

DEVELOPMENT OF THE SECTOR OF HIGH TECHNOLOGY: IDENTIFYING ASPECTS OF PROCESS DETERMINATION

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Abstract. The author of the presented paper aims at discovering the patterns of the development of the sector of high technology in the context of social, economic and technological progress; to develop and prove the suggested methodology necessary to assess the process of the development of the sector of high technology according to the processes of internationalisation. Main theories and systematic analysis of national and regional programs dedicated for the development of the sector of high technology are analysed here. Theoretical assumption to use human development index for the measurement of country's readiness to develop the sector of high technology on example of EU is also discussed and examined here, too. The author's suggestion to investigate the processes of the development of the sector of high technology on industrial, business, national and international level is raised. As a result, the author determines main aspects defining the development of the sector of high technology on every level of the process. Empirical verification of the suggestion, based on cluster analysis, correlation analysis and dispersion calculations, justifies the application of the methodology on example of the sector of high technology of the EU countries.

Keywords: sector of high technology, high technology development, patent, human development index, innovative process, internationalisation.

Jel classification: F14, F18, F21, F23, F47, O1, O14, O15

1. Introduction

The relevance of the research on the development of the sector of high technology is based on theoretical and practical realia. The realia of the theoretical origins are associated to the abundance of the research papers dedicated to the search of new factors of economic growth, demonstrating the predominance of high-technology economy in the future economies. The realia of the practical character are based on the changes over the recent years in financial markets, and the new challenges determined by those changes in the global community, as well as the latest trends that reflect upon the decline of the economic impact of the OECD countries, supporting the values of democracy and market liberalisation, and the increasing competitiveness of the BRIC countries that represent the closed type of economic policies.

Thus, the theoretical and practical realia highlighted importance of the development and implementation of the alternative methods of the economic development, while the applied theoretical models could meet new challenges and requirements determined by:

- development of a common cultural, social, economic and information environment on the global scale;
- priorities for creation of the knowledge society and the knowledge economy;
- possibilities to respond to the needs, on one hand, related to the development of the high technologies in the state, on the other hand, required for the development of both – business and academic sector;
- international competition and the increasing pace of innovation processes.

The object of the scientific research includes the developing processes of the sector of high technology.

The goal of the paper is to analyze and evaluate the trends and prospects for the development of the sector of high technology in various countries and regions of the world; to develop a theoretical model based upon the application of the methodology of complex evaluation of the process of development of the sector of high technology, designated for economic solutions on the national or regional scale, adapted to the conditions of the European Union.

In summary, the relevance of the paper can be grounded as a need to create a new type of economy in Lithuania and in any other countries of EU, whose greater part should be characterized by technology oriented export and increasingly growing number of working places designed for exceptionally high qualification and well-educated professionals. This is a key precondition for the development of modern society, to ensure the material well-being, social security and long-term development prospects.

2. Theoretical aspects of the high technology development

The first concepts of the sector of high technology and the high technology development are discovered in the papers of Hymer (1960), Vernon (1966), Dunning (1977), Johanson and Vahne (1977). The above mentioned authors describe the sector of high technology as a specific type of industry, which depends on the processes of exchange in the international economy. Thus, U.S. Office of Technology Assessment in its edition *Technology, Innovation, and Regional Economic Development* (1984) provides one of the first definitions of the sector of high technology and defines it as industries, involved in the process of new product design, development and launch into the market applying scientific and technical knowledge.

The Organization of Economic Development and Cooperation (OECD) recognize those high technology industry areas, where research and development are significant in promoting sales of final outputs such as: air industry, the pharmaceutical industry, computers and office equipment, communication tools, and the scientific (medical, precision measurement, optical) measures (Lioshky 2009).

According to the National Science Foundation of the United States of America, there is no single preferred method for identifying high technology industries (National Science Foundation 2009). Therefore, the National Science Foundation indicates two main criteria necessary for development of high technology sector:

- skilled labor force which is understood as occupational employment, and the percentage of particular occupations within industries change over time, reflecting upon the changes in employment growth, as well as the business structure;
- research intensity, where data is derived from studies of publicly traded companies is known as R&D dollars as a percent of total sales.

Capon and Glazer (1987) argue that *technology* should be understood as a certain knowledge

enabling new forms of industry and including the product and process *know-how* (practical experience), where the product technology is explained through the adaptation of new ideas in the final output, and the process technology reflects the implementation of new ideas in the process of manufacturing. Lundvall and Johnson (1994) propose to include in the definition of the technology not only the specific knowledge – *know-how*, *know-who*, but also the specific skills required for the creation of new technologies – *know-what*, *know-why*.

Therefore, Gardner, Johnson, Lee, Wilkinson (2000) see the result of the sector of high technology as modern and innovative *production*, based on the research, scientific and technological application. On the other hand, according to Bozkaya, Romain, Potterie (2003) the sector of high technology is focused on the use of modern technologies in the process of manufacturing and service, where the functional performance requires the participation of highly-skilled labour force.

Scientific literature defines the development as a process, which is oriented into creating of new opportunities improving economic performance (Hoff *et al.* 2000; Stern 2002), and includes the structural changes in the economic system (Šimelevič *et al.* 2002). The scientists have recently argued that the concept of the development involves both, qualitative and quantitative, changes (Grabowski *et al.* 2007), characterised by the indicators of economic growth (Bresnakan, Trajtenberg 1995).

Summing up, the high technology development may be understood as a continuous process important for economic growth and social stability. The analysis of theoretical aspects highlights the high technology development as a key factor to combine the economy priorities and the interests of social classes worldwide.

2.1. Impact of the processes of internationalisation on the development of the sector of high technology

Examining the reflection of internationalisation processes in modern economic theories and the possibilities of its application developing the sector of high technology, it is determine that the internationalisation processes in the scientific literature are recognised in two main ways – in the broad sense, as a set of factors promoting international cooperation (Teichler 2004; McIntyre 2005; Marginson, van der Wende 2007), and in the narrow sense as a number of one state borders crossing relations, relevant in the context of economic and social life (Rudzki 1995; Passera 2004; LiPuma 2006; Mohrman, Ma, Baker 2008). Summing

up the definitions of internationalisation processes it can be concluded that the processes of internationalisation can be seen as a strategy or policy, focused on promotion of mobility, development and innovation, moving beyond the borders of one country (Ackers 2008), involving aspects of international trade and foreign direct investment (Mayer, Ottaviano 2008).

Analysis of theoretical models (Boyer, Arnalbe, Barre 1999; Wessner 1999; Etzkowitz, Gulbrandsen, Levitt 2000; Viale, Campodall'Orto 2000; Casas, Gortari, Santos 2000; Feinson 2003; Marton 2006; Steen, Liesch 2007; Longhi, Nijkamp 2007), dedicated for analysis of national markets developing high technology sector in the context of internationalisation, has underlined that the essential assumption ensuring a successful development of the sector of high technology is related to the cooperation of industrial, business and academic areas on national level, and possible demerits may be compensated by stimulating enhancement of internationalisation processes, supporting mobility of two factors of production – labour force and capital – on international level.

Analysis of scientific literature (Gray 1986; Trabold-Nuebler 1991; Lerner 1994; Charnes, Rousseau, Semple 1997; Hatzichronoglou 1997; Chambers, Chung, Fare 1998; Demeuse, Crahay, Monseur 2002; Carpenter, Petersen 2002; Bottazzi, Da Rin 2002; Bouis 2003; Fagerberg 2003; Filho, Salomon, Marins 2007; Contractor, Mudambi 2008; Martinkus, Žilinskas 2008), dedicated to the evaluation of attractiveness of national markets concludes that offered models of evaluation of internationalisation processes developing high technology sector are based on sectors competitiveness and efficiency, where competitiveness express opportunities for high technology sector development on international level, and efficiency investigates impact on national economy. It is important to note that the proposed models of evaluation are narrow in nature and deals with isolate aspects of internationalisation processes or sector of high technology, thereby it must be concluded that the literature models, ideas, theoretical insights, enabling a comprehensive assessment of the impact if the processes of internationalisation on high technology sector development.

Summing up, the majority of scientists evaluates the process of development of sector of high technology on different levels of the processes of internationalisation:

- national level, revealing inner opportunities based on the analysis of macroeconomic factors (Tvaronavičienė, Grybaitė, Korsakienė 2007; Tva-

ronavičius, Tvaronavičienė 2008; Lapinskiene, Tvaronavičienė 2009);

- regional level, showing synergy effect of cooperation between several countries developing the sector of high technology (Melnikas 2002);

- international level, analysing the common tendencies of the investigated process worldwide (Snitka 2002).

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2.2. Analysis of national and regional programs developing the sector of high technology

Systematic analysis of national and regional programs of main world regions developing the sector of high technology has revealed, that OECD countries are increasingly directed to understanding the dynamics of the knowledge-based economy and its relationship to traditional economics, as reflected in “*new growth theory*”, representing synthesis of the concepts of “*information society*”, “*learning economy*” and “*national innovation systems*” and leading to a new focus on the role of technology, information and learning in economic performance (OECD 1999). Therefore, the process of the development of the sector of high technology consists on variety of economic, social and technical dimension, such as financial resources, expenditure on research and development, investment, „*human capital*“, technological change.

Thus, the seventh framework programme for research and development (FP7) of European Union has underline the main priorities developing the sector of high technology: cooperation (*collaborative research*), ideas (*European Research Council*), people (*human potential, Marie Curie actions*) and capacities (*research capacity*) (Eurostat 2010). European Commission's strategy based on Lisbon goals (European Commission 2011) aims at creating the European Research Area, a unified area, in which researchers can move and interact seamlessly by ensuring the free circulation of researchers, knowledge and technology across Europe (Eurostat 2010).

Currently the scientists have concerns regarding the significant changes on international landscape and increasing competitiveness of emerging markets (OECD 2010 a; OECD 2010 b; OECD 2010 c; Geisler 2002; Gerasymchuk, Sakalosh 2007; Dhaoui 2008; Gao 2009; Guerin, Manzocchi 2009; Li 2010; Bendikov, Frolov 2007).

Thereby, Russia's “2020” development strategy requires to reach the goals of the innovation scenario, which would bring the country up to the

level of developed industrial economies. The scientists (Dmitriev 2008) provides three suggestions necessary for implementation of the innovation scenario:

- the state investment in infrastructure in order to change the „resource course“ and attract investment into real economic sectors;
- the alleviation of the demographic problem to improve the contribution of human resources to support economic growth and reduce fiskal burden;
- the reforms of weak market institutions implementing effective solutions to the first two challenges.

The analysis of national and regional programs has revealed that in the process of development the sector of high technology all main world regions are focused on the balance among economic growth, social stability and good governance, ensuring both, technical and social progress.

Summing up, in order to prepare and implement the effective theoretical solutions, dedicated for high technology sector development in the context of internationalisation, it is necessary to take into consideration the following circumstances:

- The variety of different countries and regions in the modern world may be distinguished regarding the specifics in social, economic, political and cultural development and in the sense of uniqueness of the development of the sector of high technology and the relevancy of this diversity requires adequate theoretical solutions.
- The concept of the development of the sector of high technology is multi-faceted: currently there is no uniform approach in the world to the concept and the description of the concepts that characterise it, nor the well-established attitudes of the development of the sector of high technology identification and classification system, either definitively established terminology describing the high technology sector development expressions and the main problems; this circumstances reflects the need to develop and adapt new concepts, criteria and evaluation methods meeting modern relevance; moreover, due to lack of a uniform definition of the high technology sector the importance of this sector is treated differently in different documents of international organisations, regional and national development programs.
- Due to activity of multinational companies and development of their networks in the sector of high technology dominate economic entities without strict national attributes; this fact implies an additional difficulty in accounting, collecting the information and conducting economic surveys at the national or regional perspective and reflects the need to seek non-traditional ways in analysis and

evaluation methods that are oriented on reconciliation of both the supranational and national sections.

3. Research methodology

The theoretical analysis of the process of the development of the sector of high technology stresses that the cooperation between highly qualified labour force, academic area, business sector and institutions is the key to the successful innovative process in economy. In other words, the development of the sector of high technology is the result of complex set of relationships among actors in the system, which includes enterprises, universities and government.

An understanding of each element of the system can help identify leverage points for enhancing innovative performance and overall high technology development. It can assist the strongest and the weakest links within the process of the development of the sector of high technology. The methodology which seeks to evaluate the readiness of each element of the system dedicated for the enhancement of the development of the sector of high technology is the most valuable in the context of internationalisation involving the increasing mobility of highly skilled labour force and capital and, as the result, assimilation of conditions in order to develop the sector of high technology worldwide.

3.1. The measurement and assessment

The measurement and assessment of the development of the sector of high technology consist of two parts.

The first part is dedicated to the analysis of the impact of the combination of gross domestic product and human development index on country's readiness to develop the sector of high technology. The cluster analysis here is in use.

The second part is dedicated to reveal the main aspects defining the process of the development of the sector of high technology. The process of the development of the sector of high technology splits into four stages: 1) *industrial level*, characterised by the number of patents per mln. Inhabitants; 2) *business level*, characterised by the number of innovative enterprises in the country; 3) *national level*, characterised by the turnover of the sector of high technology; and 4) *international level*, focusing on the share of the sector of high technology in the world export. The methodology of variation of economic phenomena based of correlation analysis and dispersion calculation is in use here.

It is assumed, that attempts to link these aspects defining the process of the development of the sector of high technology will show that improved innovative capacity of enterprises in terms of products, patents and productivity contribute to the high performance of the country on international level in terms of world export of the sector of high technology.

3.2. Detailisation of methodology of empirical research

Cluster analysis focuses on the analysis of particular types of indicators (Pryor 2006), which can be grouped according to their impact on country's readiness to develop the sector of high technology and other assumptions in this process.

The most common mathematical basis for the classification of the objects is a calculation using the function depending on the pair of operational taxonomic units (Schloss, Handelsman 2006):

$$d_r(\tilde{j}, \tilde{k}) = \left(\frac{1}{n} \sum_{i=1}^n |X_{ij} - X_{ik}|^r \right)^{1/r} \quad (1)$$

where:

- $d_r(\tilde{j}, \tilde{k})$ – coefficient of space for operational taxonomic units j and k ,
- n – number of attributes,
- X_{ij} – attribute i for operational taxonomic unit j ,
- X_{ik} – attribute i for operational taxonomic unit k ,
- r – integer number.

In order to establish the strength of relationship between the indicators characterising the development of the sector of high technology and the classification of the results of the cluster there is necessary to determine the *determination coefficient* and the *empirical correlation ratio*.

Determination coefficient represents the relation of the intergroup and general dispersion (Bartosevičienė, Stukaitė 2009). In order to find the intergroup dispersion the set of averages of the analysed aspects in every cluster should be calculated:

$$\bar{x} = \frac{\sum \bar{x}_j f_j}{\sum f_j}, \quad (2)$$

- where,
- \bar{x} – average of the analysed aspect of all clusters,
- $\sum \bar{x}_j f_j$ – total of averages of the analysed aspects of the countries f_j of the clusters j ,

$\sum f_j$ – total of the countries f_j of all clusters.

Intergroup dispersion is calculated according to the following formula:

$$\delta^2 = \frac{\sum (\bar{x}_j - \bar{x})^2 f_j}{\sum f_j}, \quad (3)$$

where:

- δ^2 – intergroup dispersion,
- \bar{x} – average of the analysed aspect,
- \bar{x}_j – average of the analysed aspect in the cluster j ,
- f_j – number of the countries of the cluster j .
- $\sum f_j$ – total of the countries of all clusters.

The average intergroup dispersion is calculated as the average of all intergroup dispersions:

$$\overline{\sigma^2} = \frac{\sum \sigma_j^2 \times f_j}{\sum f_j}, \quad (4)$$

where,

- $\overline{\sigma^2}$ – average intergroup dispersion,
- σ_j^2 – average intergroup dispersion of cluster j ,
- f_j – number of the countries of the cluster j .

The general dispersion is calculated regarding the composition rule:

$$\sigma^2 = \overline{\sigma^2} + \delta^2, \quad (5)$$

where:

- σ^2 – general dispersion,
- $\overline{\sigma^2}$ – average intergroup dispersion,
- δ^2 – intergroup dispersion.

Determination coefficient represents relation of intergroup dispersion and general dispersion:

$$\eta^2 = \frac{\delta^2}{\sigma^2}. \quad (6)$$

Empirical correlation ratio represents the square root of determination coefficient:

$$\eta = \sqrt{\eta^2}. \quad (7)$$

3.3. Future research

Future research may be focused on evaluation of the efficiency of the development of the sector of high technology regarding established four levels of the process in the context of internationalisation. It may be proposed to evaluate the efficiency of the development of the sector of high technology with the consideration to analyse the impact of

the internationalisation processes in a way of stimulated mobility of labour force and capital and to take into account the impact of the efficiency increasing sources, which might be selected by performed multi-criteria methods, such as SAW or COPRAS (Podvezko 2011).

4. Results of empirical research

Empirical research aims at discovering new patterns in gathering information necessary to see the contours of global challenges more clearly and to identify the main directions for responding to them in following areas:

- responding to the global economic crisis;
- targeting new growth areas and evolving markets;
- competing in new conditions of world economy;
- creating universal area for global research;
- investing and developing knowledge-based economy.

Performed comparative analysis of macroeconomic factors affecting the development of high technology sector in the Baltic states has confirmed the idea of four levels of assessment: national (number of patents), business (number of innovative enterprises), industrial (turnover of production of high technology sector), international (share of export of the sector of high technology in the country's export) (Ambrusevič 2010).

Performed comparative analysis of sources, dedicated to the high technology sector development has justified the inclusion of economic freedom index and human development index into suggested methodology of evaluation of the development of the sector of high technology. Conducted correlation analysis of 169 world countries between gross domestic product per capita and human development index has shown, that chosen criteria are statistically correct and may be implemented in further analysis (correlation coefficient 0.6519).

Comparative analysis of macroeconomic factors affecting the development of high technology sector in the large-scale economies has confirmed the idea of four levels of assessment: national (number of patents), business (number of innovative enterprises), industrial (turnover of production of high technology sector), international (share of

export of the sector of high technology in the country's export).

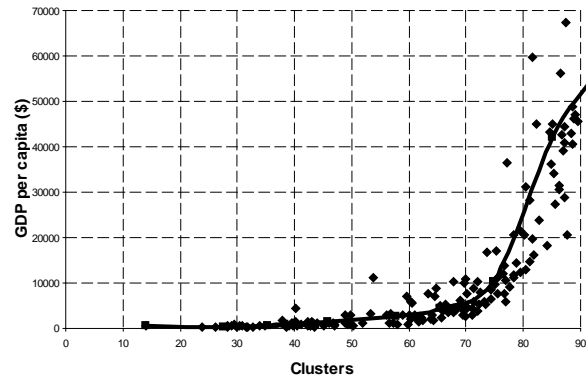


Fig.1. Analytical expression of the correlation analysis

Cluster analysis based on revealing the spaces of human development index has identified six groups of countries. Each group of country may be identified regarding the average, minimal and maximal value of gross domestic product per capita, common for all countries of the certain group. The results are in use in order to establish the tendencies of the process of development of the sector of high technology in each cluster.

Table 1. Results of the cluster analysis

Cluster	Index space	Average GDP/capita (\$)	Min. GDP/capita (\$)	Max. GDP/capita (\$)
1	0,8-1,0	43 282	12 879	134 400
2	0,6-0,8	7 272	1 380	36 412
3	0,4-0,6	1 778	392	11 033
4	0,2-0,4	820	322	1 705
6	0,0-0,2	439	180	768

Calculation of determination coefficient is in use in order to discover the dependence between grouping factors and established factors, characterising high technology development, on the example of the European Union.

The results of empirical research are given in tables 2–3.

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Table 2. Comparison of EU countries high technology sector development criteria (Source: Eurostat, Patent statistics)

Countries	Human development index	Cluster	Number of patents	Number of innovative enterprises, %	Turnover of the sector of high technology, % of GDP	Share of the sector of high technology in the world export, %
Belgium	0.867	1	1348	21.6	2.49	1.20
Bulgaria	0.743	4	11	8.3	0.82	0.02
Czech Republic	0.841	2	74	13.6	3.55	0.60
Denmark	0.866	1	945	15.8	2.53	0.58
Germany	0.885	1	22689	19.0	3.68	7.68
Estonia	0.812	2	8	15.8	1.34	0.04
Ireland	0.895	1	263	19.3	11.28	1.56
Greece	0.855	1	72	20.2	0.45	0.06
Spain	0.863	1	1260	6.1	1.32	0.52
France	0.872	1	7465	18.0	4.28	4.37
Italy	0.854	1	4446	10.2	2.26	1.31
Cyprus	0.810	2	13	13.6	0.29	0.01
Latvia	0.769	3	13	7.2	1.21	0.01
Lithuania	0.783	3	5	8.0	0.99	0.03
Luxembourg	0.852	1	90	28.5	1.77	0.46
Hungary	0.805	2	79	6.2	10.78	0.75
Malta	0.815	2	9	16.5	0.41	0.07
Netherlands	0.890	1	2825	17.1	2.33	4.18
Austria	0.851	1	1503	23.0	2.32	0.75
Poland	0.795	3	116	7.5	1.4	0.17
Portugal	0.795	3	78	12.3	1.65	0.15
Romania	0.767	3	15	5.1	0.52	0.06
Slovenia	0.828	2	64	17.9	3.2	0.05
Slovakia	0.818	2	31	9.4	2.22	0.11
Finland	0.871	1	1401	23.0	10.78	0.69
Sweden	0.885	1	1665	22.8	4.23	0.98
United Kingdom	0.849	2	5490	12.0	2.94	5.86

Table 3. Evaluation of dependance of high technology sector development factors on clustering features

Index space	Number of countries	Number of patents per mln. inhabitants	Inter-group dispersions	Average number of innovative enterprises (%)	Inter-group dispersions	Average turnover of the sector of high technology (%)	Inter-group dispersions	Average of share of the sector of high technology in the world export, %	Inter-group dispersions
0,850–0,900	13	140.2	6357.28	18.82	31.02	3.82	10.51	1.87	4.49
0,800–0,849	8	21.76	660.71	13.13	13.11	3.09	9.78	0.94	3.53
0,750–0,799	5	3.67	6.36	8.02	5.56	1.16	0.15	0.08	0.004
0,700–0,749	1	1.45	0	8.30	0	0.82	0	0.02	0
General dispersion		7286.977		38.531		9.1147		3.7285	
Determination coefficient		0.5529		0.4849		0.1239		0.1395	
Empirical correlation ratio		0.7436		0.6963		0.3520		0.3735	

The determination coefficient shows the impact of the cluster on the size of the indicators characterizing the process of the development of the sector of high development, and the empirical correlation ratio reflects the strength of relation

between the chosen aspects (Table 2). The calculation has shown that the variation of the index space have the greatest impact on the number of patents per mln. inhabitants, which defines the industrial level of the development of the sector of

high technology (determination coefficient 0,5529), and the number of innovative enterprises, which defines business level of the development of the sector of high technology (determination coefficient 0,4849). Therefore, the research revealed that the variation of the index space is appropriate for predictions regarding two parameters characterizing the development of the sector of high technology in the European Union: the number of patents per mln. inhabitants (empirical correlation ratio 0,7436) and the number of the innovative enterprises (empirical correlation ratio 0,6963). This leads to the conclusion that the results of the cluster analysis are appropriate to use in a process of assessment of country's readiness to develop the sector of high technology on industrial level, where the main indicator is the number of patents per mln. inhabitants, and on business level, where the key indicator is the number of the innovative enterprises in the country.

Performed empirical evaluation of theoretical guidelines of the method assessing the process of the development of the sector of high technology on the example of the countries of European Union has shown that suggested methodology can be implemented in practice in comprehensive evaluation of the development of the sector of high technology in different countries and regions.

5. Conclusions

Performed comparative analysis of high technology sector development in large-scale economies has justified the inclusion of economic freedom index and human development index into suggested theoretical model. Evaluation of strength of connection between grouping factors and investigated factors discovered that cluster analysis may be implemented by making predictions regarding number of patents and number of innovative enterprises. Results of evaluation of set of criteria in the example of the European Union have revealed that established ranks of countries meet tendencies of high technology development on international level by analysing share of high technology sector in world export.

Evaluation of strength of connection between grouping factors and investigated factors discovered that cluster analysis may be implemented by making predictions regarding number of patents and number of innovative enterprises. Results of evaluation of set of criteria in the example of the European Union have revealed that established ranks of countries meet tendencies of high technology development on international level by analysing share of high technology sector in world export.

Performed empirical evaluation of theoretical guidelines of the method assessing the process of the development of the sector of high technology on the example of the countries of European Union has shown that suggested methodology can be implemented in practice in comprehensive evaluation of the development of the sector of high technology in different countries and regions.

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