

The Efficiency Indicators of the Involvement of Scientific Institutions on European and International Patents Formation as Innovations Management Tools

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Abstract: Innovations management is very important for innovation development. Academic staff employed in scientific institutions creates the knowledge needed to develop innovation. New knowledge generated by scientific institutions is offered to the public in different forms. It is therefore important to clarify the efficiency of the academic staff involvement in the production of European and international patents. These efficiency indicators can serve as tools for innovation management in scientific institutions. The object of the research is the formation of European and international patents at scientific institutions in various branches of science. The subject of the research is the comparative analysis of the efficiency of formation of European and international patents at scientific institutions in various branches of science in Latvia. The objective of the research is the analysis of efficiency indicators of the involvement of scientific institutions in European and international patents formation as innovation management tools in various branches of science in Latvia in the period from 2013 to 2018. The following tasks were determined to reach the objective: to study the formation of European and international patents at scientific institutions in various branches of science; and to implement the tools for innovation management of scientific institutions in various branches of science in Latvia. Research methods used in the paper are: content analysis, economic analysis, and economic experiment.

Keywords: Efficiency Indicators, European Patents, International Patents, Scientific Institutions, Innovation Management

1. Introduction

Every six years, the Ministry of Education and Science of the Republic of Latvia (MoES) shall organise an international evaluation of scientific institutions (SIs) registered in Latvia (IESI). The last IESI took place for the period from 2013 to 2018. In order to establish the dynamics of the efficiency indicators of academic staff involved in the formation of European and international patents (EPS) at Latvian SIs = (MoES, 2021), the authors used the output data of findings across the set of SIs evaluations in the period from 2013 to 2018 offered by "Technopolis-group" (TG). It provides an opportunity for the authors to calculate the EPS indicators at Latvian SIs and to compare their dynamics during the period from 2013 to 2018. The research is limited by the fact that more recent data required for the study are not currently available.

Data of the comparative analysis will help to develop support and motivation programs to increase the efficiency of involvement of academic staff in the EPS formation. In addition, the comparative analysis will establish whether the score on the research quality at Latvian SIs in the IESI by TG coincides with the place of the relevant Latvian SI in the ratings of the EPS indicators, and whether the score on research quality of the Latvian SI also reflects the efficiency of the involvement of academic staff of the Latvian SI in the EPS formation.

Hypothesis: The score on the SIs research quality shows the efficiency of the EPS formation in Latvian SIs.

2. Theoretical Background

In the past decade a significant amount of scientific literature has addressed the socio-economic impacts of university-industry research and development collaboration (Lima et al., 2021).

The authors rely on the research on understanding, adapting, and applying intellectual capital (IC) in universities (Mercado-Salgado et al, 2016); and the research on the role of human capital in educational and training process at a university (Contu, 2017) presented different aspects of IC. Spica et al (2017a) state that IC is an economic category, the spiritual value created by the human potential, and it can be accumulated and converted into the value of other types of capital. By investigating certain information about the management of education, the capacity and significance of the country's total economic capital movement can be increased.

Scientific articles, monographs, and national and international patents form the totality of IC of each SI. From this set of elements forming IC, European and international patents are conventionally considered IC. Such European and international patents provide an opportunity to determine the international competitiveness of various scientists, SIs, and branches of science in Latvia.

Spica et al (2017a; 2017b) have developed four indicators of the efficiency of the IC formation in a higher education establishment (HEE): (1) the efficiency of the involvement of academic staff in the IC formation per year in percentage (AIK); (2) the efficiency of the involvement of academic staff with Doctorate degree in the IC formation per year in percentage (DIK); (3) the efficiency of the involvement of students in the IC formation per year in percentage (SIK); and (4) mutual efficiency of the involvement of the academic staff with Doctorate degrees and the academic staff without Doctorate degrees in the IC formation per year in times, (DE).

To calculate the AIK, DIK, SIK, and DE of a HEE, Spica et al (2017a; 2017b) elaborated four formulas:

(1) $AIK = (ZPS : AS) \times 100$; (2) $DIK = (ZPS : DS) \times 100$; (3) $SIK = (ZPS : SS) \times 100$; (4) $DE = DIK : AIK$; where: ZPS represents the number of the HEE scientific publications per year; AS represents the number of academic staff in full-time jobs per year; DS represents the number of academic staff in full-time jobs holding Doctorate degrees per year; and SS represents the number of students per year.

3. Methodology

In their study, the authors will conduct a comparative analysis of SIs involved in the EPS formation in various branches of science in Latvia. It will comprise evaluation of SIs in six branches of science: (1) Engineering and Computer Sciences (E&CS); (2) Natural Sciences (NS); (3) Medical and Health Sciences (M&HS); (4) Agriculture, Forestry, and Veterinary Sciences (A&F&VS); (5) Social Sciences (SS); and (6) Humanities and Art Sciences (H&AS).

For the purposes of the study, the authors have modified the above formulas. Specifically, they calculated the EPS efficiency indicators for total numbers of full time equivalent (FTE) academic and research personnel (KIK), for FTE academic personnel (AIK), for FTE academic research personnel (PIK) and for PhDs completed at the SI (SIK). In addition, all the above EPS efficiency indicators were calculated for total number of self-reported outputs of European and international patents (EPS). The authors calculated mutual efficiency indicators (PE) regarding involvement of the FTE academic research personnel (PS) and the FTE academic personnel (AS) in the EPS formation in times.

In the present research, the authors have used the following data from the IESI: output data on the number of the FTE academic personnel (AS), the number of the FTE academic and research personnel (PS), the total number of the FTE academic and research personnel (KS), the number of the PhDs completed (SS), and the number of European and international patents (EPS) in period 2013-2018 per SI in Latvia. The authors revised the above EPS for one year. TG analysed 62 SIs of Latvia.

In this study, one EPS is accepted as one unit of IC. Next, using the modified formulas (1); (2); (3); and (4), the authors calculated KIK, AIK, PIK, SIK, and PE. Then, according to the results obtained through the authors' calculations, a corresponding place in the rating was assigned to each SI of Latvia per year and each of the above indicators KIK, AIK, PIK, and SIK.

Each place in the rating was then assessed with an appropriate score, where the lowest score is 1 point and the highest score is 5 points. This assessment system enables comparing the quantitative efficiency indicators of SIs in various branches of science in Latvia calculated by the authors with the IESI overall assessment criterion: the research quality of the SI. The relevant Panel of the TG was a score of the research quality of each SI using the scale where score 5 means outstanding level of research, score 4 means very good level of research, score 3 means good level of research, score 2 means adequate level of research, and score 1 means poor level of research (MoES, 2021).

Next, the unified overview of all six branches of science in Latvia was created. Here, the SIs were arranged according to the rank obtained in their sector of science. Furthermore, indicators of the efficiency of the involvement of academic staff of each SI in the EPS formation were added. The authors then selected one SI with the highest efficiency indicator of the involvement of academic staff in the EPS formation from the unified review of the branches of science in Latvia, accepted it as the basic indicator, and equated it to 100%. Then, the authors calculated the proportion of the efficiency of the involvement of academic staff of each SI in the base indicator.

In the next step, a rating scale of the results obtained was created on five-score system, where the highest score is five points, and the lowest score is one point. The new efficiency rating system for the involvement of academic staff of SIs in the EPS formation created by the authors provides for granting one point for the obtained efficiency indicators from 1% to 20%, 2 points - for the obtained efficiency indicators from 21% to 40%, 3 points - for the obtained efficiency indicators from 41% to 60%, 4 points - for the obtained efficiency indicators from 61% to 80%, and 5 points - for the obtained efficiency indicators from 81% to 100%,

Afterwards, the authors compared the results of their own estimates of SI quantitative indicators to the relevant Panel of the TG's results of qualitative indicators and calculated the difference between the indicators and the changes. For this purpose, for each SI, the authors calculated the score of indicators recording efficiency of EPS and the average score of each scientific sector. Finally, the authors compared these scores with scores of the research quality of each SI developed by the TG Panel.

4. Results

To calculate the efficiency of the involvement of academic staff in the EPS formation, the authors used formulas that were developed and approved already before and then modified by the authors:

$$AIK = (EPS : AS) \times 100 \quad (1)$$

$$PIK = (EPS : PS) \times 100 \quad (2)$$

$$KIK = (EPS : KS) \times 100 \quad (3)$$

$$SIK = (EPS : SS) \times 100 \quad (4)$$

$$PE = PIK : AIK \quad (5)$$

Table 1: Performance indicators of the involvement of academic staff of SIs in the EPS formation in one year and the comparative analysis thereof in various branches of science in Latvia in the period from 2013 to 2018

AIK rating	E&CS AIK (%)	E&CS AIK (%) of base indicator	E&CS AIK score	NS AIK (%)	NS AIK (%) of base indicator	NS AIK score	M&HS AIK (%)	M&HS AIK (%) of base indicator	M&HS AIK score	A&F&VS AIK (%)	A&F&VS AIK (%) of base indicator	A&F&VS AIK score	SS AIK (%)	SS AIK (%) of base indicator	SS AIK score
1	8	100	5	4	50	3	2	25	2	0	0	0	1	13	1
2	5	63	4				0	0	0	0	0	0			
3	5	63	4												
4	4	50	3												
5	4	50	3												
6	3	38	2												
7	1	13	1												
8	1	13	1												
9	0	0	0												
Average	4	50	3	7	88	5	9	113	5	3	38	2	0	0	0

According to Table 1 the highest AIK indicator in the EPS formation in one year is 8% and was accepted by the authors as the basic indicator or 100%. This indicator has been achieved by a SI representing the E&CS. Consequently, the efficiency indicator of the SIs of other branches of science in Latvia were attributed to this higher efficiency indicator in order to determine their proportion as a percentage. Then, according to the new rating system developed by the authors, each SI was assigned a certain number of points.

Table 2: Performance indicators of the involvement of academic research personnel of SIs in the EPS formation in one year and the comparative analysis thereof in various branches of science in Latvia in the period from 2013 to 2018

PIK rating	E&CS PIK (%)	E&CS PIK (%) of base indicator	E&CS PIK score	NS PIK (%)	NS PIK (%) of base indicator	NS PIK score	M&HS PIK (%)	M&HS PIK (%) of base indicator	M&HS PIK score	A&F&VS PIK (%)	A&F&VS PIK (%) of base indicator	A&F&VS PIK score	SS PIK (%)	SS PIK (%) of base indicator	SS PIK score
1	11	100	5	3	27	2	6	55	3	3	27	2	1	9	1
2	9	82	5	1	9	1	3	27	2	0	0	0			
3	7	64	4	1	9	1	1	9	1						
4	4	36	2				0	0	0						
5	3	27	2												
6	2	18	1												
7	2	18	1												
8	1	9	1												
9	1	9	1												
10	1	9	1												
11	0	0	0												
12	0	0	0												
Average	4	36	2	1	9	1	3	27	2	1	9	1	0	1	1

Having compared the numbers collected in Table 2, the authors conclude that the highest PIK indicator of 11% is given to a SI representing the E&CS, while the lowest PIK indicator of 0% is received by two SIs in the E&CS, by a SI in the M&HS, and by a SI in the A&F&VS. It follows that only two SIs get the highest score of 5 points, only one SI gets 4 points, only one SI gets 3 points, five SIs get 2 points, and other nine SIs get 1 point.

Table 3: Performance indicators of the involvement of PhDs completed at SIs in the EPS formation in one year and the comparative analysis thereof in various branches of science in Latvia in the period from 2013 to 2018

SIK rating	E&CS SIK (%)	E&CS SIK (%) of base indicator	E&CS SIK score	NS SIK (%)	NS SIK (%) of base indicator	NS SIK score	M&HS SIK (%)	M&HS SIK (%) of base indicator	M&HS SIK score	A&F&VS SIK (%)	A&F&VS SIK (%) of base indicator	A&F&VS SIK score	SS SIK (%)	SS SIK (%) of base indicator	SS SIK score
1	38	100	5	11	29	2	22	58	3	15	39	2	1	3	1
2	22	58	3	7	18	1	13	34	2	3	8	1			
3	7	18	1	1	3	1	1	3	1						
4	5	13	1				1	3	1						
5	4	11	1												
6	2	5	1												
7	2	5	1												
8	1	3	1												
9	1	3	1												
10	1	3	1												
11	1	3	1												
12	0	0	0												
Average	3	8	1	2	5	1	4	11	1	2	5	1	0	0	0

In Table 3, according to the SIK indicators, the first place and highest score (5 points) is taken by a SI in the E&CS, while the lowest SIK indicator of 0% is received also by a SI in the E&CS. No SI gets 4 points, two SIs get 3 points, three SIs get 2 points, and the rest of SIs get 1 point.

According to Table 4, the highest KIK indicator is 11% and it represents a SI in the E&CS. In six branches of science only one SI gets 5 points and only one SI gets 3 points; six SIs get 2 points, seven SIs get 1 point, and other seven SIs get 0 points. It follows that the total academic staff of SIs in various branches of science in Latvia in the period from 2013 to 2018 did not compete in the EPS formation in the international scientific environment.

Table 4: Performance indicators of the involvement of total academic staff of SIs in the EPS formation in one year and the comparative analysis thereof in various branches of science in Latvia in the period from 2013 to 2018

KIK rating	E&CS KIK (%)	E&CS KIK (%) of base indicator	E&CS KIK score	NS KIK (%)	NS KIK (%) of base indicator	NS KIK score	M&HS KIK (%)	M&HS KIK (%) of base indicator	M&HS KIK score	A&F&VS KIK (%)	A&F&VS KIK (%) of base indicator	A&F&VS KIK score	SS KIK (%)	SS KIK (%) of base indicator	SS KIK score
1	11	100	5	3	27	2	6	55	3	3	27	2	0	0	0
2	4	36	2	1	9	1	3	27	2	0	0	0			
3	3	27	2	1	9	1	1	9	1						
4	3	27	2				0	0	0						
5	2	18	1												
6	1	9	1												
7	1	9	1												
8	1	9	1												
9	0	0	0												
10	0	0	0												
11/12	0	0	0												
11/12	0	0	0												
Average	2	18	1	1	9	1	2	18	1	1	5	1	0	0	0

Table 5: Performance indicators of the mutual efficiency indicators regarding involvement of total academic research personnel and total academic staff of SIs in the EPS formation in times a year, quality of research (QTG) scores by TG, new total quantity KIK scores of SIs, and the comparative analysis thereof in various branches of science in Latvia in the period from 2013 to 2018

KIK rating	E&CS PE	E&CS QTG score	E&CS KIK score	NS PE	NS QTG score	NS KIK score	M&HS PE	M&HS QTG score	M&HS KIK score	A&F&VS PE	A&F&VS QTG score	A&F&VS KIK score	SS PE	SS QTG score	SS KIK score
1	0	4	5	0	4	2	0	5	3	0	3	2	1,0	3	0
2	0	2	2	0	4	1	0	4	2	0	4	0			
3	1,5	2	2	0,2	4	1	0,6	4	1						
4	2,6	2	2				0,9	3	0						
5	0,9	2	1												
6	0,5	3	1												
7	0,2	2	1												
8	0,2	3	1												
9	0,7	3	0												
10	0	3	0												
11/12	0,4	3	0												
11/12	1,4	3	0												
Average	0,6	-	1	0,2	-	1	0,4	-	1	0,2	-	1	1,8	-	0

In Table 5, the PE indicators rest in the range from 0.2 to 2.6 in respect of SIs in Latvia. The highest PE is held by a SI in the E&CS while the lowest PE belongs to two SIs in the E&CS and to one SI in the NS.

The highest average rate of the PE indicators is 1.8 in the SS; the second highest average rate of the PE indicators is 0.4 in the M&HS. It follows that academic research personnel of the SI in the SS are more effective as their academic personnel in the EPS formation. The lowest average rate of the PE indicators is 0.2 in the NS and the A&F&VS. It follows that the academic research personnel of the above branches of science are little effective in the EPS formation compared with academic personnel at SIs in the NS and the A&F&VS.

Table 6: The summary of performance indicators of the involvement of total academic staff of SIs in the EPS formation in one year and the comparative analysis of their total margins of AIK, PIK, SIK, and KIK indicators in various branches of science in Latvia in the period from 2013 to 2018

Scores	Total margins of AIK (%)	Total margins of PIK (%)	Total margins of SIK (%)	Total margins of KIK (%)	Total average margins of AIK (%)	Total average margins of PIK (%)	Total average margins of SIK (%)	Total average margins of KIK (%)
0	-	-	-	-	-	-	-	-
1	1 - 1	1 - 2	1 - 7	1 - 2	-	0 - 1	2 - 4	1 - 2

Scores	Total margins of AIK (%)	Total margins of PIK (%)	Total margins of SIK (%)	Total margins of KIK (%)	Total average margins of AIK (%)	Total average margins of PIK (%)	Total average margins of SIK (%)	Total average margins of KIK (%)
2	2 - 3	3 - 4	11 - 15	3 - 4	3 - 3	3 - 4	-	-
3	4 - 4	6 - 6	22 - 22	6 - 6	4 - 4	-	-	-
4	5 - 5	7 - 7	-	-	-	-	-	-
5	8 - 8	9 - 11	38 - 38	11 - 11	7 - 9	-	-	-

The comparison of QTG scores by TG with the new total quantity KIK scores calculated by the authors bring to conclusion that they differ from score of 1 point to score of 4 points in total. The assessment of the QTG scores and new KIK scores of each SI in various branches of sciences in Latvia results in a conclusion that the new KIK scores were too low except three SIs in the E&CS where QTG and KIK scores coincided.

From the results summarised in the six tables authors conclude that among all AIK, PIK, SIK, KIK indicators with score 1, the total margins of SIK indicators and the total average margins of SIK indicators are the highest ones. They are followed by the total margins of PIK and KIK indicators and the total average margins of KIK indicators. The total margins for all indicators with score 5 belong to AIK, PIK, SIK and KIK indicators. The total margins for all scores from 1 to 5 were found only for AIK indicators and PIK indicators.

5. Conclusions

The study of the authors did not result in confirming the hypothesis. The scores of SIs research quality do not represent the efficiency of the EPS formation in Latvian SIs. The comparison of the QTG scores of TG group with the new KIK scores conducted by the authors results in conclusion that the difference between them is from score 1 to score 4 in total.

The study shows that new performance indicators KIK of the involvement of total academic staff of SIs in the EPS formation in various branches of sciences in Latvia in the period from 2013 to 2018 were lower as presented by the results compiled by the relevant Panel of the TG, except for the three SIs in the E&CS where QTG and KIK scores coincided.

The authors are encouraged to extend the methodology for international evaluation of scientific institutions with four efficiency indicators AIK, PIK, SIK, KIK of the involvement of academic staff and PhDs completed at SIs in the EPS formation per year in percentage and PE in times as well as performance indicators of the comparative analysis thereof in various branches of science in the country.

The novelty of the research is as follows: the methodology allows comparison of the efficiency of the involvement of SIs in the formation of European and international patents in the country, determination for indicators of total limits of AIK, PIK, SIK, KIK in conformity with them, and clarification of the score evaluation system for IESI.

Ethics Declaration

The authors declares that there are no ethical issues related to the research presented in this paper.

AI Declaration

The authors declares that no significant AI tools or technologies were used in the conduct the research for this paper.

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