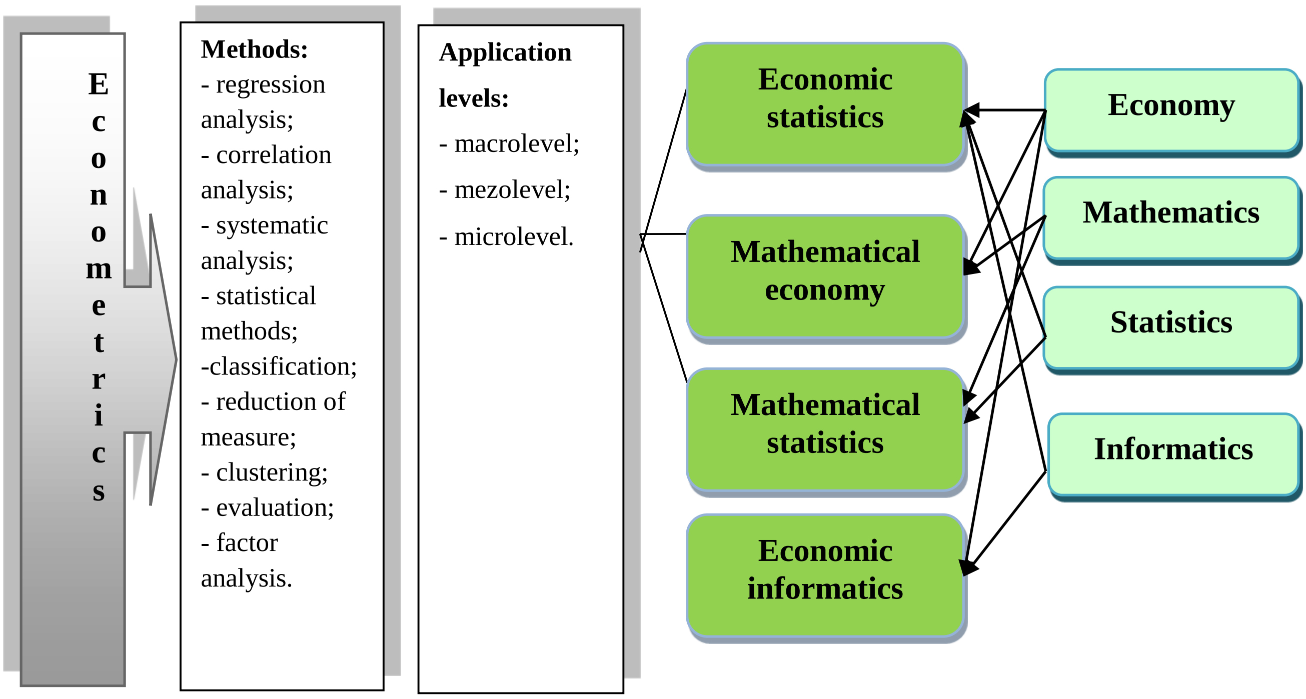

Figure 2. Interaction of econometrics with basic sciences

Many application software packages are used for building econometric models in technology parks. They include Eviews, Spss, Stata, Statistica, Limdep, Shazam, Micro Tsp, Minitab, Sas, Matlab, Maple, Excel, Prognosis, and Gretl. Econometric Views (EViews) has some advantages as macroeconomic forecasting, scientific data analysis, modeling of economic processes, analysis of financial issues, forecasting of market situation, etc.

Review of multifactor regression models for the manufacturing of innovative products or services in technoparks

The process of building a complex model for managing the effective functioning of technoparks necessitates the use of multivariate optimization. Relevant methods are used to address structured issues, where the functional dependencies of the parameters of technopark are known. In the cases when the information about functional dependence is insufficient, the modeling is defined as complete or partially unambiguous modeling. The uncertainty in such poorly or complexly structured issues can be eliminated in two ways. The first way is related to the individual assessment of the decision maker and the use of the principle of preference in the assessment of possible solutions. The second way is identified by the qualitative and quantitative description of the object or process. It is characterized by the use of mathematical methods for the data transformation. Therefore, it is recommended to fill in the unspecified data using regression analysis methods and to reduce the decision-making problem to the vector problem of mathematical programming. Various methods and algorithms based on the criteria normalization are available for solving these issues.

These methods solve the issue with the equal criteria or with the priority of one criterion over others. Regression analysis, methods for solving the above mentioned problems and the technique for optimal assessment of experimental data shape a new information technology model of decision-making in the uncertainty. In [16], it is shown that in general, performance of any technopark depends on the parameters within certain boundaries. This performance can be described with a number of sets of criteria that are functionally dependent on the parameters shown. A mathematical model that solves the problem of selecting the optimal decision for technopark is given here. The general mathematical description of this problem is illustrated in [10, 11, 16]. Methods based on criteria normalization can be used for the solution of this issue. They provide the problem solution through both equal criteria and the given priority of the criterion.

Initial indicators have been first set out for building an econometric model for the analysis of innovate and scientific product manufacturing in the work of technoparks.

Y - is a dependent variable and characterizes the volume of total innovative products in technology park. X_i - are independent variables and characterize the following indicators in technoparks: X_1 - volume of investments, X_2 - main production and infrastructure funds, X_3 - salaries of employees, X_4 - volume of turnover in technoparks, X_5 - costs of innovation projects, X_6 - costs of scientific projects, X_7 - costs of innovation-oriented applied work, X_8 - innovation level of management, organizational structure and scope of activity, X_9 - efficiency of using basic and high tech equipment, X_{10} - innovative business environment, X_{11} – startup stimulating tools.

Taking into account all of these, an econometric model of technopark is proposed as follows and, consequently, its corresponding parameters are determined by computer software packages based on the least squares method [6, 16]:

$$y = a_0 + \sum_{i=1}^{11} a_i X_i + E$$

To assess the performance of technopark, the hierarchy of both indicators and goals-criteria are established. Generalized indicators and goals-criteria are placed at the top level in accordance with the basic focus areas, whereas relatively specified indicators and goals are placed at low levels [12, 13]. An information model of technopark is built using the interaction mechanisms of these indicators and criteria.

The ratio of the indicators to each other is analyzed in accordance with the relevant formulas and evaluation tables are drawn up. These objectives are ranked according to the power of impact on the main result to assess the effectiveness of a technoparks performance. In accordance with the algorithm shown in the previous section, the relevant importance ratios are determined based on expert assessments.

Information about the indicators group related to both top and low levels is used to analyze the technopark's performance and make comparative assessments. The ratio of the indicators to each other is analyzed and compiled in the evaluation tables. To evaluate the effectiveness of the technopark's performance, these goals are ranked according to the power of impact on the main result. Relevant ratios are assigned to them. This process is implemented by the expert group in the following stages [16]:

In the first stage, the rank of each criterion is determined. At the second stage, the relative importance of each criterion is determined. If necessary, at the third stage, any number of sets of sub-criteria is defined corresponding to criterion. Then, as at the first and second stages, the group of experts defines the respective ranks and relative importance ratios for each sub-criteria. In other words, the expert group evaluate each sub-criteria, and the total of these scores are calculated. Once the corresponding ranks are assigned, the numbers that are inversely correlated against the total sum of scores are calculated, and the obtained results are normalized.

At the fourth stage, the degree of realization or the effectiveness indicator of each criterion and its relevant sub-criteria is determined. Then, the criteria for integral efficiency of technopark's performance can be defined as a function of these criteria.

In particular cases, the result may be obtained by determining the functions as linear functions, which are defined as a multiplication of the corresponding criterion values and their relative importance ratios [16].

Analysis of expert assessments on comparative assessment of technoparks performance. The system of indexes, sub-indexes and indicators system on the comparative assessment of technoparks' performance is divided into different hierarchical levels [14]. Level 1 includes technopark composite index, Level 2 - 10 indices, Level 3 - 106 sub-indices, and Level 4 - 320 macro/micro indicators. Level 4 includes official statistics and other external and internal indicators. Level 4 indicators play a key role in determination of sub-indices on Levels 3 and 2 by experts. In this case, absolute indicators and their specific values are used. The approach, here, differs and may be implemented individually according to each specific situation. Accordingly, weight coefficients are explored, which are provided by the experts to the indices selected to form the proposed composite index for the comparative assessment of the technoparks performance [14, 15]. Then, the final score for each index is calculated. As a result of an expert assessment, the impact (weight) coefficients of the following selected indexes are evaluated.

1. Significance and scaling index;
2. Infrastructure and information support index;
3. Affordable business environment index;
4. Investment financial stocks and material and technical resources index;
5. Innovative potential, activity and environment index;
6. Human resources and qualified personnel training index;
7. Research, experimental developments and innovative projects index;
8. Innovation products and services index;
9. Effective management and creative results index;
10. Social and ecological development index.

Practical realization of expert evaluations of the offered models for management of innovative product manufacturing in technoparks. To study the performance of technoparks, their possible socio-economic development indicators are analyzed. To evaluate the performance of technoparks and detect the relationship between some indicators, correlation-regression analysis methods are used. The volume of manufacture of overall innovative products or services is taken as an explored indicator. An econometric model technoparks' performance is built based on its initial indicators. To reveal important factors, a bivariate correlation matrix, which determines technoparks' performance, is built [17].

Thus, based on the final table of regression analysis and the additional features of the factors impact assessment, the volume of the total innovation product in technopark can be predicted.

Conclusion

Technoparks are considered to be a driving force of economic development during the transition to information society and knowledge-based economy. In modern time, the use of mathematical methods and techniques in the innovative production processes in technoparks are topical issues in terms of acceleration of building knowledge-based economy and intellectual society and ensuring sustainable economic development. An expert method for determining weighted coefficients was developed according to the indices selected in the formulation of the proposed composite index for the comparative evaluation of technoparks' performance. As a result of the expert assessment, the impact (weighted) factors of selected indices were determined. The final expert score for each index was calculated.

An econometric model based on the initial indicators of the technology parks was built. Initial indicators on multi-factor regression model for econometric analysis of innovative and science-intensive product manufacturing in technology parks were proposed. Estimated calculations show that developed regression models can be used in practice. The statistical significance of all models was confirmed by the Fischer criterion. Styudent t analysis showed that the factors included in the regression models were statistically significant and had a significant impact on the overall product volume. Using the multiple regression analysis, the volume of total innovative product in technopark was calculated.

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