

COPRAS Approach for Efficiency Assessment of R&D Expenditures in Technology Transfer Process

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Abstract. Higher education institutions (HEI) performance results depends not only on successful innovative technology transfer (TT) activities and university-industry cooperation, but also on governance funding, distributed by the priority for certain research and development (R&D) fields. The purpose of this article is to propose a concept to assess the efficiency of R&D funding by sector of performance in European countries. The main goal of the paper is to propose a concept to assess the efficiency of R&D funding in European countries, provide insights, recommendations, and point out tendencies for the future improvement of European funding system for HEIs. Multicriteria ranking method COPRAS – an instrument for analysis and decision-making. The empirical research is based on Eurostat data for the period of 2005–2014. Expenditures on R&D gives the fluent explication of European R&D funding (investments) emphasizing the execution of innovation and TT activities at universities. The proposed assessment model allows comparing performance results and rank countries according the efficiency of research funding. Empirical results reveal that the comparatively higher efficiency of research expenditures is in the Northern European countries, Luxembourg and France. Latter tendency slowing to move forward and enhance performance results of HEIs, as well as countries' economic growth.

Keywords: HEI, R&D, performance, COPRAS, technology transfer (TT).

JEL Classification: G32, O32, O34.

Conference topic: Contemporary Financial Management.

Introduction

Decision making methods helps to analyse the performance measures of higher education institutions (HEI), to show the direction improving technology transfer (TT) process. Huge research papers prove that the more governance investments the better TT results could be reached. Important point here is the R&D fields which countries are selected as the priority to strengthen and develop innovative activities for the future.

This article is based on analysing European countries through comparing the data of R&D expenditures by sector of performance. The purpose of this article is to propose a concept to assess the efficiency of R&D funding by sector of performance in European countries, provide insights, recommendations, and point out tendencies for the future improvement of European funding system for HEIs.

European documents show the priority to invest for R&D. "Europe 2020" document's one of the priority is to invest (public and private) into the R&D – at least 3% of GDP (European commission 2016). Latter need related with the demand to base economic development by knowledge, innovation and TT activities. In comparison, National Progress Programme for Lithuania for the period 2014–2020 is intending to reach R&D funding – 1,9% of GDP for Lithuania. Statistics Lithuania provides the total R&D expenditure in Lithuania for 2015 – 0,9% GDP, meanwhile for Europe this indicator is – 1,9% GDP in 2015 (Statistics Lithuania 2016).

First of all, it should be selected the method for analysis and decision-making. The empirical research is based on Eurostat data for the period of 2005–2014 (ten years) (Eurostat 2017).

The object of the research is – R&D expenditures by sectors of performance, identified by Eurostat as the main sectors participating in R&D activities (Eurostat 2017). In addition, sectors of performance are selected also on the base TT and innovation process, where are participating such parties as HEIs, business (also non-profit based) and government. It is important to evaluate R&D expenditures in every sector of performance to provide insights and recommendations to achieve better performance results.

Main research tasks:

- to create a data set of R&D expenditures in TT process by sectors of performance for European countries;
- to develop approach to assess the efficiency of R&D funding by sector of performance in European countries;
- to analyse performance results: R&D expenditures, by sectors of performance and provide insights and recommendations.

This article is organized as follows. In the section of Performance indicators to explicit R&D expenditures in TT process, we discuss chosen performance indicators for the research. Next section describes COPRAS approach. Later all 8 COPRAS steps (methodology of COPRAS) are explained for use. The concluding remarks are given in the section of Conclusions.

Performance indicators to explicit R&D expenditures in TT process

Performance indicators of R&D expenditures in TT process are important to see the picture of different sectors with their investment to R&D. The performance of innovation and technology transfer processes depends on the amount of investments for innovation activities. Therefore, we need a clear picture of investments from different sides: business, higher education, government, non-profit organizations. Efficiency assessment of R&D expenditures in TT process encompasses European countries R&D performance indicators ranking by the best results. Efficiency assessment in this paper performed in 4 different sectors of performance, identified in Eurostat database (Eurostat 2017):

- business enterprise sector;
- government sector;
- higher education sector;
- private non-profit sector.

All mentioned sectors and its parties (business, science or government institutions) are involved into the TT and innovation processes.

The research of this article involves such indicators as showed in Table 1.

Table 1. Performance indicators of R&D expenditures in TT process (*Source*: compiled by authors according to Eurostat 2017)

Indicators				
<i>Intramural R&D expenditure (GERD) (Euro per inhabitant)</i>	<i>Intramural R&D expenditure (GERD) (Purchasing Power Standard (PPS) per inhabitant at constant prices)</i>	<i>Sector of fund – All sectors (Euro per inhabitant)</i>	<i>Total R&D expenditure (Euro per inhabitant)</i>	<i>Total R&D activity (Euro per inhabitant)</i>

The same performance indicators, mentioned in Table 1, were evaluated in every 4 sector of performance. In total, calculation was performed for 20 performance indicators in 4 sectors, analysing 28 European countries.

COPRAS approach to assess the efficiency of expenditures for R&D

In contemporary world, quantitative multi-criteria decision-making (MCDM) methods have been used as a rule for comparative evaluation of technological and economic or social processes, and also to determine the best alternative within a number of options and rank those alternatives by their performance results (Podvezko 2011).

The main concept of quantitative evaluation methods is converting the values of criteria, which are characterizing a certain process, and weights of criteria into a one dimension – the criterion of the method. In the case of maximizing criteria, the best is the largest value, and in another case – during calculation of minimizing criteria, the best is the smallest value. Performance indicators of criteria and their units are also different. All alternatives are comparing between each other, and ranking in accordance with calculated values of certain criterion (Podvezko 2011).

For the analysis we choose the data from Eurostat database in the period of [2005–2014] (Eurostat 2017). Every analyzed sector of performance invests different part of their budget for R&D processes. Investments contribute to the innovation and economic growth as a result. It is necessary to see the investments measures and compare them between each others. Therefore, all performance indicators should be putted on one platform. For latter purpose we should choose one of decision-making methods.

What is the main aspect of use MCDM methods? MCDM methods need the use of precise determined data. This means that should be precisely determined performance ratings of alternatives and weights of criterion (Popovic *et al.* 2012).

During the selection of sector of performance for R&D investments, decision-making persons usually make a choice between different available alternative sectors of performance based on certain attribute. What is multi-criteria decision-making problem in this article? The answer is – the selection of sector of performance for R&D investment

can be considered as a problem. Often multi-criteria decision-making (MCDM) methods usually proposed to use for selection of the most appropriate sector (Popovic *et al.* 2012).

The scientists from Vilnius Gediminas Technical University (VGTU) – Zavadskas, Kaklauskas and Sarka in 1994 were introduced the complex proportional multi-criteria evaluation method, called – COPRAS (in other words: COMplex PROportional ASsessment). This method allows quantitative multi-criteria evaluation of minimizing and maximizing chosen complex indicators of various criteria. A number of authors are used COPRAS (and its extension) or other MCDM methods in their research papers (Zavadskas, Kaklauskas 1996; Kaklauskas *et al.* 2006; Ginevicius 2008; Zavadskas *et al.* 2008a, 2008b, 2008c; Turskis *et al.* 2009; Kaklauskas *et al.* 2010; Kracka *et al.* 2010; Tupenaite *et al.* 2010; Chatterjee *et al.* 2011; Tavana *et al.* 2013; Aghdaie *et al.* 2013; Zavadskas *et al.* 2014a, 2014b; Ghorabae *et al.* 2014; Hashemkhani Zolfani, Bahrami 2014; Pitchipoo *et al.* 2014; Bausys *et al.* 2015; Nguyen *et al.* 2015; Liou *et al.* 2016; Mulliner *et al.* 2016; Xue *et al.* 2016; Mousavi-Nasab, Sotoudeh-Anvari 2017; Koçak *et al.* 2017; Rivera *et al.* 2017; Rezazadeh *et al.* 2017; Sen *et al.* 2017; Zolfani *et al.* 2017).

To assess the efficiency of R&D funding by sector of performance in European countries is possible applying decision – making method – COPRAS, which allows normalizing data and grouping them by the priority. This method was chosen as the one of the quite simple and clearly understandable multicriteria method to use and analyze the funding “levels” of R&D. The research results are leading with insights and recommendations for the future to fund R&D activities in one or another sector of performance, with the goal – to put the country into the higher economic level.

For applying COPRAS method we should to form the data decision matrix D of the criteria (j – criterion), which are describing the alternatives i_j ($j = 1, 2, \dots, n$) compared between each other. We need statistical data or expert estimates data, also the weights (significances) ω_i ($i = 1, 2, \dots, m$) of criteria, where n is the number of criteria and m is the number of the alternatives compared.

Methodology of COPRAS

COPRAS multiple-criteria decision-making method was introduced by Zavadskas and Kaklauskas (Podvezko 2011). Let's see the approach to assess the efficiency of R&D funding by sector of performance in European countries step by step. This approach could be used also to assess any other performance results and prioritize them by the best.

COPRAS Step 1. Data decision matrix formation

To solve certain problems in the business – science area, first of all it should be formed decision-making matrix from the data, as in this case, Eurostat. Latter matrix is constructed by the formula 1 (Organ, Yalcin 2016):

$$D = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \cdot \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdot & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdot & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdot & x_{3n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ x_{m1} & x_{m2} & x_{m3} & \cdot & x_{mn} \end{bmatrix}, \quad (1)$$

where: D – decision-making matrix, A – selected European countries for research, x – the data from Eurostat database for every country in certain year, m – the number of alternatives, n – the number of chosen criteria.

COPRAS Step 2. Decision-making matrix normalization

Second step is needed to convert performance indicators to normalized dimensions values and later use them for the calculation. COPRAS method normalization formula is presented in formula 2 (Organ, Yalcin 2016):

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}, \quad (2)$$

where: x_{ij} – i -th alternative performance of the j -th criterion; \tilde{x}_{ij} – the normalized value of j -th criterion; m – the number of alternatives.

COPRAS Step 3. Defining of weighted normalized decision-making matrix

Weighted normalized decision-making matrix is forming after the step of construction normalized decision-making matrix. The weighted normalized decision-making matrix is forming by the next formula 3 (Organ, Yalcin 2016):

$$D^* = d_{ij} = x_{ij}^* * w_j, \quad (3)$$

where: x_{ij} – the performance of i -th alternative; w_j – weight of criterion.

COPRAS Step 4. Maximizing and minimizing index calculation for every alternative

This stage is intended for identifying which alternatives will be maximized and which – minimized. So, each alternative is categorized as minimizing and maximizing index. See the formulas 4 and 5 for that purposes (Organ, Yalcin 2016):

for maximizing index calculation:
$$S_{i+} = \sum_{j=1}^k d_{ij}, \text{ when } j = 1, 2, 3, \dots, k. \quad (4)$$

for minimizing index calculation:
$$S_{i-} = \sum_{j=k+1}^n d_{ij}, \text{ when } j = k+1, k+2, \dots, n. \quad (5)$$

COPRAS Step 5. Relative weight's calculation for every alternative

Relative weight's Q_i calculation for i -th alternative is performed by the formula as follows (Organ, Yalcin 2016):

$$Q_i = S_{+i} + \frac{\min_i S_{-i} \sum_{i=1}^m S_{-i}}{S_{-i} \sum_{i=1}^m \frac{i}{S_{-i}}} \quad (6)$$

COPRAS Step 6. This step is intended to determine the priority order for each alternative

The priority order is given based on the weight of each alternative; the results are distributed by comparing alternatives weights between each other. The essence is that the higher rank has the alternative with the higher relative weight. This alternative with the highest weight is the most acceptable alternative in comparison with all rest (Organ, Yalcin 2016).

$$A^* = \left\{ A_i \mid \max_i Q_i \right\}, \quad (7)$$

where A – the priority order of alternatives.

COPRAS Step 7. Performance index calculation.

Performance index calculation is performing by the formula 8 as showed below (Organ, Yalcin 2016):

$$P_i = \frac{Q_i}{Q_{\max}} * 100\%, \quad (8)$$

where P_i – performance index of alternatives.

Alternative with 100 degree means the best one. The ranking of alternatives performed by the order from the best one, to the worst (Organ, Yalcin 2016).

COPRAS Step 8. Ultimate ranking of alternatives.

This step is follows after the calculation of performance index P_i of alternatives. The aim of this step is to distribute the results of P_i from the best to worst to make the conclusion and prepare final results of the research.

Empirical Results

For deeper analysis to understand which 4 sectors: business, higher education, government, non-profit organizations are investing for R&D the most, comparing selected European countries. Analysis incorporate the data which shows how much investments mentioned 4 sectors are investing in chosen one: if we analyse business sector, we see how much all 4 sectors invests to chosen business sector.

Empirical results are described in order of chosen performance data in every year, starting from 2005 till 2014 (Eurostat 2017). It was selected 10 years range to see the better view while comparing investments results to R&D taking 4 sectors implementing technology transfer and innovation processes in their activities.

Research is constructed of 28 chosen European countries (alternatives) and 5 performance indicators of R&D expenditures in TT process (criteria), which are mentioned in Table 1 (Eurostat 2017):

- Intramural R&D expenditure (GERD) (Euro per inhabitant).
- Intramural R&D expenditure (GERD) (Purchasing Power Standard (PPS) per inhabitant at constant prices).
- Sector of fund – All sectors (Euro per inhabitant).
- Total R&D expenditure (Euro per inhabitant).
- Total R&D activity (Euro per inhabitant).

All steps from 1 to 8 were performed by proposed approach. Indicators were maximized for the research. Indicators weights were chosen equal, because the research was performed without qualitative expert's surveys. Therefore, when 5 indicators have the weight of 1, every indicator has the weight of 0,2 ($1:5 = 0,2$).

Table 2. COPRAS calculation results of sector 1 of performance: Business enterprise sector [2005–2014]
(Source: compiled by authors)

Country	Calculated results (average)	Rank
Sweden	200	1
Finland	184	2
Luxembourg	183	3
Denmark	174	4
Austria	138	5
Germany	122	6
Belgium	100	7
France	89	8
Ireland	84	9
Netherlands	76	10
United Kingdom	71	11
Slovenia	49	12
Italy	36	13
Spain	33	14
Czech Republic	25	15
Portugal	21	16
Estonia	19	17
Hungary	14	18
Malta	13	19
Croatia	7	20
Slovakia	6	21
Greece	6	22
Poland	5	23
Lithuania	4	24
Latvia	4	25
Cyprus	4	26
Bulgaria	3	27
Romania	2	28

As we see from the Table 2, the best results of investments to R&D of business sector have these countries: Sweden, Finland, Luxembourg, Denmark, Austria and others. Lithuania is on the 24 place from 28.

The Table 3 shows that such countries as: Luxembourg, Germany, Finland, France and Netherlands are in TOP 5 of investors to R&D of government sector. Lithuania is on the 24 place from 28. Clear results we see in Table 4 of evaluating the biggest investors to R&D for higher education sector. Countries, which invest the most: Denmark, Sweden, Finland, Netherlands and Austria. Lithuania is on the 19 place from 28.

Table 5 explicit analysis results of investors to R&D for non-profit sector. Performance results showed that these countries invest to R&D for non-profit sector the most: Portugal, Cyprus, United Kingdom, Italy and France. Lithuania is on the 24 place from 28. Covering all sectors to get general picture which European countries invest to R&D the most for all 4 sectors, we get these results, that Finland, Luxembourg, Denmark, Sweden and France are investing to R&D the most. Lithuania is on the 22 place in total from 28.

Table 3. COPRAS calculation results of sector 2 of performance: Government sector [2005–2014] (Source: compiled by authors)

Country	Calculated results (average)	Rank
Luxembourg	391	1
Germany	212	2
Finland	191	3
France	175	4
Netherlands	142	5
Slovenia	106	6
Sweden	104	7
Belgium	100	8
Spain	94	9
United Kingdom	86	10
Austria	82	11
Italy	82	12
Czech Republic	74	13
Denmark	69	14
Ireland	58	15
Hungary	38	16
Croatia	37	17
Poland	35	18
Cyprus	35	19
Slovakia	35	20
Greece	35	21
Estonia	31	22
Portugal	29	23
Lithuania	29	24
Latvia	24	25
Bulgaria	19	26
Romania	19	27
Malta	10	28

As we see, the best results in investments to R&D belong to the most economically developed countries in Europe: Luxembourg, Germany, Finland, France and Netherlands. The worst results in this sector have Malta, Romania, Bulgaria, Latvia.

Let's see the picture of investing values for higher education sector in Table 4.

Table 4. COPRAS calculation results of sector 3 of performance: Higher education sector [2005–2014]
(Source: compiled by authors)

Country	Calculated results (average)	Rank
Denmark	237	1
Sweden	217	2
Finland	162	3
Netherlands	159	4
Austria	156	5
Belgium	100	6
Ireland	100	7
Germany	97	8
United Kingdom	95	9
France	90	10
Luxembourg	70	11
Italy	63	12
Spain	54	13
Portugal	51	14
Estonia	45	15
Czech Republic	31	16
Cyprus	30	17
Slovenia	29	18
Lithuania	28	19
Greece	25	20
Malta	22	21
Latvia	17	22
Croatia	17	23
Hungary	15	24
Poland	14	25
Slovakia	14	26
Romania	4	27
Bulgaria	2	28

Higher education sector is one of the most important one to push countries to the higher level through innovations. As we can see, the results from Table 4, such countries as Denmark, Sweden, Finland, Netherlands and Austria invest to R&D for higher education sector the most. Northern countries are active in this activity. The lowest expenditures have Bulgaria, Romania, Slovakia, Poland and Hungary.

Table 5. COPRAS calculation results of sector 4 of performance: Private non-profit sector [2005–2014]
(Source: compiled by authors)

Country	Calculated results (average)	Rank
Portugal	286	1
Cyprus	242	2
United Kingdom	217	3
Italy	204	4
France	183	5

Continued Table 5

Country	Calculated results (average)	Rank
Finland	162	6
Denmark	109	7
Belgium	100	8
Austria	82	9
Sweden	60	10
Estonia	53	11
Greece	22	12
Czech Republic	21	13
Spain	10	14
Bulgaria	5	15
Slovenia	5	16
Poland	5	17
Slovakia	3	18
Romania	3	19
Croatia	1	20
Germany	0	21
Ireland	0	22
Latvia	0	23
Lithuania	0	24
Luxembourg	0	25
Hungary	0	26
Malta	0	27
Netherlands	0	28

Portugal, Cyprus, United Kingdom, Italy and France take attention and investing for R&D for private non-profit sector. Lithuania spends on R&D much less money and it is on the rank 24. Strange, but the worst result for private non-profit sector shows Netherlands, when it seems it should be vice versa. On the other hand, if we compare the Netherlands performance results on investments to R&D for higher education sector; in this case this country is in the TOP 5 from the best. It means, that this country more pay attention into the investments for higher education sector, and it is right step to turn country into the best achievements in technology transfer and innovation activities and its performance results.

Table 6. COPRAS calculation results of performance: All 4 sectors [2005–2014] (Source: compiled by authors)

Country	Rank (average)	Group
Finland	1	1
Luxembourg	2	
Denmark	3	
Sweden	4	
France	5	2
United Kingdom	6	
Austria	7	
Germany	8	

Continued Table 6

Country	Rank (average)	Group
Belgium	9	3
Portugal	10	
Italy	11	
Netherlands	12	
Cyprus	13	4
Ireland	14	
Spain	15	
Slovenia	16	
Czech Republic	17	5
Estonia	18	
Greece	19	
Hungary	20	
Croatia	21	6
Lithuania	22	
Slovakia	23	
Poland	24	
Malta	25	7
Latvia	26	
Bulgaria	27	
Romania	28	

Last Table 6 allowed seeing aprobated results and formulating the conclusion that COPRAS method allowed us to see the TOP countries that pay attention and see the need of investing to R&D. Calculation results distributed by 7 groups. The best investors to R&D into all 4 analysed sectors are these countries from group 1: Finland, Luxembourg, Denmark and Sweden. Here we see three northern countries and Luxembourg. In group 2 are: France, United Kingdom, Austria, and Germany. Group 3 lead such countries as Belgium, Portugal, Italy and Netherlands. And if we carefully see all groups we see, that the most economically developed countries invests to R&D the most. Lithuania is on the 22 place from 28.

Conclusions

It was formed decision-making matrix based on Eurostat data: R&D expenditures in TT process by sectors of performance for European countries. There are a number of various decision-making methods to evaluate performance results, however COPRAS method is quite easy in use and allows taking the multi-criteria indicators with different values putting them on the one platform, giving them certain weights and compare them giving the rank of performance. The advantage of COPRAS is that here are separately evaluating maximizing and minimizing criteria and its influence on the total evaluating result. COPRAS was suggested for the approach while Eurostat data was aprobated using mentioned multicriteria decision-making method. The results showed, that this method is fully applicable to assess the efficiency of R&D funding by sector of performance.

During analysis of Eurostat data in the range of 10 years: [2005–2014], COPRAS results showed, that the best performance results on R&D investments into 4 sectors (business, higher education, government, non-profit) have these European countries (starting from the higher performance results) in TOP 10: Finland, Luxembourg, Denmark, Sweden, France, United Kingdom, Austria, and Germany. It shows that northern countries together with France, UK, Austria and Germany are investing for R&D the most.

Northern countries, as Sweden, Finland and Denmark are in the TOP 10, except government sector, where Denmark is in the TOP 14. However, in total results northern countries win before others.

After analyzing performance results, let us provide some results, insights and recommendations following.

Northern countries, and also Luxembourg, France, UK, Austria and Germany care about their countries from the deep understanding, that only through fostering TT and innovation activities, funding them, is the key to push the

country on the higher level. It means that only through the process of motivating and funding university – business activities we can achieve better economic results in the future. Such mutual relations help to born new ideas and bring innovative technologies into the industry. Year to year, realizing one contry's direction of the certain strategy and vision, gives good results. Strategic goals should be estimated in regard with R&D funding in every country.

In comparison, Lithuania should pay more attention to R&D and investments into TT and innovation activities to reach its strategy and have performance results of R&D funding – 1,9% GDP. Investing more, Lithuania would have higher rank than 22 (group 6). On the other hand, the Latvia is also the leader from the back (total rank is 26), and Estonia is 18-th. So, the best performance results in Baltics have Estonia, second – Lithuania, and Latvia – 3-rd.

Comparing higher education sector, Estonia is funded the most (rank 15), Lithuania (rank 19) and Latvia (rank 22). If we see government support for Baltics, it is quite near: Estonia (rank 22), Lithuania (rank 24), Latvia (rank 25). Busines sector: Estonia (rank 17), Lithunia (rank 24), Latvia (rank 25). We see that business sector in Estonia invest much more into R&D than Lithuania and Latvia.

Portugal, Cyprus, United Kingdom, Italy, France and Finland are the most active in support private non-profit sector for R&D activities. While Spain has the middle performance results from all 4 analyzed sectors in comparison with other countries.

Bulgaria, Romania and Malta have the lowest expenditures performance values in comparison with other European countries, and this could be related to the quite low economic development rate and low funding rate for R&D.

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