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THE EFFECTIVENESS OF EMPLOYMENT IN HIGH-TECH AND SCIENCE-INTENSIVE BUSINESS AREAS AS IMPORTANT INDICATOR OF SOCIO-ECONOMIC DEVELOPMENT: CROSS-COUNTRY CLUSTER ANALYSIS

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Abstract: *Employment is one of key parameters of the economy, which characterizes its efficiency, possibility of using the labour potential and growth of population's well-being. The level of employment is the most important indicator of the effectiveness of socio-economic policy of the state. A high level of employment in high-tech and science-intensive business areas is a driver of sustainable economic development of countries, increasing labour productivity, ensuring leadership in the market, and reducing the productions costs. Thus, the assessment of the effectiveness of population employment in high-tech and science-intensive service areas is significant today, as it is a comprehensive assessment of the country's development, its current state in high technologies and further prospects for working with them. The research purpose consists in determining the maximum, most effective value of the population employment efficiency index in high-tech and science-intensive service spheres based on cross-country cluster analysis. The sample of countries all over the world were divided into 3 clusters, taking into account the rating value of the following indices: employment in high- and medium-high-tech production sectors and science-intensive business service spheres; enterprises that conducted training to develop / improve the ICT skills of their personnel; new registered enterprises. During the research there were statistical data analysis, cluster analysis using Ward's method and software Statgraphics, optimization method using Frontier Analyst software. As a result, the efficiency of population employment in high-tech and science-intensive business service sectors of 36 countries in 2021 was determined, and accordingly reference countries with high population employment in this research sphere were identified. The potential reserves for increasing the targeted value of the population employment index in high-tech and science-intensive sectors were also characterized. The obtained results can be useful for business managers, they can adopt the experience of doing business in countries with more effective indicators, with the aim of developing employees, providing them with new training and knowledge that will facilitate doing business in the future.*

Keywords: economic growth, efficiency, innovation, labour potential, new business, population employment, research, sustainable development, technologies.

JEL Classification: J21, J24, O11, O32.

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Introduction

A sufficient level of employment in high-tech and science-intensive business areas is a driver of sustainable economic development of countries, increasing labour productivity, ensuring leadership in the market, and reducing the productions costs (Shchytov & Meshko, 2012). The assessment of the effectiveness of population employment in high-tech and science-intensive service areas is significant today, as it is a comprehensive assessment of the country's development, its current state in high technologies and further prospects for working with them.

The development of business services sphere is largely explained by growth of exactly high-tech services in connection with knowledge transformation into an independent factor of production. So, due to the development of the sphere of high-tech services and global economic integration, there is a significant increase in the employment of the population in the world economy. This is a service area known abroad as knowledge intensive services (KIS) and it is quite new and little studied. About 151,297 thousand of people or 68.7% of the total employed population work in the EU service sector, half of whom are in the field of high-tech services, and a third of whom have higher education. The other half works in the service sector with less intensive use of knowledge (Less Knowledge Intensive Service – LKIS). For the European Union, the average indicator of the employed population in this field is 32.96%, of which 9.2% work in the field of high-tech services with the most intensive use of knowledge (high-tech KIS) (Antonyuk & Shchetinina, 2017). In countries such as Luxembourg, Denmark, Norway, and Iceland, more than 40% of the total employed population of these countries work in the high-tech services sector.

Outsourcing plays an important role in the employment of the population in the field of high-tech services. The advantages of outsourcing are the growth of business profitability, involvement of other people's experience, reliability and stability, speed of execution, flexibility of business scales, expansion of the range of own services. Disadvantages of outsourcing include: the threat of non-compliance with confidentiality, the cost of outsourcing can often be higher than the cost of keeping records by internal employees, the threat of bankruptcy of the outsourcing company. The Czech Republic, Ireland, Hungary, and some countries outside the EU felt the positive impact of outsourcing (Kearney, 2022).

The development of high-tech services is a key feature of the knowledge-based economy. High-tech services are the engine not only of the service sector, but also of the economy in general. Important tasks of state institutions for the development of high-tech services are the implementation of reforms in the field of education, the resolution of administrative barriers, to overcome barriers to innovation and technical changes in the field of services, the creation of a competitive high-tech business environment, tax incentives for KIS enterprises to increase labour productivity, providing financial support, offering new services and creating new jobs, supporting the development of small and medium-sized businesses.

That is why this research issue is relevant for today. The main purpose is to determine the maximum, most effective value of the population employment efficiency index in high-tech and science-intensive service spheres based on cross-country cluster analysis.

Literature Review

Writing the article, the following publications were analysed. Kostenok (2015) investigated employment of the population as traditionally considered an important indicator of the country's development. The author grounded that employment of the population, its features, scales, and forms, as well as achieving a low level of unemployment are main goals of macroeconomic policy. The article also examines the development of industry at the current stage and its impact on the level of employment.

Pukhovs′ka et al. (2015) described the current state and trends of professional development of enterprise personnel in the countries of the European Union in the context of the "Europe 2020" strategy, revealed features and modern

models of financing professional training and development of personnel of enterprises in EU countries. The also offered recommendations of use in Ukraine the European experience implementation programs of professional training and development of personnel in production.

Ivanova (2021) considered significance of human potential, digital information technologies and digital skills of the person in security of effective management of business processes, in acceptance of management decisions. It is shown that active use of human potential maybe promotes saving time for obtaining a ready-made solution. It is justified that providing such management is possible thanks to priorities of human potential formation in the direction of development of mental abilities, creative thinking, increase of knowledge compared to mastery skills, in particular digital.

The efficiency of business working capital management taking into account employment was studied by Habib (2022). Efficient knowledge management as a factor of business development was described by Prokopenko et al. (2016) and developing a system of knowledge management in general – by Alomari et al. (2020). Artyukhova et al. (2022) put attention on the aspect of knowledge marketing. The issue of science and technology impact in the relationship with employment was investigated by Jazdauskaite et al. (2021). Privarnikova & Kostiuchenko (2012) examines the state of the high-tech in Ukraine, the development of the scientific, technological and innovation sectors, taking into account similar programs in other countries to improve the state of the high-tech and science-intensive sector.

Methodology and research methods

The sample of 36 countries in 2021 were divided into 3 clusters, taking into account the rating value of the following indices: employment in high- and medium-high-tech production sectors and science-intensive business service spheres; enterprises that conducted training to develop / improve the ICT skills of their personnel; new registered enterprises.

During the research there were statistical data analysis, cluster analysis using Ward's method and software Statgraphics, optimization method using Frontier Analyst software.

Cluster analysis was used as a multivariate method of statistical research according to which the collection belongs data that contain information about selective objects, and ordering compared them homogeneous, similar between groups. A cluster is understood as a group of objects which located in multidimensional spacious variables as close as possible to each other and at the same time as far away as possible from objects from other groups. The centre of the cluster is the most typical representative of this cluster (its geometric centre). According to the characteristics of the cluster centre, it is possible to judge all clusters (Klasternyy analiz).

The algorithm of clustering was built as certain method of sorting quantity clusters and definitions of its optimal value in the sorting process and included 5 main steps:

1) selection of the samples for clustering;

2) determination of the characteristics by which the objects in the sample will be evaluated;

3) calculation of the values of one or another measure of similarity between objects;

4) application of cluster analysis to create similar groups objects;

5) checking the reliability of the cluster solution results.

Cluster analysis methods allow solving the following problems:

1) classification of objects taking into account reflective features, essence, nature of objects. The solution of such problem leads to deepening of knowledge about the aggregates of objects subject to classification;

2) verification of the proposed assumptions about the presence of a certain structure in the investigated set of objects;

3) construction of new classifications for phenomena that have been little studied, when it is necessary to establish the presence of connections within the aggregate and try to bring structure to it.

The generalized clustering procedure can be described in the following stages:

1) the 1st stage – in the multidimensional space, random objects (or objects that are the most distant from each other) are selected as the initial centres of clusters;

2) the 2nd stage – each object belongs to the cluster of which centre it is the closest located;

3) the 3rd stage – when all objects are assigned to one or another cluster, their centres are listed: the geometric centre of the cluster is calculated;

4) the 1st stage and the 2nd stage are repeated: each object belongs to one or another cluster and the centres of the clusters are again iteratively enumerated.

The process is repeated until the changes in the cluster centres become zero (the optimal solution is reached) or the permissible number of iterations is exceeded.

Using the Statgraphics Centurion package, the selected statistics were divided into 3 clusters using Ward's method.

The Ward method is one of the hierarchical agglomerative methods of cluster analysis (Metody klasternoho analizu). The process is based on elementary steps:

1) finding and combining the two most similar objects in the similarity matrix;

2) the basis for placing an object in a cluster is the minimum variance within it is involved in the fact that it deals with a cluster classified object;

3) on some previous combination in one cluster it is the consideration of losses with cluster-averaged parameters;

4) the next two most similar objects are next, and the procedure is repeated with step 2 until the similarity matrix is exhausted. Only the Euclidean difference is used as an evaluation for the methods.

Results

The Table 1 consists of input data for this research.

Table 1. Input data

	Enterprises that conducted training for development / promotion of ICT skills of their staff	Employment in high- and medium-high-tech production sectors and knowledge-intensive service areas	Number of new registered enterprises
Belgium	18	4.0	27248
Bulgaria	5	4.3	50753
Czech Republic	11	11.5	27881
Denmark	18	4.9	36384
Germany	12	10.1	7072
Estonia	10	4.3	17696
Ireland	12	4.2	2075
Greece	8	1.7	5761
Spain	9	4.0	99231
France	8	4.1	76276
Croatia	11	3.6	13618
Italy	8	6.4	10135
Cyprus	12	0.9	13647
Latvia	7	2,2	10318
Lithuania	7	2.6	6352
Luxembourg	13	0.7	6207
Hungary	8	9.6	22328
Malta	16	3.3	5166
Netherlands	15	2.8	67127
Austria	11	6.1	3486
Poland	8	5.4	43523
Portugal	10	3.3	33641

Table 1 (cont.). Input data

	Enterprises that conducted training for development / promotion of ICT skills of their staff	Employment in high- and medium-high-tech production sectors and knowledge-intensive service areas	Number of new registered enterprises
Romania	4	6.3	73889
Slovenia	11	10.4	4309
Slovakia	9	11.2	1359
Finland	15	5.8	1359
Sweden	11	4.2	4996
Iceland	8	1.7	2667
Norway	14	2.4	2792
United Kingdom	12	2.4	663616
Montenegro	17	5.9	2818
North Macedonia	6	4.7	5686
Serbia	9	5.1	8236
Turkey	5	4.8	62674
Bosnia and Herzegovina	9	4.0	2814
Ukraine	7	2,3	1259

Sources: compiled by the authors based on (Eurostat database, 2021; OECD.Stat database, 2021).

The data were marked by the following way: K1 – enterprises that conducted training to develop / improve the ICT skills of their personnel, K2 – employment in high- and medium-high-tech production sectors and knowledge-intensive service areas, K3 – number of new registered enterprises.

Then the data were divided into 3 clusters using Ward's method (Fig. 1).

Cluster Analysis

Cluster Analysis

Data variables:
k1 (Підвищення навичок ІКТ)
k2 (Зайнятість у високотехнолог)
k3 (Нові зареєстровані підприємства)

Number of complete cases: 36
Clustering Method: Ward's
Distance Metric: Squared Euclidean
Clustering: observations
Standardized: yes

Cluster Summary

Cluster	Members	Percent
1	9	25,00
2	26	72,22
3	1	2,78

Centroids

Cluster	k1	k2	k3
1	15,3333	3,41111	18083,1
2	8,61538	5,31154	23001,3
3	12,0	2,4	663616,

Figure 1. Results of cluster analysis by Ward's method

Sources: calculated by the authors using the Statgraphics Centurion package

From the analysis, the first cluster includes 9 countries, namely: Belgium, Denmark, Cyprus, Luxembourg, Malta, the Netherlands, Finland, Norway, Montenegro. The second cluster includes 26 countries: Bulgaria, the Czech Republic, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Latvia, Lithuania, Hungary, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Sweden, Iceland, North Macedonia, Serbia, Turkey, Bosnia and Herzegovina, Ukraine. Only one country, Great Britain, entered the third cluster.

The absence of gaps between the stages of combining elements, which can be seen on the dendogram of the distribution (Fig. 2), indicates a normal distribution of the cluster.

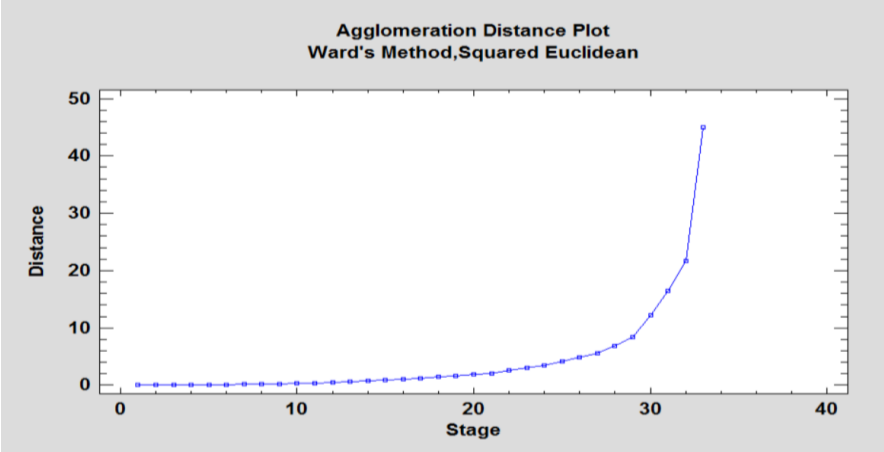


Figure 2. Dendrogram of distribution

Sources: built by the authors using the Statgraphics Centurion package

Among the countries of the 1st cluster, Finland is the most effective in terms of employment in high- and medium-high-tech production sectors and knowledge-intensive service areas (Table 2). Recognition of a country as effective (reference) is achieved on the condition that it achieves 100% of the value of the target parameter, countries with an average level of efficiency have 90 to 99.99 points. Otherwise, they are ineffective.

Table 2. Countries' distribution by the level of new registered enterprises (for the 1st cluster)

Country	Scores, %	Country	Scores, %	Country	Scores, %
Belgium	57.5%	Luxembourg	13.9%	Netherlands	48.3%
Denmark	70.4%	Malta	53.3%	Norway	44.3%
Cyprus	19.4%	Montenegro	89.8%	Finland	100%

Sources: compiled by the authors using the Statgraphics Centurion package

The countries located on the vertical or horizontal border of the frontier graph are "reference" according to the initial and input parameters of the study (Fig. 3).

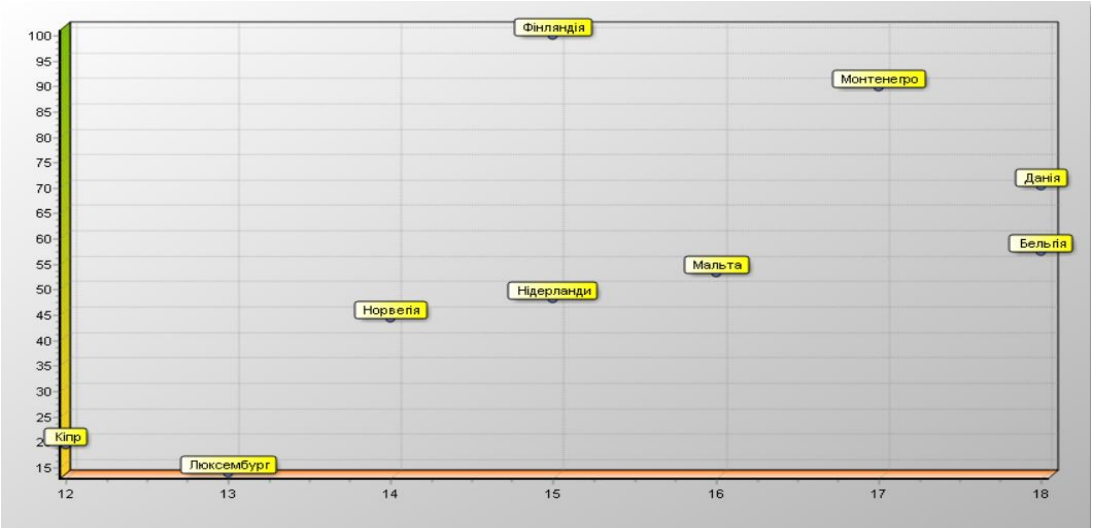


Figure 3. Graph of countries' efficiency (for the 1st cluster)

Sources: built by the authors using the Frontier Analyst software

Similar calculations were carried out for all other countries divided by clusters. The generalized distribution of the effectiveness is given in Tables 3-4. The second cluster was divided into two groups – the first includes 12 countries, the second – also 12.

Table 3. Countries' distribution by the level of new registered enterprises (for the 1st group of the 2nd cluster)

Country	Scores, %	Country	Scores, %	Country	Scores, %
Spain	31.8%	Poland	53.4%	Hungary	100%
Bulgaria	62.5%	Portugal	27.2%	France	37.6%
Estonia	56.6%	Romania	100%	Croatia	61.5%
Latvia	49.6%	Turkey	67%	Czech Republic	95.9%

Sources: compiled by the authors using the Statgraphics Centurion package

Among the countries of the 2nd cluster of the 1st group, Romania and Hungary are the most efficient in terms of employment in high- and medium-high-tech production sectors and knowledge-intensive service areas, the Czech Republic also has a fairly high indicator (Table 3). The countries located on the vertical or horizontal border of the frontier graph are "reference" according to the initial and input parameters of the study (Fig. 4).

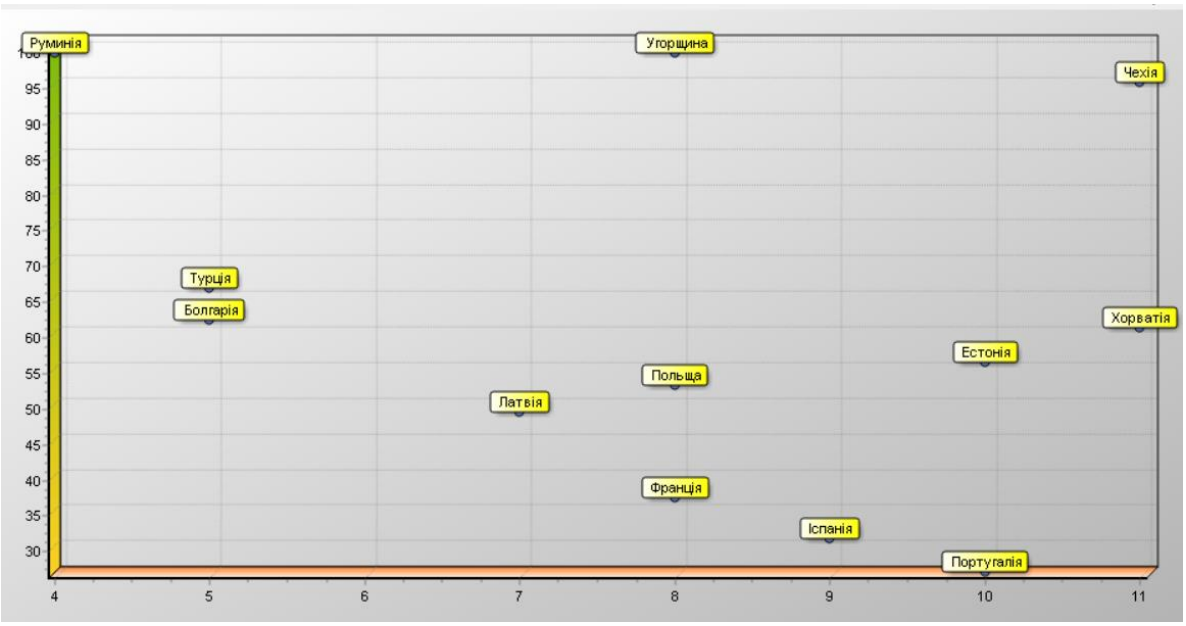


Figure 4. Graph of countries' efficiency (for the 1st group of the 2nd cluster)

Sources: built by the authors using the Frontier Analyst software

Similar calculations were carried out for the countries of the 2nd group of the 2nd cluster (Table 4).

Table 4. Countries' distribution by the level of new registered enterprises (for the 2nd group of the 2nd cluster)

Country	Scores, %	Country	Scores, %	Country	Scores, %
Ireland	28.1%	Lithuania	29.8%	Slovakia	100%
Iceland	17.1%	Germany	67.6%	Slovenia	76%
Austria	44.6%	North Macedonia	62.9%	Ukraine	26.4%
Greece	17.1%	Serbia	45.5%	Sweden	30.7%

Sources: compiled by the authors using the Statgraphics Centurion package

Among the countries of the 2nd cluster of the 2nd group, Slovenia is the most effective in terms of employment in high- and medium-high-tech production sectors and knowledge-intensive service areas (Table 4). The countries located on the vertical or horizontal border of the frontier graph are "reference" according to the initial and input parameters of the study (Fig. 5).

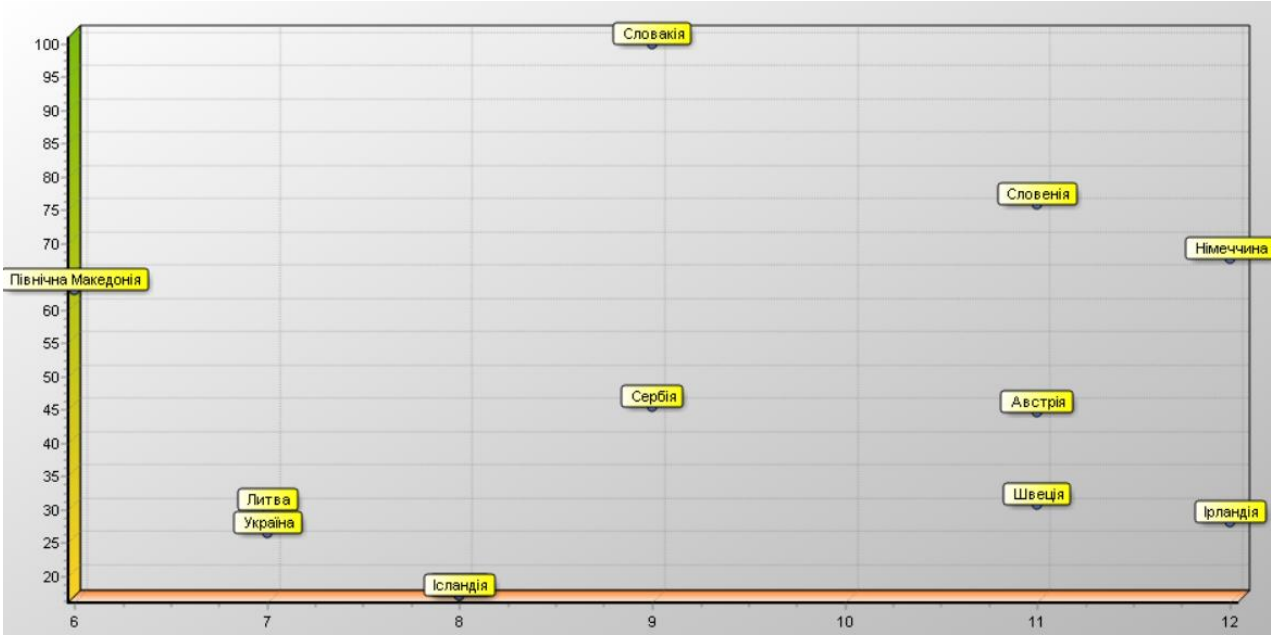
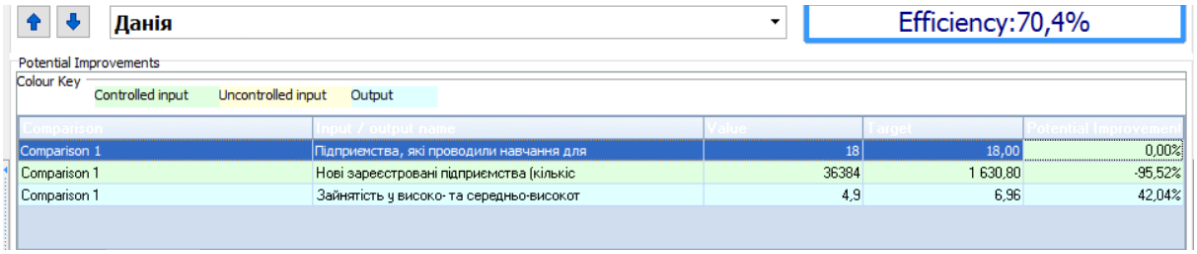


Figure 5. Graph of countries' efficiency (for the 2nd group of the 2nd cluster)

Sources: built by the authors using the Frontier Analyst software

For inefficient countries, it is advisable to apply measures to increase their values in terms of employment in high- and medium-high-tech production sectors and knowledge-intensive service areas. As an example, in the first cluster the value of the index is 70.4% for Denmark, and its potential value (in comparison with the "reference" country Finland) can be improved to 112.04, i.e., growth by 42.04 % (Fig. 6).



Comparison	Input / output name	Value	Target	Potential improvement
Comparison 1	Підприємства, які проводили навчання для	18	18,00	0,00%
Comparison 1	Нові зареєстровані підприємства (кількіс	36384	1 630,80	-95,52%
Comparison 1	Зайнятість у високо- та середньо-високот	4,9	6,96	42,04%

Figure 6. Country's efficiency for Denmark

Sources: built by the authors using the Frontier Analyst software

The 3rd cluster consists of only one country, therefore, in the research process, the analysis of the 3rd cluster is not conducted.

Conclusions

The analysis of the data made it possible to identify the most effective countries in terms of employment of the population in high-tech and science-intensive business service areas. In order to take into account, the peculiarities of enterprises that conduct training for the development / improvement of ICT skills of their personnel and newly registered enterprises, clustering was carried out, as a result of which 3 clusters were obtained. The first cluster included 9 countries, the second – 26 countries (during further analysis, the cluster was divided into two groups) and in the third only 1 country (therefore, in the research process, the analysis of the third cluster was not conducted). The procedure of distribution into 3 clusters was confirmed by the agglomeration protocol due to the Ward method using Statgraphics software. The reference country in the first cluster is Finland. In the second cluster of the first group the reference countries are Romania and Hungary. In the second cluster of the second group the reference country is Slovenia. Recognition of a country as effective (reference) was achieved on the

condition that it achieves 100% of the value of the target parameter, countries with an average level of efficiency have 90 to 99.99 points. Otherwise, they were ineffective. The obtained results can be useful for business managers, they can adopt the experience of doing business in countries with more effective indicators, with the aim of developing employees, providing them with new training and knowledge that will facilitate doing business in the future.

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Data Availability Statement: Not applicable.

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