The Use of the Weighted Sum Method to Determine the Level of Development in Regional Innovation Systems – Using Czech Regions as Examples[1]

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Abstract

Recently, the importance of the regional innovation system issue has grown considerably, especially because many regions are currently working on the implementation of an innovation strategy that would create and support innovation activities and processes. In this context, it should be noted that extensive support for the processes of a regional innovation system (or strategy) is frequently associated with the use of public funds. To ensure maximum efficiency for the allocation of resources, it is necessary to have a method that is able to analyze regional innovation systems and their level of development. Such a method has not yet been published. The aim of this paper is to use the weighted sum method to evaluate the effects arising from the existence of regional innovation systems as well as to determine their level of development. This is a completely new approach for determining how developed a regional innovation system is in practice. This case study applies this method using four Czech regions.

Keywords: *regional innovation system, region, innovation, weighted sum method*

JEL Classification: O18, O31

Introduction

Modern regional policy tools are currently used for actively supporting regional development using a common concept. Innovation is thus seen as a tool for economic and social development. Furthermore, creating innovation facilitates

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[1] The authors thank the anonymous reviewers whose comments and suggestions helped to significantly improve the quality of this resulting paper. This work was supported by a grant provided by a scientific research project under Czech Science Foundation Grant No: 13-02836S.

mutual cooperation and other types of interaction between relevant actors engaged (not only) at the regional level as described by the triple helix theory.

The actors mentioned in this theory belong to the private sector, the sector for knowledge creation (universities, research centers and other institutes of higher education) and the non-profit sector (especially the public non-profit sector). The triple helix theory describes the mutual relations between the aforementioned actors, which are typically known to be highly dynamic. These same actors are the key players in the regional instruments currently under discussion, such as industrial clusters (Stejskal and Hajek, 2012) and regional innovation systems.

The relationship between triple helix members functions well under the condition that there is mutual trust, recognition of the benefits resulting from their cooperation, synergy and even partial overlap of their roles. Etzkowitz (2008) and Blažek and Uhlíř (2011) have reported the three main steps of the triple helix´s formation:

1. The creation of a "*knowledge space*" at the regional level, i.e., a sufficient concentration of research and development in nearby or related fields.

2. The creation of a "*consensus space*" as an environment inside which individuals from different institutions and different professional backgrounds and experiences can meet in order to generate new ideas and strategies.

3. The creation of an "*innovation space*" as an organizational structure which aims to achieve the objectives agreed upon in the previous steps.

The main contribution of the triple helix theory consists of the creation of an environment leading to achieving mutual synergies and creating positive effects for all participants as a spillover effect for the surrounding environment and other entities. Moreover, the triple helix theory has crucial importance for the development of the knowledge economy and the diffusion of innovation in the three aforementioned sectors (Lundvall and Johnson, 1994). However, it is not easy to create – or to enhance – mutual communication and cooperation between the different actors in practice (Powell and Snellman, 2004).

1. Theoretical Background

Many regional policy instruments integrate elements operating on the principles of the triple helix, especially: networking, industrial clusters, cluster initiatives, learning regions, innovation systems at the national and regional level and others. These systemic tools often incorporate other designated instruments. Thus, supporting their formation and their effective use should be able to produce a significant positive synergistic effect.

According to many studies related to innovation systems (for an overview of these studies see Tödtling and Trippl, 2005), regions (defined as smaller than a national region and larger than a local unit) are considered to be the key to innovation systems working effectively for the following reasons:

- First: regions differ according to their industrial specialization and their innovation performance (Howells, 1999; Breschi, 2000; Paci and Usai, 2000).
- Second: knowledge spillover effects play the key role in the innovation process and are usually geographically bounded (Audretsch and Feldman, 1996; Bottazzi and Peri, 2003; Asheim and Coenen, 2005; Stejskal and Hajek, 2015).
- Third: the growing importance of “tacit” knowledge has been indicated (Polanyi, 1966; Howells, 2002; Gertler, 2003; Matatkova and Stejskal, 2013) for a successful innovation process. The latter is often influenced by interventions due to political representation or by public administration institutions. However, interventions due to political representation are more often seen at the regional or local level (Cooke, Boekholt and Tödtling, 2000).

Many scholars have confirmed that regions are the most suitable area (space) for innovation. Next, it is necessary to define the framework and instruments that enhance the innovation process (Cooke, Gomez Uranga and Etxebarria, 1997; Morgan, 2007; Sternberg and Arndt, 2001; Antonioli, Marzucchi and Montresor, 2014). The original paradigm for national innovation systems was thereby temporarily[2] refuted and attention was transferred to the concept of the regional innovation system (RIS), which was introduced in the 1990´s. The main idea for introducing this instrument and its growing popularity are detailed by Cooke (1995) and many others (Cook and Memedovic, 2003; Uyarra, 2011). The regional innovation system can be thought of as the institutional infrastructure supporting innovation within the production structure of a region (Asheim and Coenen, 2005). This system is due to the fact that firms collaborating locally and adequately supported by public institutions are better able to achieve a higher level of innovation, generate high quality jobs and contribute to regional growth. Therefore, many scholars (P. Cook, R. R. Nelson, B. T. Asheim, A. Isaksen, M. Heidenreich, etc.) are engaged in accurately defining the RIS and, additionally, in finding the most effective way to create and support them.

Most of the scholars mentioned above agree on Cooke's definition (Cooke, 2006), which claims that the regional innovation system is useful for economic and innovation opportunity studies as well as being a functional instrument for enhancing companies' innovation processes. These processes are underpinned by the mutual interdependence of knowledge flows and the systems on which they depend. Furthermore, this highlights the importance of building mutual

[2] That it was temporary refers to the fact that, in the past 15 years, certain researchers have pointed to the significance of national innovation systems, even proposing the creation of national systems by using regional ones (e.g., Chung, 2002; Guan and Chen, 2012; Borrás and Edquist, 2013; Lyasnikov, Dudin et al., 2014).

relationships based on trust. The regional innovation system therefore includes a set of public and private institutions that produce substantial systemic effects encouraging enterprises in the region to adopt common standards, expectations, values, attitudes and practices, with the condition that they support the innovation culture and strengthen the process of knowledge spillovers (Hajkova and Hajek, 2011; Hajek, Henriques and Hajkova, 2014).

The latter definition underscores the structure of the regional innovation systems. According to Isaksen (2001), this structure consists of firms in the most important industrial fields of the region, organizations promoting knowledge and the interaction between them as the most important component. Each functional regional innovation system contains two or three sub-systems – which, according to Cooke (2002), are the sub-systems of knowledge creation and diffusion, knowledge use and application and, lastly, regional policy, which can significantly promote the formation of regional innovation systems when appropriately selected instruments are used (Tödtling and Triple, 2005).

In this context, the regional innovation system is the most appropriate instrument for utilizing the diffusion of knowledge as an important competitive advantage for a region. This is emphasized in Boschma (2004) and consists of the ability to share knowledge and cooperation between the private and public sectors by introducing new findings into practice. The most important aspect of regional innovation systems is the creation of both formal and informal knowledge networks among educational institutions in the public and private sectors (Hansen, 2002). According to Breschi and Lissoni (2001), it is possible to achieve appropriate support for each element of the system by a naturally occurring knowledge spillover between educational institutions and enterprises in the same region. This knowledge spillover leads to innovation in enterprises and, therefore, in the region.

According to literature focusing on regional innovation systems, various authors have tried dividing the RIS into specific categories by certain characteristics (Braczyk, Cooke and Heidenreich, 1998; Asheim and Coenen, 2005; Cooke, 2006). These authors divide the RIS according to the size of the region's incorporated companies, their financing methods or the territorial limits of the regional innovation system.

It is also possible to divide regional innovation systems according to the degree of their infrastructure development within the region:

- RIS with hard[3] elements but without any soft[4] infrastructure elements,
- RIS with highly developed hard and highly undeveloped soft infrastructure,
- RIS with highly developed hard and partially developed soft infrastructure,
- RIS with highly developed hard and highly developed soft infrastructure,
- RIS with a developed network for knowledge diffusion.

2. The Regional Innovation Strategies in the Czech Republic

After its entry into the European Union, the Czech Republic introduced regional innovation strategies as one of its regional policy instruments, leading to the decentralization of innovation policy to the regional level and aiming for effective financing and support of the innovation process within the regional framework (Skokan, 2004). The purpose of the innovation strategy is to develop and support of the regional innovation system functioning (Blažek et al., 2012). The Czech Republic has been progressing in the same direction as western European countries (Howells, 2005).

Table 1 gives an overview of existing Regional Innovation Strategies that have been gradually established by Czech regions. Table 1 shows that there are some regions where Regional Innovation Strategies were not adopted or were not properly updated.

T a b l e 1

An Overview of Regional Innovation Strategies in the Czech Republic

Region	RIS 2001 – 2006	RIS 2008 – 2013
Jihočeský		RIS (2010)
Jihomoravský	RIS1 (2002); RIS2 (2005)	RIS (2009, 2013)
Karlovarský		SKKK (2008 – 2010)
Královéhradecký		RIS (2010 – 2015)
Liberecký		RIS (2009)
Moravskoslezský	RIS1 (2003)	RIS2 (2010)
Olomoucký		RIS (2011)
Pardubický	RIS1 (2006)	
Plzeňský	BRIS (2004)	
Praha	BRIS (2004)	
Středočeský		
Ústí nad Labem	INBO (2005)	
Vysočina		RIS (initiated in 2010)
Zlínský		RIS (2008)

Note: Abbreviations in the Table 1 represent the different names of strategy documents in different regions of the Czech Republic.

Source: Skokan (2010), updated on April 22, 2014.

From the data in Table 1, it is clear that the strategy documents, which are supposed to support and shape existing regional innovation systems in the Czech regions, are updated over a very long time period. Specifically, there is not any coordination on the part of the developer of the national strategy for supporting

[3] *Hard infrastructure RIS* – physical infrastructure, which includes industrial zones, technological parks, science and research parks and innovation centers.

[4] *Soft infrastructure RIS* – technological infrastructure endowed with the latest devices and equipment; knowledge infrastructure, a type of infrastructure that facilitates knowledge transfer between organizations and enterprises.

innovation (Srholec and Zizalova, 2014). In 2015, the situation should change, because, on the basis of the European Commission directive, the Ministry of Education, Youth and Sport of the Czech Republic is currently working on preparing the Czech Research and Innovation Strategy for Smart Specialization (RIS3). The RIS3 should be the key basis for the approval of operational programs promoting investments in research, development, innovation and information technologies financed by the EU Structural Funds for the 2014 – 2020 programming period. Since the Ministry of Education, Youth and Sport of the Czech Republic is the main undertaker of the initiative, public funds are used to create the RIS3 strategy. Therefore, these funds should be spent effectively; their result will be highly developed strategy documents for different Czech regions.

The implementation of regional innovation strategies (meant to support the operation of regional innovation systems) has been frequently supported by public funds in the past and will likely continue to be in the future. Therefore, it is important to monitor whether providing public support contributes to attaining RIS objectives such as the emergence and diffusion of knowledge with an emphasis on the region's innovation capacity and competitiveness – while avoiding a regional innovation paradox. In comparison with more advanced regions, the regional innovation paradox exists in undeveloped regions and consists of the direct conflict between a region's relatively higher need to spend on supporting innovation and its relatively lower capacity and limited ability to absorb public spending earmarked for innovation support and investment in activities connected with innovation.

The innovation paradox is not the result of market failure but is the result of a systemic failure of policy management. The solution for the innovation paradox requires policies that increase the regions' capacity for absorbing investment funds for innovation activity. It is necessary to apply institutional changes within the RIS and to thoroughly map the relationships between the individual entities cooperating in the RIS (Oughton, Landabaso and Morgan, 2002). Moreover, one appropriate solution is to create a regional strategy that the public authorities can use to better direct public funds towards eliminating barriers and facilitating cooperation (Skokan, 2010).

For the need of this analysis, it is important to first define the RIS and its characteristics. Several authors (e. g., Andersson and Karlsson, 2004; Asheim and Coenen, 2005; and Cooke, 2006) have dedicated their work to this issue. They assign the RIS some of the same features, but there is still no clear consensus for a classification of its characteristics. This makes it impossible to perform the aforementioned analyses of actual RIS operation and economic efficiency (Zabala-Iturriagagoitia et al., 2007; Kravtsova and Radosevic, 2012).

Just as there is no agreement on the definition (i. e., the fundamental characteristics) of an RIS, there is no one unanimous approach for how to evaluate them. In the literature, it is possible to note that each author evaluates the RIS using their own perspective (for example, that of absorptive capacity, RIS impact on the economic region, RIS influence on science- -technology parks, their ability to generate findings, etc.) At the same time, they use common analytical methods such as input-output analysis, factor or cluster analysis (Padmore and Gibson, 1998), the participatory approach (Diez, 2001), the regional development platform method (Harmaakorpi, 2006) and the knowledge production function approach (Fritsch, 2002). However, none of these analyze the overall level achieved by an RIS.

The goal of this paper is to suggest a method for determining the degree of a regional innovation system's development using the weighted sum method (WSM), a multi-criteria decision making method. One of this paper's goals is to apply this method to a selected sample of regions in the Czech Republic and demonstrate its appropriateness for practical use.

3. The Methodology for Determining the Degree of RIS Development

3.1. Characteristics of the Method Used

The weighted sum method (WSM) is based on the principle of utility maximization (Fiala, Jablonský and Maňas, 1997). This method has been simplified by using only a linear utility function. Calculations are then manageable without the use of specialized software.

First, we created a normalized criteria matrix R = (r_{ij}) whose elements are obtained from the criteria matrix Y = (y_{ij}) using the transformation rule, (1):

$$r_{ij} = \frac{y_{ij} - D_j}{H_j - D_j},\ r \in 0;\ 1,\ \forall i = 1, \ldots, pj = 1, \ldots, k \qquad (1)$$

where

r_{ij} – the normalized value for the *i*-th alternative and *j*-th criterion,
D_j – the basal value, the lowest possible value an alternative acquires in the *j*-th criterion,
H_j – the ideal value, the best possible value an alternative acquires in the *j*-th criterion.

Obviously, $r_{ij} = 0$ for the basal alternative, and $r_{ij} = 1$ for the ideal alternative (Chyna, Kuncova and Seknickova, 2012).

When using the additive form of multi-criteria utility functions, the utility of the option a_i is then expressed by (2):

$$u(a_i) = \sum_{j=1}^{k} v_j r_{ij}, \ \forall i = 1, \ldots, p \quad (2)$$

where

v_j – the corresponding element from the weight vector,

r_{ij} – the normalized value gained from (1).

Obviously, the alternative with the highest utility value is considered as a compromise. In addition, the WSM makes it possible to arrange all the alternatives with respect to their utility values (Chyna, Kuncova and Seknickova, 2012).

The option that reaches the maximum utility value is selected as being the best, or the results can allow the variants to be classified according to their decreasing utility values.

As seen in Eq. (2), the vector of criteria weights must be determined for calculating utility. In the context of this analysis, we use the Fuller´s triangle method. The determination of weights is based on a pairwise comparison between criteria (Šubrt, 2011). Because of the pairwise comparison, the number of comparisons is equal to:

$$N = \binom{k}{2} = \frac{k(k-1)}{2} \quad (3)$$

Each comparison may be performed inside Fuller´s triangle. Criteria are numbered as serial numbers 1, 2,…, *k*. Users then work with the triangular diagram; the double lines formed by serial numbers are arranged in pairs so that each pair of criteria appears exactly once. The user indicates (by encirclement) which criterion is more important for comparing each pair. We mark the number of encirclements of *i*-th criterion as n_i. The weight of the *i*-th criterion is then calculated as:

$$v_i = \frac{n_i}{N}; \ i = 1, \ 2, \ldots, \ k \quad (4)$$

The main advantage of this method is the simplicity of the information required from users. If it is necessary to exclude zero weight, the number of encirclements may be increased by one with the condition that the denominator in Eq. (4) must also be increased accordingly.

3.2. The Definition of RIS Characteristics

Using study findings and detailed results coming out of Czech and foreign literature (e. g., Cooke, Gomez Uranga and Etxebarria, 1997; Andersson and Karlsson, 2004; Doloreux and Parto, 2005; Hudec, 2007; Skokan, 2010), Table 2 defines set characteristics for a “standard” form for the RIS. If the set of characteristics cited above exists within one region, the authors agree that we can say that a regional innovation system exists in its basic form. At the same time, none of the authors mention the degree of development, precisely because the degree to which a characteristic has been achieved will vary from one RIS to another. Therefore, the degree to which they have been achieved increases the likelihood of positive effects being created when an RIS exists in a given region. For example, these effects can be observed via an increase in regional GDP or a decrease in the unemployment rate. However, many of these effects bring positive measurable results over the long term, which precludes the causal analysis of economic indicator changes. Consequently, it is not relevant to analyze the effects of the RIS directly.

The RIS characteristics that have been defined (see Table 2) represent criteria which will be quantified and then used to constitute the members of the criteria matrix used when applying the WSM. The quantification of the criteria must be done on the basis of descriptive analysis and information obtained from expert assessments or controlled interviews with experts on regional issues.

T a b l e 2

Regional Innovation System Characteristics

RIS Layer	Characteristic	Abbr.
Companies	Existence of industrial clusters	A1
	Existence of specific innovating enterprises in the fields	A2
	Number of patents in the fields	A3
Support organizations	Existence of IPS	B1
	Existence of business incubators	B2
	Existence of regional development agencies	B3
	Existence of other support and complementary organizations	B4
Environment and infrastructure	Existence of an RIS not older than (or updated for longer than) 5 years	C1
	Existence of animators (actors) in the region and the fields	C2
	Existence of an organization shaping the professional community in the fields	C3
	Existence of professional societies or associations in the fields	C4
	Existence of public finance (funding) schemes	C5
	Existence of private finance (funding) initiatives	C6
	Existence of hard innovation infrastructure elements	C7
	Existence of technological infrastructure	C8
	Existence of knowledge infrastructure	C9
Relationships, Links	Existence of communication channels	D1
	Existence of projects confirming cooperation and synergy	D2

Source: Matatkova and Stejskal (2011).

Particular characteristics were grouped on the basis of results derived from research findings on RIS layers. The characteristics cited above also contain those of the triple helix (these concern enterprises, support organizations, knowledge and public organizations as well as the environment and investment infrastructure). Relationships and links are two of the most important characteristics and should not be overlooked.

For the purposes of this analysis, the characteristics mentioned above are divided into three groups (see Table 3). The first two groups describe characteristics that are necessary and supportive in in the region (physical infrastructure including industrial zones, technological parks, scientific research parks, innovation centers, etc.) and institutions. The existence of these characteristics does not reflect whether the RIS is working or not. They only describe the physical substance of the RIS and can be used as a binary variable (whether present or not) or to quantify the number of institutions. The third group consists of characteristics that have a quantitative nature or contain characteristics whose quality significantly depends on the scope and quality of the individual RIS (typically, the number of patents). On the basis of their analysis, we can conclude that an existing RIS leads to cooperation, knowledge spillovers and a synergic effect and, thus, the creation of innovation. This type of RIS will have a positive impact as a result of the public interventions that have been created and supported.

Table 3

The Weight Assigned to Each Criterion Based on the Fuller´s Triangle Calculation

Criterion	v_i
I. Group: Necessary Characteristics	**0.333**
A2	0.222
B1	0.167
B2	0.028
C1	0.042
C2	0.042
C3	0.181
C5	0.083
C6	0.152
C7	0.083
II. Group: Supporting Characteristics	**0.167**
A1	0.499
B3	0.167
B4	0.167
C4	0.167
III. Group: Qualitative Characteristics	**0.5**
A3	0.3
C8	0.133
C9	0.3
D1	0.067
D2	0.2

Source: Authors' own calculations.

It is logical that each characteristic will not have the same meaning for RIS existence and operation. We need to assign a weight to each characteristic inside each group; this weight provides information about the significance of each characteristic. The Fuller´s triangle method was used to assign weights. Preference ranking was done by ten experts in collaboration with the company the Berman Group, which also consulted on the project; they have been specializing in local and regional economic development since 1999. In 2013, the Berman Group assisted in updating regional innovation strategies in the Olomoucký and Karlovarský Regions and is now (in 2015) assisting in the creation of RIS S3 Czech Republic for the forthcoming period.

The expert evaluation of preferences makes it possible to determine the criteria weights and their appropriate grouping according to Eq. (4). The resulting weights are summarized in Table 3.

The sum of the weights assigned to groups I. – III. equals one, just as the sum of the weights within each group is also equal to one.

Next, the WSM was applied for determining the weight of each characteristic. The method's application will be divided into three progressive steps corresponding to the division of criteria from the three groups cited above. All the steps of the analysis process will correspond to the WSM as explained in Section 3.1.

4. The Application of the WSM

4.1. Selecting Regions for Analysis

For conducting pilot analysis using the WSM, it is important to select regions. For the needs of this paper, four regions were selected in the Czech Republic: the Jihomoravský Region (JMK), the Moravskoslezský Region (MSK), the Královéhradecký Region (KHK) and the Pardubický Region (PK). These regions were selected with regards to data availability and their level of RIS development. In other words, we selected regions with existing RISes at various stages of development (proof that an RIS exists in these regions is listed in Matatkova and Stejskal, 2011; 2013).

The difference in RIS development level can be inferred from the fact that the Moravskoslezský Region and the Jihomoravský Region actively support the creation of their RISes to a greater degree using strategies and additional regional policy instruments. This fact is demonstrated by Table 1, which shows that a Regional Innovation Strategy was first prepared in 2002 – 2003 by the two regions cited above. Since then, the Moravskoslezský Region has updated its strategy in the form of their Regional Innovation Strategy 2010 – 2020, which has been supported by several action plans. Since 2002, strategy documents have been updated twice by the Jihomoravský Region. In the latter region, a Regional Innovation Strategy for the period of 2009 – 2013 exists, and preparatory work has been done for a third update.

On the other hand, the Pardubický Region drew up one Regional Innovation Strategy document in 2006 that is still effective, and there are no expectations that it will be updated. The same situation is evident in the Královéhradecký Region, which currently has only one Regional Innovation Strategy document for the period of 2010 – 2015; this is a relatively new document and, consequently, in the first stages of its development.

4.2. The Evaluation of Necessary RIS Quantitative Characteristics

Criteria included in the group of quantitative characteristics are listed in Tables 2 and 3. Descriptive analysis was provided by an expert appraisal from the creator of the Czech Republic's RIS in April 2013. The results are summarized in Table 4.

T a b l e 4

Necessary Quantitative Characteristics

Region/ Criteria	**A2***	**B1**	**B2*** **	**C1**	**C2****	**C3**	**C5**	**C6**	**C7**
KHK	6th place (2010)	YES	YES (2/9)	YES (2010)	YES (2)	YES	NO	NO	YES
PK	4th place (2010)	YES, few	YES (1/0)	NO (2006)	YES (6)	YES	NO	NO	YES
JMK	2nd place (2010)	YES, many	YES (5/33)	YES No. 3 (2009)	YES (9)	YES	YES	YES	YES
MSK	9th place (2010)	YES	YES (6/78)	YES No. 2 (2010)	YES (2)	YES	YES	YES	YES

* Order established under the World Competitiveness Yearbook 2010.
** The number in parentheses indicates the number of animators (actors) working in the region.
*** The number in parentheses indicates the number of business incubators and the number of firms working in the region.

Source: Authors' own calculations according to an expert appraisal and publicly available information.

When establishing a criteria matrix, it is necessary to give a point value to each indicator. Scoring was used for the sequence of the regions according to the assessment of each criterion. The poorest result was recorded as zero and the best as three. After point evaluation maximizing all criteria, it is possible to establish an initial criteria matrix where rows and columns correspond to Table 4:

$$\begin{bmatrix} 1 & 2 & 1 & 1 & 1 & 3 & 2 & 0 & 3 \\ 2 & 1 & 0 & 0 & 2 & 3 & 2 & 0 & 3 \\ 3 & 3 & 2 & 3 & 3 & 3 & 3 & 3 & 3 \\ 0 & 2 & 3 & 2 & 1 & 3 & 3 & 3 & 3 \end{bmatrix}$$

Criteria in this matrix are maximized; we can therefore determine the maximum value H and the minimum value D from each column j: H = (3; 3; 3; 3; 3; 3; 3; 3; 3); D = (0; 1; 0; 0; 1; 3; 2; 0; 3).

Using Eq. (1), the initial criteria matrix is transformed into a normalized criteria matrix. Elements of this matrix express the indicator value of each variant according to certain criteria:

$$\begin{bmatrix} 0{,}33 & 0{,}5 & 0{,}33 & 0{,}33 & 0 & 0 & 0 & 0 & 0 \\ 0{,}67 & 0 & 0 & 0 & 0{,}5 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0{,}67 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0{,}5 & 1 & 0{,}67 & 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

The normalized criteria matrix makes it possible to calculate the indicator value cited in Table 4 in each region on the basis of Eq. (2). It is important for that calculation to determine the weighting vector v_1; its compilation is based on values presented in Table 3: v_1 = (0.222; 0.167; 0.028; 0.042; 0.042; 0.181; 0.083; 0.152; 0.083). The following results are those for the RIS development level in the selected regions according to indicator value calculations. These results are presented in Table 7.

4.3. The Evaluation of RIS Supporting Quantitative Characteristics

This group of characteristics was also analyzed using an expert appraisal and focused on their level of development in the selected regions. The completed results are summarized in the Table 5.

T a b l e 5

Supporting Quantitative Characteristics

Region/Criterion	A1	B3	B4	C4
KHK	YES (3)	YES	YES	YES
PK	YES (2)	YES	YES, very little	YES
JMK	YES (3 – 5)	YES	YES, very little	YES
MSK	YES (10)	YES	YES	YES

Source: Authors' own calculations according to an expert appraisal and publicly available information.

Once again, each criterion was evaluated using points and by following the same method used for the necessary quantitative characteristics. The results consist of a criteria matrix whose rows and columns correspond to Table 5:

$$\begin{bmatrix} 1 & 3 & 2 & 3 \\ 0 & 3 & 1 & 3 \\ 2 & 3 & 3 & 3 \\ 3 & 3 & 2 & 3 \end{bmatrix}$$

Because the criteria matrix is maximized, we can specify the maximum and the minimum values H and D for each column j: H = (3; 3; 3; 3); D = (0; 3; 1; 3).

The following is the normalized criteria matrix formed on the basis of the transformation formula, (1):

$$\begin{bmatrix} 0,33 & 0 & 0,5 & 0 \\ 0 & 0 & 0 & 0 \\ 0,67 & 0 & 1 & 0 \\ 1 & 0 & 0,5 & 0 \end{bmatrix}$$

The calculation of the effects' values for regions resulting from Table 5 is computed according to Eq. (2) using the normalized criteria matrix. The value of each effect is then calculated according to weighting vector v_2. Values are compiled using Table 3: v_2 = (0.499; 0.167; 0.167; 0.167). The calculation of the effect values gives the results summarized in Table 7.

Quantitative characteristics are concerned only with innovation infrastructure. On their basis, we can decide whether organizations that contribute and diffuse knowledge in each region exist and to what extent they exist; they make it possible to evaluate each region's innovation potential. Therefore, evaluating the use of this potential is made possible by the analysis of the third group of characteristics – the group of qualitative characteristics.

4.4. Evaluating the Effect of the Existing Qualitative Characteristics

The results of the expert appraisal for the cited criteria's existence, their degree of evolution, all is summarized in Table 6.

Table 6

Qualitative Characteristics

Region/Criterion	A3	C8	C9	D1	D2
KHK	37	YES	YES	YES, few	YES, few
PK	31	YES, limited	YES	YES, few	YES, very few
JMK	105	YES	YES	YES	YES
MSK	69	YES	YES	YES, few	YES

Source: Authors' own calculation according to the expert appraisal and publicly available information.

The criteria were also point evaluated using the same methods. The result consists of a criteria matrix whose rows and columns correspond to Table 6:

$$\begin{bmatrix} 1 & 3 & 3 & 2 & 2 \\ 0 & 2 & 3 & 2 & 1 \\ 3 & 3 & 3 & 3 & 3 \\ 2 & 3 & 3 & 2 & 3 \end{bmatrix}$$

Because the criteria matrix has been maximized, we can specify the maximum H and the minimum value D for each column j: H = (3; 3; 3; 3; 3); D = (0; 2; 3; 2; 1).

Next follows the normalized criteria matrix formed on the basis of the transformation formula, (1):

$$\begin{bmatrix} 0,33 & 1 & 0 & 0 & 0,5 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 0,67 & 1 & 0 & 1 & 1 \end{bmatrix}$$

The calculation of the effects' values in the regions resulting from Table 6 is computed according to Eq. (2) using the normalized criteria matrix. The value of each effect is calculated according to weighting vector v_3, and values are compiled using Table 3: v_3 = (0.3; 0.133; 0.3; 0.067; 0.2). The calculation of the effects' values gives the results summarized in Table 7.

4.5. The Assessment of RIS Level for the Selected Regions

The previous sections have also assessed the effects resulting from existing RIS characteristics. This step consists of the overall quantification of RIS effects. This part analyzes the key instruments that have been assigned to each group of the regional innovation system characteristics described in Table 3.

The vector of their weight is $v_{4,}$, and its value is the following: v_4 = (0.333; 0.167; 0.5).

The value of indicators within the selected regions obtained for each group of characteristics is summarized in Table 7.

T a b l e 7

Effect Values Within Each Group

Indicator Value				
Criterion Group/Region	*KHK*	*PK*	*JMK*	*MSK*
Required Quantitative Characteristics	0.17986	0.16974	0.72676	0.37464
Supporting Quantitative Characteristics	0.24817	0	0.50133	0.58250
Qualitative Characteristics	0.33200	0	0.70000	0.60100

Source: Authors' own calculation.

The overall values of the effects resulting from the existing RIS in the selected regions are calculated using the weighted sum of each effect. The values are listed in Table 8.

T a b l e 8

Overall Indicator Values for RIS Development Level

Region	Total Value of the Effect	Order
JMK	0.72676×0.333 + 0.50133×0.167 + 0.7×0.5 = **0.67573**	1.
MSK	0.37464×0.333 + 0.5825×0.167 + 0.601×0.5 = **0.52253**	2.
KHK	0.17986×0.333 + 0.24817×0.167+ 0.332×0.5 = **0.26734**	3.
PK	0.16974×0.333 + 0×0.167 + 0×0.5) = **0.05652**	4.

Source: Author's own calculation.

The partial values of the indicators listed in Table 7 demonstrate the degree of RIS advancement in the selected regions. According to the value results, the least developed is the Pardubický Region, whose RIS has only a hard infrastructure. The Pardubický Region had the poorest results according to the other groups of characteristics. We would therefore recommend that the regional authorities of the Pardubický Region complete their missing RIS elements and revitalize the system by coordinating cooperation projects. Compared to the other selected regions, the Pardubický region´s RIS shows the least positive effects. Thus, we can define the Pardubický region´s RIS as an RIS with a *highly developed hard and partially developed soft infrastructure*. In opposition to the Pardubický Region, the Jihomoravský Region was evaluated as the best according to the values obtained from the indicators used; these indicate that the Jihomoravský Region has a completely functional RIS (an *RIS with an advanced network for knowledge diffusion*). The Jihomoravský RIS satisfies the main goals, which are the creation and diffusion of knowledge and the development of innovation and its subsequent commercialization.

Those results correspond to the highest indicator value indicating the presence of qualitative characteristics. This confirms the existence of cooperation projects and synergy within the RIS; the high indicator value also stems from the existence of knowledge and technological infrastructure accompanied by a relatively high number of patents in the industry.

The achievement of such positive results in the Jihomoravský Region is probably due to the regular updating of their Regional Innovation Strategy – it is currently using its third update. Furthermore, the South Moravian Innovation Centre has a certain value for implementing goals resulting from the innovation strategy and then evaluating the effectiveness of these objectives.

The Moravskoslezský Region indicates that it is a r*egional innovation system with highly developed hard and soft infrastructures*, but its values are lower than those of the Moravskoslezský Region. More precisely, it shows lower values in the group of characteristics depicting the recovery of the regional innovation system. At the same time, unlike the Královéhradecký and Pardubický Regions, the Moravskoslezský Region shows higher values for both categories of quantitative characteristics.

Both the Královéhradecký and Pardubický Regions are classified as regional innovation systems with highly advanced hard and partially advanced soft infrastructures; this is illustrated by the effect values in each group, which hover around 0.2. Their values are slightly higher for the required quantitative characteristics that define the hard infrastructure.

Conclusions

The level of RIS development was determined by the level to which the defined characteristics had been developed. The level of RIS development was depicted by determining values using the WSM and by the descriptive analysis summarized in Tables 4 – 6.

The use of the WSM is simple in terms of calculating and obtaining specific values. On the other hand, the use of this method has some drawbacks in that it does not show the effects resulting from each characteristic. It only gives the accumulated value for the effects of each indicator. Furthermore, using such a method requires the weighting vector to be expressed numerically.

The results derived from the use of the WSM can be authenticated by the use of another multi-criteria evaluation of the alternative. This method consists of the analytic hierarchy process (AHP) for validating results and is appropriate because it works on the same principle as the WSM, and its results are easy to compare. The use of the AHP method provides more detailed values than the WSM. On the other hand, the application of the AHP makes it easier to evaluate the degree of RIS advancement.

This paper provides evidence that, with the help of the appropriate analytical model, it is possible to evaluate regional innovation systems at the level of the individual region. Due to highly demanding input data, it is necessary for the evaluation to be conducted by an independent, professionally qualified entity (for example, an expert from a university or research center). Thanks to the way the selected indicators are composed, it is possible to provide partial results as part of the analysis – these testify to the individual determinants for the innovation policies implemented in the region. This gives these economic (and also sometimes political) entities a definite form of feedback; they show which areas and which specific aspects can be improved and where to allocate financial resources from private or public sources. Regarding the method's versatility, it is also possible to use it in a reasonable way as the foundation for the benchmark evaluation system.

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