*Bajmócy, Z. – Lengyel, I. (eds) 2009: Regional Competitiveness, Innovation and Environment. JATEPress, Szeged, pp. 99-121.*

# Measuring the Innovation Performance of Hungarian Subregions

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*Today's spatial economic processes are heavily influenced by the conditions of the learning-based economy. In this peculiar framework one of the main drivers of regional change is technological change occurring through the sequence of innovations. Therefore, the interpretation and measurement of territorial innovation capacity has become one of the main fields of interest in regional economics; however, the analyses conducted in lower levels of territorial aggregation raise several methodological problems.*

*Present paper aims to analyse and evaluate the innovation capacity of the Hungarian LAU-1 subregions on the theoretical basis of the regional systems of innovation. We rank the innovation capacity of the subregions along distinct dimensions and also complexly, then we carry out the classification of the subregions, and we also analyse the spatial regularities of the innovation capacity. In the last chapter we attempt to shed light on the limitations of the applied approach in order to discuss the problems of the usual methods of innovation-measurement and thus to provide possible future research directions.*

*Keywords:* *regional systems of innovation, measuring innovation capacity, subregion*

## 1. Introduction

In today's "knowledge-based" or "learning-based" economy there exists a close correlation between innovation capacity and the desired economic processes of the different regions. Through learning and innovation capacity, regions acquire unique resources that are hard to reproduce and help them to perform well in the territorial competition (Storper 1997, Lengyel 2003). Therefore, grasping the innovation capacity (potential) of the different territorial units has become a field of intense research.

Although innovation research is primarily not rooted in regional science (Solow 1957, Nelson–Winter 1982, Inzelt 1998, Marinova–Phillimore 2003, Fagerberg 2005), spatiality has still been closely associated to the study of the innovation process and innovation capacity right from the beginning (Hägerstrand 1952, Moulaert–Sekia 2003, Dőry 2005, Lagendijk 2006).

On the one hand, regional science has drawn attention to the fact that innovation is a spatial phenomenon which largely depends on region-specific resources impossible to reproduce elsewhere (Ács et al 2000, Asheim–Gertler 2005, Storper 1997). Consequently, the spatial situation and proximity of players represents an important determining factor of innovation (Varga 2009).

On the other hand, it also explored that analysis on the subnational level assumes essential importance when exploring the innovation capacity (Doloreux 2002, Tödtling–Trippl 2005, Hollanders 2006, Lengyel–Rechnitzer 2004), since the innovation potential of a given country may assume some characteristic spatial structure and display significant territorial disparities.

The *present paper* deals with this latter subject area by analysing the structure of national innovation capacity on the level of subregions. The first part of our paper reviews the interpretation possibilities of regional innovation capacity together with the measurement approaches deriving from them. This is followed by introducing the methodology of our subregional analysis and demonstrating the results emerging from the survey.

Our survey focused on various aspects. On the one hand, it aimed to utilize the experience of the most significant Hungarian and international studies that focus on the measurement of the innovation capacity of territorial units. On the other hand, we intended to gain an overall ranking also covering the different subareas that, beyond comparing the performance of the different territorial units, can also be used to identify the relative strengths and weaknesses of a given subregion. Furthermore, we intend to offer a categorization of Hungarian subregions based on innovation capacity. Beyond all that, we analyse the regularities of the spatial structure of subregional innovation capacity, the potential (spillover) effects of neighbouring subregions.

The final chapter of the paper examines the limitations of the applied approach, by which we also attempt to draw attention to some crucial points that represent general problems of the measurement approaches of territorial innovation capacity. This also offers potential future research directions. Finally, we summarize our most important findings.

## 2. Interpreting and measuring the innovation capacity of regions

The innovation process is closely linked to spatiality. Storper's (1997) concept of the "regional worlds of innovation" alludes to this, while the different territorial innovation models (TIM) unfold the same idea (Dőry, 2005, Moulaert–Sekia 2003, Lagendijk 2006). Therefore, innovation does not merely have a spatial aspect, but the spatial situation (distribution) of the players and the given regional environment exercise an endogenous influence on its outcome (Varga 2009).

Regional science has constructed various concepts (TIM) that aimed to explain the excelling innovation performance of certain regions (and consequently their competitiveness and success). These theories basically provide a description of the peculiar characteristics of successful regions compared to others.

The concept of *regional innovation systems* (RIS), that has assumed special significance among TIM models in relation to explaining innovation capacity, partly follows this tradition. Besides emphasising spatiality, this approach obviously carries the attributes of the system models of innovation as well. Compared to other TIM models, the RIS concept carries one considerable advantage in terms of the interpretation possibility of territorial innovation capacity. The concept of regional innovation systems (similarly to national innovation systems) derives the innovation performance of regions from elements that are more or less present in all regions and differ only in terms of their performance and the frequency of interactions among the elements. This way, by reviewing system elements and their relations we may gain a picture about the innovation performance (potential) of the region[1].

Tödtling and Trippl (2005) describe regional innovation systems as an open formation, the major elements of which are the subsystems of "knowledge-generation and diffusion", that of "knowledge application and exploitation", their system of relations and the policies influencing all these. Similarly to Cooke's (2004) interpretation, they emphasise the social embeddedness of RIS. The RIS concept does have strong institutional and evolutionist economic roots, thus, amongst factors influencing innovation activity, they review the historically emerged local institutional and infrastructural environment, system of rules and relations and mechanisms of interest representation.

Doloreux (2002) also defines regional innovation systems as the total of elements and relations. He classifies the players of the system into four basic categories: companies, institutions, knowledge infrastructure and regional innovation policy. He emphasises interactive learning, knowledge creation, proximity and social embeddedness as most important system mechanisms.

In the course of defining the elements of the regional innovation system (and potential at the same time), Dőry (2005) highlights six categories: R&D activities of enterprises, relations of enterprises, innovation-related services, technology supply, policies and regional environment. Consequently, this approach in fact includes factors similar to those formerly mentioned as well: the system of knowledge creation and exploitation as well as the background conditions and policies facilitating this.

Although it does not always occur in the systematization of RIS elements in an explicit way, yet, recognizing the role of the background factors that enable the learning capacity of players and therefore the continual adaptation capacity of the region constitute an inherent part of the approach. The concept of the so-called "smart" infrastructure (Malecki 1997, Stimson et al 2006) represents a pattern widely used for systematizing these background factors. The "smart" infrastructure

[1] At the same time, we must note that certain authors (similarly to other TIM models) interpret RIS as the collection of attributes that distinguishes certain regions in the course of territorial competition. So according to them, the mere existence of the system elements is not enough to construct a RIS, since it also requires the presence of actual regional (local) among the subsystems (Asheim–Coenen 2005).

embraces physical and “soft” elements as well as (knowledge-intensive) business services, which essentially encourages the learning capacity of the companies in the region.

Consequently, the interpretation of RIS and therefore regional innovation capacity means grasping certain relevant elements and the system of relations existing among them. Available approaches practically emphasize the importance of *knowledge creation, knowledge exploitation, the background conditions enabling or encouraging these (“smart” infrastructure) and the complex system of relations existing among them.* So essentially, when grasping the innovation capacity of regions, reviewing these categories seems effective. Consequently, grasping innovation capacity requires a complex measurement approach.

The majority of practical attempts aiming at the measurement of innovation reflect on this. In the literature we can see two significantly different approaches concerning the area of measuring the innovation performance of territorial units. *One of the schools* (that seems more dominant in Europe) concentrates on quantifying the elements of the innovation system and the relations existing among them. The surveys carried out in the frameworks of the “European Trend Chart of Innovation” belong here: the different Scoreboard reports and the methodological background studies of these (EIS 2007, Arundel–Hollanders 2005, Hollanders 2006, Kanerva et al 2006). Most Hungarian attempts may also be classified to fall in this group: Csizmadia and Rechnitzer’s (2005) survey concentrating on Hungarian cities, Kocziszky’s (2004) study focusing on subregions in Northern Hungary or the regularly published reports entitled “Innovation in Western Transdanubia” (Csizmadia et al 2008). The strength of these attempts definitely lies in the complex interpretation of innovation – going beyond research and development and its outputs – and the application of the results of innovation system theories, while the problem of the selection and potential weighting of indicators represents their weakness.

At the same time, there exists a substantially *different approach* in measuring innovation capacity, where innovation capacity is reduced to an indicator considered relevant (while the rest of indicators are taken into consideration only indirectly, in the light of the relation to this dependent variable). Porter and Stern’s (2003) “National Innovation Capacity” index may represent the best known example of innovation surveys falling in this family. When ranking the innovation capacity of countries, they consider the number of patents registered at the United States Patent and Trademark Office to be the dependent variable. Other indicators are entered in the National Innovation Capacity index based on what type of relation they have with the dependent variable above (in a regression model).

The strength of the approach lies in the relative objectivity of selecting the indicators (based on their explanatory power) and weighting them (weight is provided by the regression coefficient) within the model. The explanatory potential of the indicator and the value of the regression coefficient clearly justify its inclusion in the survey. However, the weakness of the approach derives from the same aspect, since the selection of a single highlighted dependent variable poses considerable problems; in fact, it equates innovation to invention. Furthermore, it is difficult to find a dependent variable that could apply almost equally well to a wide range of countries (territorial units). This is why the work of Porter and Stern, for example, is subject to a lot of criticism (despite the fact that it is frequently cited).

On the whole, in our opinion the approaches based on system models can draw a much more diversified picture about the innovation capacity of territorial units together with its structure despite their certain weaknesses. Moreover, they reflect the nature of the innovation process much more, and can leave the linear approach of innovation behind. Therefore, our analysis carried out in the present paper is committed to this approach.

## 3. Methodology

Our analysis provides the comparison (ranking) of the innovation capacity of the Hungarian subregions, their classification and we also examine the regularities in the spatial distribution of innovation capacity. The 168 Hungarian subregions defined by Government Decree 244/2003 constituted the basic *units of the analysis*. Although the presently valid classification defines 174 subregions, the statistical data used by us could not be aggregated according to the new territorial classification in all cases.

*The first step of the analysis* was the selection and grouping of the set of applicable indicators. In creating the groups of indicators, we strived to provide the building elements of a “typical” regional innovation system in line with the measurement approaches based on the literature of innovation systems. We established three categories, each of which constitutes the basis of a subindex. These are: knowledge creation, knowledge exploitation and the “smart” infrastructure (Table 1).

The indicators of the subindex of *knowledge creation* measure the capacity of creating scientific and technological knowledge. These indicators are widely used; they constitute the elements of most innovation analyses. We must note that several approaches narrowly interpreting innovation do not go beyond this range of indicators; and draw conclusions by equalizing research and development (R&D) with innovation. Since R&D does not necessarily lead to innovation, and innovation does not necessarily presume R&D (OECD 2005), it is essential to develop further categories.

*Table 1.* Indicator set for measuring subregional innovation capacity

| Category | | Indicator | |
|---|---|---|---|
| **Knowledge creation** | 1 | Number of R&D performing units per 100000 inhabitants | 1 |
| | 2 | Total staff of R&D units per 1000 inhabitants | 2 |
| | 3 | Number of scientists with PhD per 10000 inhabitants | 3 |
| | 4 | Number of teaching staff of higher education institutions per 1000 inhabitants | 4 |
| | 5 | Investments of R&D units per 1000 inhabitants | 5 |
| | 6 | R&D costs per 1000 inhabitants | 6 |
| | 7 | Expenditures of R&D places per 1000 inhabitants | 7 |
| | 8 | Number of patents in a 5 year period per 10000 inhabitants | 8 |
| **Knowledge exploitation** | 1 | Export sales as a percent of total sales | 9 |
| | 2 | Export sales per inhabitant | 10 |
| | 3 | Number of foreign owned companies per 1000 inhabitants | 11 |
| | 4 | Share capital of foreign owned companies as a % of total share capital | 12 |
| | 5 | Incomes from intellectual properties per inhabitant | 13 |
| | 6 | Percent of companies in NACE 24 and 29-34 divisions within all companies (high and medium tech manufacturing) | 14 |
| | 7 | Percent of companies in NACE 64 and 72-73 divisions within all companies (high-tech services) | 15 |
| | 8 | Percent of companies in NACE 74 division within all companies (business services) | 16 |
| | 9 | Number of knowledge-intensive firms with more than 50 employees per 100000 inhabitants | 17 |
| **Smart-infrastucture** | 1 | Per cent of employees with university or college degree | 18 |
| | 2 | Percent of white collar workers in leading positions within all employees | 19 |
| | 3 | Number of full-time students in higher education institutions per 1000 inhabitants | 20 |
| | 4 | Number of ISDN lines per 1000 inhabitants | 21 |
| | 5 | Broad band internet access per 1000 inhabitants | 22 |
| | 6 | Registered members of public libraries per 1000 inhabitants | 23 |
| | 7 | Cinema visits per 1000 inhabitants | 24 |
| | 8 | Museum visitors per 1000 inhabitants | 25 |
| | 9 | Tourist arrivals in public accommodation establishments per 1000 inhabitants | 26 |

*Note:* At indicators 14-16 the sector codes refer to TEÁOR'03. The source of data: TEIR – Hungarian Spatial Development Information System (indicators 4, 9-13, 20-26, reference year: 2007), Hungarian Statistics Office (HSO) Central and Territorial Database (indicators 14-17, reference year: 2005), HSO R&D Database (indicators 1-2. 5-7, reference year: 2007), HSO Census Database (indicators 18-19, reference year: 2001), Hungarian Patent Office Pipacsweb Database (indicator 8, reference year: 2000-2004) and Hungarian Academy of Sciences General Assembly Database (indicator 3, reference year: 2004).

*Source:* own construction

The indicators included in the subindex of *knowledge exploitation* substantially aim at grasping the characteristics of the private sector capable of exploiting innovations, so on the one hand, it uses indicators like export share or the presence of foreign direct investment, on the other hand, it indicates the share of the knowledge intensive sectors.

The subindex of the *"smart" infrastructure* systematizes the factors that are required for the operation of the performances measured by the two other subindexes. This, on the one hand, means the presence of "talent" and the conditions necessary for its maintenance (e.g. cultural activities, entertainment), the "openness" of the region in a non-economic sense (e.g. the number of visitors) and the utilization of information and communication technologies.

In the course of selecting actual indicators associated with the different subindexes, the sets of indicators included in various former measurement attempts were reviewed[2], taking into consideration the subregional availability of the different indicators. Based on all this, the survey was started with *26 indicators*, eight of which were classified in the subindex of knowledge creation, nine fell in the subindex of knowledge exploitation and another nine were included in that of the "smart" infrastructure.

Since the analysis aims at grasping innovation capacity, we tried to avoid including elements – present in various reviewed analyses (Csizmadia–Rechnitzer 2005, Kocziszky 2004) – that indicate the general income producing capacity of the economy, since this results in confusion in grasping capacities for innovating and capacities emerging from innovation.

Furthermore, it is also important to highlight that all of our indicators measure relativized values; we mostly used indexes that represent the size of the region as the base of projection. The advantage of this lies in the fact that the values of the different subregions become comparable, while its drawback is that it does not measure the absolute concentration of activities, although in certain cases there is a presumable relation between the volume and efficiency of innovation-related activities (Varga 2009).

*The second step of the analysis* involved the comparation of the innovation capacity of subregions and their ranking. In calculating the different indexes (and providing the rankings this way), we relied on the methodology used in the surveys of the "European Innovation Scoreboard" (EIS) – both the Summary Innovation Index (SII) and the Service Sector Innovation Index (SSII) is constructed in a similar

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[2] The Summary Innovation Index (EIS 2007) of the European Innovation Scoreboard (EIS), the Service Sector Innovation Index (Kanerva et al 2006) of the European Trend Chart on Innovation, the EXIS Summary Index (Arundel–Hollanders 2005), the Euro-Creativity Index of Florida–Tingali (2004), the set of indicators of the European Regional Innovation Scoreboard Summary Index (Hollanders 2006), the indicators applied in Csizmadia and Rechnitzer's (2005) analysis of the innovation potential of Hungarian cities and the set of indicators used in Kocziszky's (2004) analysis of the innovation potential of the subregions in the Northern Hungarian region.

way. Our "Subregional Summary Innovation Index" (SRSI) was created through the following steps:

- *Defining the minimum and maximum values* of the different indicators. It was true for almost all the indicators that the data of one or two subregions excelled (usually in the positive direction) compared to the Hungarian average value. Data were considered as outlier if their deviation from the national average was above three times the standard deviation. Outlier data were not taken into account in the course of defining minimum and maximum values (this was needed to prevent the subsequently emerging scale from being too concentrated).
- *Rescaling data*. We deducted the minimum value emerging in relation to the given indicator from each figure, and divided by the difference of the maximum and minimum value. This way each rescaled value falls between 0 and 1. Outlier data received the value of 0 or 1 (depending on the direction of the deviation).
- *Establishing subindexes*. The different subindexes emerge as the arithmetical average of the values of the indicators associated to them. The potential weighting of the indicators may represent a possible step; however, in the course of the analysis – in harmony with the methodology of EIS – emphasis fell on clarity.
- *Developing the SRSI and establishing ranking*. The SRSI is the arithmetical average of the three subindexes. The ranking of the Subregional Innovation Capacity derives from ranking SRSI values in a decreasing order. Index (and subindex) values are values measured on a ratio scale; therefore, they are suitable for grasping the distance from other regions, and comparison with the national average.

Consequently, the SRSI index of the different subregions characterises the region's innovation capacity in a complex way based on a complex set of indicators. The approach goes beyond frequently used analyses focusing on R&D: besides the capacity of knowledge creation, it also characterises the subsystem of knowledge exploitation and the quality of the "smart" infrastructure necessary for operating all these. Therefore, the innovation capacity of regions that have good performance based on the SRSI is generally the result of a complex performance with multiple foundations. At the same time, it might happen that a region assumes a relatively advanced position in the ranking based on the SRSI due to the outstanding value of a given area; therefore, the analysis of performance according to the different subindexes is also required.

*The third phase of the analysis* consists of providing the potential classification of subregions based on their innovation capacity. This occurred similarly to the method of Csizmadia and Rechnitzer (2005) in their analysis of the innovation potential of Hungarian cities. Classification took place on the basis of the three subindex values.

We carried out K-means cluster analysis using the standardized values of the three subindexes. The analysis was completed with three, four and five clusters. Classification seemed relatively stable, the increase in the number of clusters led to the further division of certain groups, but no significant change occurred in the members of the different groups. Based on the dispersion of distance measured from the cluster centre, the establishment of five groups resulted in the emergence of most homogeneous (and most easily interpretable) clusters; therefore, this seemed the most supported solution.

In the fourth step of the analysis, we examined the spatial regularities of subregional innovation capacity, that is, whether the data of adjacent territorial units are similar. In fact, we measured spatial autocorrelation with the help of the Moran index on the national level, and the "Local Moran Index" on the subregional level.

The index number proposed by Moran in 1948 called the Moran index measures spatial autocorrelation similarly to the autocorrelation of time series data (Moran 1950, Anselin 1988, Dusek 2004). It is calculated in the following way:

$$I = \frac{M}{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}} \frac{\sum_{i=1}^{M}\sum_{j=1}^{M} x_i w_{ij} x_j}{\sum_{i=1}^{M} x_i^{\,2}}$$, where

- M: the number of territorial units, in our case this means 168 subregions,
- $x_j$: the value of the examined data values associated to territorial unit j, in our case, the value of the different subindexes and the SRSI associated to subregion j.
- $w_{ij}$: item j of line i of the neighbourhood matrix, its value is 1 if subregions i and j are neighbours, otherwise it is 0.

Since the neighbourhood of territorial units can be interpreted in multiple ways, therefore, various neighbourhood matrixes can be created. In the followings, we used bastion neighbourhood as the basis, which means that $w_{ij}$ received the value 1 if subregions i and j have a shared border area, otherwise the value of $w_{ij}$ is 0.

The size of the pseudo-significance level calculated by the Monte Carlo method and the algebraic sign of the value I define the size of autocorrelation and its direction indicated by the actual Moran I value (Table 2).

*Table 2.* The interpretation of the Moran Index

| Significance | Index value | Interpretation |
|---|---|---|
| p < 0,05 és | I < – 0,00598 | Strong negative autocorrelation |
| 0,05 ≤ p < 0,1 and | I < – 0,00598 | Weak negative autocorrelation |
| 0,1 ≤ p | | Autocorrelation is not significant |
| 0,05 ≤ p < 0,1 and | I > – 0,00598 | Weak positive autocorrelation |
| p < 0,05 and | I > – 0,00598 | Strong positive autocorrelation |

*Note:* „p" represents pseudo-significance. Index value must be compared to -1/(M-1), which, in our subregional database, has a value of -0,00598

*Source:* own construction on the basis of Cliff and Ord (1981)

The other index number – closely related to the Moran Index – calculated by us is the Local Moran Index that can be interpreted as the local index number of spatial autocorrelation. These values can be calculated separately for each subregion. In our case, the actual subregional standardized value of the examined innovation index is multiplied by the joint average standardized value of the neighbours of the subregion. If the Local Moran Index value calculated this way is positive, then the given subregion is similar to its neighbours; if, on the other hand, the value is negative, then it is different from them. This way subregions can be divided in five categories based on their comparison to the original standardized index value (Table 3).

*Table 3.* The interpretation of the Local Moran Index

| | Interpretation | Condition |
|---|---|---|
| **High – High** | Both the given subregion and its neighbours have and index values significantly above the average. | Local Moran I > 0<br>Standardized indicator value > 0<br>p < 0,05 |
| **High – Low** | The given subregion has significantly above the average, while its neighbours below the average index values. | Local Moran I > 0<br>Standardized indicator value < 0<br>p < 0,05 |
| **-** | No significant correspondence. | p > 0,05 |
| **Low – High** | The given subregion has significantly below the average, while its neighbours above the average index values. | Local Moran I < 0<br>Standardized indicator value > 0<br>p < 0,05 |
| **Low – Low** | Both the given subregion and its neighbours have and index values significantly below the average. | Local Moran I < 0<br>Standardized indicator value < 0<br>p < 0,05 |

*Note:* „p" represents pseudo-significance.

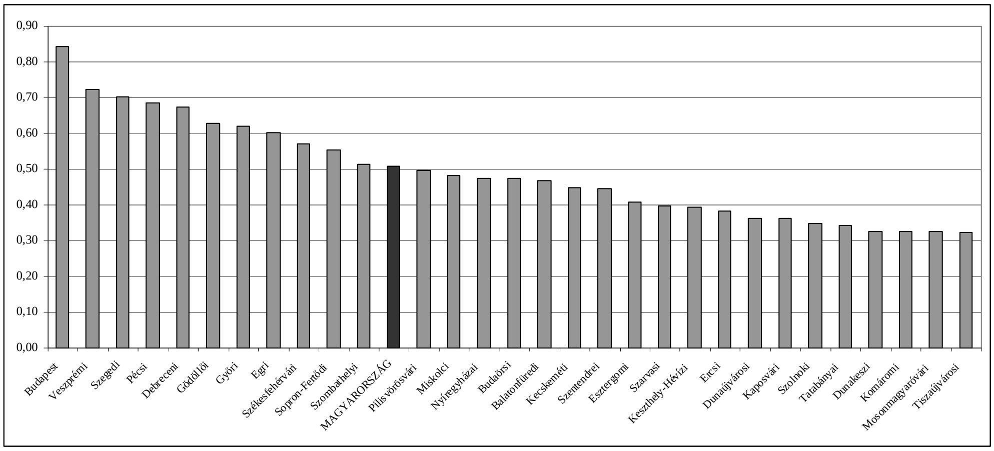
*Source:* own construction

## 4. The innovation capacity of Hungarian subregions

The innovation capacity of Hungarian subregions is comprehensively introduced with the help of the SRSI and its subindexes, which is followed by the classification of subregions based on innovation capacity and the analysis of spatial regularities.

One of the most general statements that can be made based on the SRSI is that in terms of innovation capacity, *Hungary is characterised by enormous disparities* (Figure 1). There are only 11 subregions with performance above the Hungarian average (0,51 SRSI value). The performance of the other 157 subregions ranges below the average. All this implies that innovation capacity is unbelievably concentrated spatially in Hungary.

*Figure 1.* Top 30 subregions based on the subregional summary index




*Source:* own calculations

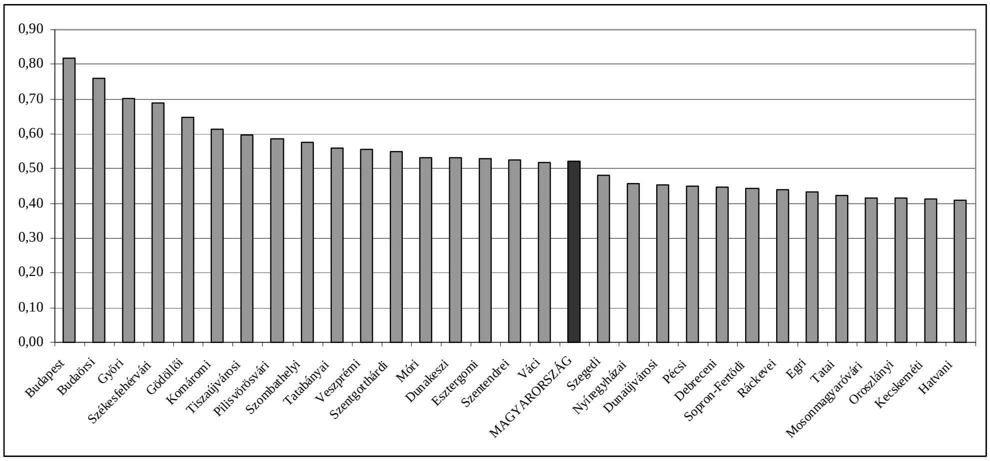
Out of the first 30 subregions, 18 have cities with county rights; however, the rank is not completely in line with expectations. Although Budapest's first place and the notable position of the Debrecen, Szeged and Pécs subregions meet expectations, the good ranks of the Veszprém, Gödöllő and Eger subregions are rather surprising. Among regional centres, the Miskolc subregion only assumed the 13th position. Out of subregions without cities with county rights the Gödöllő subregion is among the first 10 (ranked 6th), while further five subregions were among the first twenty: the Pilisvörösvár, Balatonfüred, Szentendre, Esztergom and the Szarvas subregions. It is important to underline, that six subregions that have cities with county rights could not make it to the first 30. These are the Zalaegerszeg (31), Békéscsaba (34), Hódmezővásárhely (38), Nagykanizsa (43), Szekszárd (44) and the Salgótarján (51) subregions.

Budapest's SRSI value (0,84) excels compared to the other subregions – although not overtly. It must also be mentioned that Budapest produced outlier values for 17 of the 26 indicators. Since in this case it automatically received the value 1 (although its performance is higher in reality), the index value carries a downward distortion. Although a relatively large number of subregions showed outlier data related to certain indicators, there were only three further subregions with more than four outlier data: the Debrecen (8), Pécs (6) and the Szeged (9) subregions.

The summarized results are further shaded by the ranks based on the different subindexes. Based on this it becomes apparent that the capacity of subregions is "one-sided" or has "multiple foundations". Budapest has the first position in the rank according to the *subindex of knowledge creation*. The subindex-based ranking reflects well the territorial distribution of major Hungarian universities and the research institute network of the Hungarian Academy of Sciences. This is obviously the consequence of the fact that a significant part of research and development activities is tied to these institutes in our country (In Hungary, the proportion of public financing compared to company financing in R&D is much higher than the European average, although this is far from true compared to the GDP).

The territorial concentration of knowledge creation is even higher than it was in the case of the SRSI. Only 10 subregions exceed the national average value (0.56). The value of the subregion ranking 30th is already below 0.25. In accordance with this, the favourable ranking of various subregions with small city centres is not necessarily accompanied by good performance in terms of absolute value. A favourable relative position may go hand in hand with an unfavourable absolute one.

*Figure 2.* Top 30 subregions based on the knowledge-exploitation sub-index




*Source:* own calculations

17 subregions exceed the national average value (0.52) of the *knowledge exploitation subindex* (Figure 2). The ranking based on this element of innovation

capacity is completely different from what would emerge in the case of knowledge creation. The Szeged, Pécs and Debrecen subregions reputed to be innovation centres assumed only positions 18, 21 and 22.

Interestingly, various subregions that excel in attracting foreign direct investment and (partly due to this) in export, also perform well according to the other indicators of the category (e.g. proportion of knowledge-intensive services).

The capacities of knowledge creation and knowledge exploitation (the capacity to manufacture products with high added value that can even be marketed internationally) are spatially divided in Hungary. Knowledge exploitation often does not utilize locally produced knowledge, while the results of R&D are poorly utilized in economic terms. Only few regions showed stable and strong positions in both areas: besides Budapest, the Gödöllő and maybe the Győr subregions may be mentioned.

The ranking deriving from the *"smart" infrastructure subindex* reflects the hierarchy of the national urban network, although with smaller differences. Beyond subregions with large city centres, some subregions with less population that function as significant (cultural) touristic targets could reach a notable position (the Keszthely-Hévíz and Szentendre subregions). At the same time, in order to reach a good position in the rank it was not enough to perform well in terms of one or two indicators. The performance of the above subregions is beyond average in terms of five or six indicators of the category. 21 subregions exceeded the national average value (0.44). It is worth noting that while in relation to knowledge creation, the value of the subregion ranking 30th already goes below 0.25, here only the subregion ranking 58$^{th}$ has the same result.

Differences in ranking are perfectly reflected in measuring the joint movement of subindex values as well. The relation existing between knowledge creation and knowledge exploitation is much looser than that of knowledge creation and "smart" infrastructure values (Table 4).

It is highly important to examine whether innovation capacity is reflected in the differences apparent in economic performance. This also serves to control the results of the survey. Both in terms of the SRSI and the different subindexes, medium or strong positive correlation manifest with the Gross Value Added per capita (GVA) and the income serving as the basis of Personal Income Tax. The connection is a bit looser with the "GVA per employee" and the "profit before tax per employee", that can be interpreted as productivity indicators, although in terms of knowledge exploitation and the SRSI, this also means a relatively strong connection.

In harmony with expectations, the subindex of knowledge exploitation shows the closest connection with income and productivity indicators, while the connection of knowledge creation is the loosest to them. This also proves the relevance that the category of the "smart" infrastructure assumes. The correlation matrix obviously proves that connection of innovation capacity and economic performance, however, the intensity of the connection implies that the two do not derive from each other in a deterministic way.

*Table 4.* Correlation matrix of certain income indicators and the subregional summary index

| | KCR | KEI | Smart | SRSI | GVA p.c. | PBT | GVA p.e. | Tax |
|---|---|---|---|---|---|---|---|---|
| **KCR** | 1,000 | | | | | | | |
| **KEI** | 0,592 | 1,000 | | | | | | |
| **Smart** | 0,778 | 0,631 | 1,000 | | | | | |
| **SRSI** | 0,919 | 0,823 | 0,900 | 1,000 | | | | |
| **GVA p. c.** | 0,476 | 0,731 | 0,521 | 0,641 | 1,000 | | | |
| **PBT** | 0,312 | 0,556 | 0,297 | 0,433 | 0,773 | 1,000 | | |
| **GVA p. e.** | 0,446 | 0,704 | 0,498 | 0,610 | 0,992 | 0,773 | 1,000 | |
| **Tax** | 0,557 | 0,878 | 0,644 | 0,769 | 0,671 | 0,451 | 0,628 | 1,000 |

*Note:* Pearson's correlation. For all values in the matrix: p<0,01. KCR: knowledge creation subindex, KEI: knowledge exploitataion subindex, Smart – Smart infrastructure subindex, SRSI: subregional summary innovation index, GVA p.c: gross value added per capita, PBT: profit before tax per employee, GVA p.e: gross value added per employee, Tax: Personal tax base per inhabitant.
*Source:* own calculations

Furthermore, another question lies in why innovation capacity shows a more intense connection with the basic values of personal income tax per citizen than it does with work productivity indexes (since as a result of innovations, we would expect improvement in productivity more than increase in incomes). The reason of this – in our opinion – is that it is difficult to separate the maintenance of innovation capacity from the presence of highly qualified "talents" working in positions that are paid better than the average.

*Table 5.* Final cluster centres in case of five cluster

| | Weak innovation capacity | "One-sided" knowledge creating | "One-sided" knowledge exploiting | Medium innovation capacity | Strong innovation capacity |
|---|---|---|---|---|---|
| | N=99 | N=3 | N=38 | N=18 | N=10 |
| **Knowledge creation (Zscore)** | -0,4523 | 2,1776 | -0,2007 | 0,8183 | 3,1144 |
| **Knowledge exploitation (Zscore)** | -0,6415 | -0,0988 | 0,7520 | 0,8990 | 1,9050 |
| **Smart infrastructure (Zscore)** | -0,4984 | -0,4025 | -0,0824 | 1,5666 | 2,5479 |

*Source:* own calculations

The analysis completed so far already implies clearly that the innovation capacity of Hungarian subregions strongly differ. Some subregions may be characterised by relatively strong innovation capacity, while the innovation performance of the majority of subregions proves rather poor. Moreover, the different rankings of the different subindexes imply that relatively strong innovation performance can be achieved in various ways, and subregions form groups in this respect too.

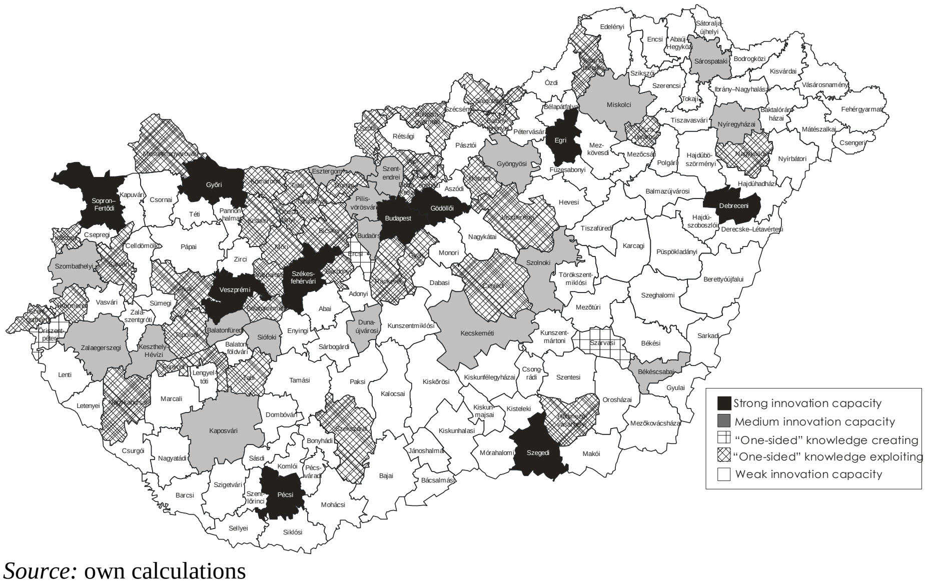
The K-means cluster analysis carried out on the basis of the standardized values of the three subindexes confirmed that subregions can be classified based on their innovation capacity. The *five groups* emerging based on the relation to the criteria defining the cluster can be interpreted relatively easily (Table 5 and Figure 3):

- *Subregions with strong innovation capacity* (10) that, in terms of all three subindexes, perform significantly above the average. The cluster is relatively homogeneous, the standard deviation of the (Euclidean) distances from the centre is 0.38 (without Budapest this value is only 0.33). Although cluster members show good performance in all three categories, their value is the strongest in terms of knowledge creation. The vast majority of cluster members are university towns.
- *Subregions with medium innovation capacity* (18) that have a relative performance in all three areas, but especially in terms of the "smart" infrastructure. Mostly subregions with larger city centres as well as certain subregions of the Budapest agglomeration belong here. This cluster is less homogeneous; the standard deviation of distances from the centre is 0.43.
- *"One-sided" knowledge exploiting subregions* (38) are the ones that show a relatively good performance in terms of knowledge exploitation while they prove rather weak in the other two areas. We must note at the same time that in certain cases this relatively good performance is explained by small size. On the other hand, certain values show such territorial concentration that the good position assumed in the subregional ranking may also cover a weak absolute performance (lagging behind the national average). The cluster is homogeneous; the standard deviation of distances is 0.28.
- *"One-sided" knowledge creating regions* (3) are the ones whose knowledge creating activity is outstanding, while their performance in terms of the other two subindexes is weak. All three subregions belonging in this group have relatively small population; therefore, the relatively strong knowledge creating capability may not assume such significance. Also due to the small number of items, the cluster is highly homogeneous; the standard deviation of distances is 0.10.
- *Subregions with weak innovation capacity* (99) include the majority of the country's subregions. The performance of these is rather weak in terms of all three subindexes. Despite the great number of items, the cluster is homogeneous; the standard deviation of the distances from the cluster centre is 0.23.

The clusters are clearly distinct; classification is obvious in almost all the cases. Compared to the classification deriving from three and four clusters, the cluster of "mediums" was further divided, and the two "one-sided" clusters emerged from it. Furthermore, some formerly strong regions migrated to the cluster of medium strength, and some other formerly weak ones fell into the category of one-sided knowledge creating subregions.

Accordingly, there are only two areas in which the borders among groups are slightly blurred. The best performers among the subregions with medium innovation capacity stand really close to the cluster of strong ones. Consequently, the classification of the subregions of Pilisvörösvár, Miskolc and Nyíregyháza is not perfectly clear. The other similar area involves the weaker members in the cluster of one-sided knowledge exploiting subregions that, based on their performance, are not far from the subregions with weak innovation capacity.

*Figure 3.* Classification of Hungarian subregions on the basis of their innovation capacity




*Source:* own calculations

We also examined *what regularities does the spatiality of subregional innovation capacity show*, and whether the data of neighbouring territorial units are similar, since in certain cases, real economic territorial relations may cross subregional boundaries, therefore, the innovation performance of the different subregions may derive from the "spillover" effects of the neighbouring region. The significance of this is particularly obvious in sight of the ring of subregions surrounding Budapest that have a relatively good innovation capacity. Such analysis may bring us closer to what the “ideal spatial distribution” of a national analysis of regional innovation would be.

Out of the SRSI and its three subindexes only one subindex involves a strongly significant (positive) autocorrelation among its territorial values, and that is the subindex of knowledge exploitation (Table 6). This means that the effect of factors strengthening the extent of knowledge exploitation goes beyond subregional boundaries.

In the case of the rest of subindexes and the SRSI, the presence of such factors surpassing subregional boundaries is not significant concerning the whole country. Still, in the area of Budapest, we can find a coherent system of subregions (Budapest and the Szentendre, Dunakeszi, Pilisvörösvár, Budaörs and Ráckeve subregions) where both subregions and their neighbours have high SRSI values, that is, they fall in the “high – high” class.

*Table 6.* Results of the global Moran I test

| Index | Moran I value | P value | Interpretation |
|---|---|---|---|
| Knowledge creation | -0,0330 | 0,30 | No significant autocorrelation* |
| Knowledge exploitation | 0,3442 | 0,00 | Strong positive autocorrelation* |
| „Smart” infrastructure | -0,0150 | 0,44 | No significant autocorrelation* |
| SRSI | 0,0622 | 0,11 | No significant autocorrelation* |

*Note:* * Significance level of 5%. Calculation were carried out by Geoda095i.
*Source:* own calculations

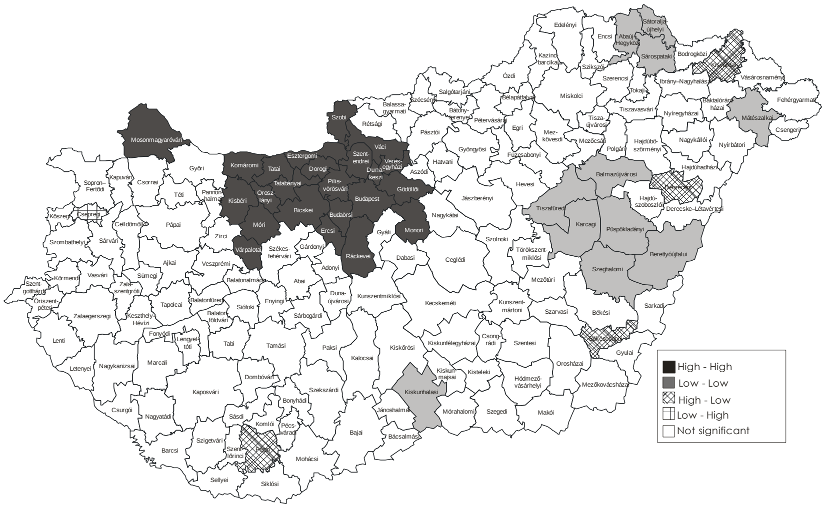
This implies that in terms of innovation capacity, the capital and the surrounding subregions constitute an organic unit, real territorial connections go beyond subregional boundaries significantly here. Results suggest that except for Budapest, there is no other significant innovation centre in the country that would have an innovation “radiation” transcending subregional boundaries (Figure 4).

Two phenomena cause the positive spatial autocorrelation of the capacity of knowledge exploitation: the spatial condensation of positive subindex values on one hand, and that of negative (standardized) subindex values, on the other hand. An intense territorial concentration of subregions with a high local Moran index value may be noticed in the area of Budapest (“high – high” class).

On the other hand, two further coherent areas are visible on the map: in the central part of the Trans-Tisza Region, and in North-Eastern Hungary, where both the subregion and its surrounding have low knowledge exploitation subindex value (“low – low” class).

So the spatiality of the knowledge exploitation capacity displays characteristic regularities. The possibility of the presence of a real regional system surpassing subregional boundaries may arise in Central Hungary (at least in terms of knowledge exploitation). At the same time, another important result lies in the fact that in the case of the other two subindexes no significant autocorrelation exists. This is less surprising in connection with “smart” infrastructure, since the values of this subindex correspond to the city-hierarchy relatively well (and consequently to its territorial appearance too). However, in terms of the subindex of knowledge creation, this definitely implies that the effect of research and development activities (and institutions dealing with research and development) does not go beyond their own subregion.

*Figure 4.* Spatial dispersion of Local Moran Index in case of the knowledge-exploitation subindex




*Note:* The figure represents the Local Moran I-Test values at a 5% level of pseudo-significance, by using bastion neighbourhodd matrix. In case of high-high relation, both the given subregion and its neighbours have high “Knowledge-exploitation” Subindex value. Calculations were carried out by Geoda095i.
*Source:* own calculations

## 5. Limitations and future research directions

The method applied in our analysis has various limitations – besides others – that are rooted in the general methodology of innovation measurement. Consequently, from the aspect of measuring the innovation capacity of territorial units and the scientific debates related to this, we consider the exploration of such limitations and the provision of potential future research direction to be of vital importance.

A part of the limitations inherent in the applied approach derive from *subnational level analysis*. This more or less characterises all similar measurement attempts, but it does not question the relevance of the method substantially. The difficulties of accessing territorial data generally require giving up complexity to a certain extent. Surveys conducted on a lower territorial agglomeration level are suitable for the utilization of company level innovation data much less than necessary, or, in the case of using company level data, they limit the scope of the survey to one or two regions (Hollanders 2006, Csizmadia et al 2008). Moreover, in this case, a fundamental result of the theory on innovation systems, namely, grasping the relations amongst the players of the system is excluded from the focus of the studies (or assumes less importance).

Approaches avoid another basic achievement of the literature on regional innovation systems, when they measure and compare the innovation capacity of regions that in certain cases have radically different characteristics based on the same criteria. The different types of the regional innovation system do not infer different measurement approaches. However, for example in a spatially embedded regional innovation system, the analysis of knowledge flows within an industrial branch and among the different branches says much more than, let us say, R&D activity would.

*The further limitations of the approach are much more of paradigmatic nature*. Related to measuring the innovation capacity of territorial units, an articulate uncertainty is apparent concerning what to measure and *what do we really measure*. On the company level, grasping innovation activity is relatively obvious (for example, in regularly conducted Community Innovation Surveys the criterion of an innovative company is clear). At the same time, the macro effect of micro level innovations may be anything (innovation, sales turnover or market share are not in direct connection). Maybe exactly because of this, it is not the innovation activity of regions, but the *capacity of innovation to contribute GDP per capita growth that is measured*. This approach, however, doubtlessly carries preconceptions: it connects the concepts of economic growth (competitiveness) and innovation capacity ex ante. In the light of this it is not surprising if innovation capacity and economic performance show close connection.

This may also explain low receptiveness to the different measurement of different regional innovation systems, since the capacity to contribute to economic growth as a “global objective function” creates a common denomination for the different regions in terms of measuring innovation capacity.

The general attribute of works aiming at comparing the performance of regions is that they *examine innovation capacity in a relative way (compared to others)*. Annually published rankings (like, for example, “Scoreboard” reports) are based on reviewing performance compared to the average. Therefore, improvement in performance corresponding to the average is interpreted as stagnation (any fallback smaller than the average would be displayed as improvement). In our opinion, this approach is basically rooted in the fact that studies (as already discussed) measure the capacity of innovation activity to contribute to economic growth (competitiveness). Competitiveness is in fact a relative category. Based on its approach, it practically does not matter what our performance is, if compared to others or our formal self it is good or undergoes improvement (Bajmócy 2007). This approach derives from the general view of mainstream economics and economic policy, according to which greater growth (competitiveness) is better than smaller (practically under all circumstances). In fact, this approach also penetrates the Lisbon strategy that created "Scoreboard" reports. Here, the main question became how much (and in what sense) the member states lag behind one another and especially behind the USA and Japan.

However, all this has another root (maybe going even deeper), and it is *the negligence* (in a certain sense) *of the Schumpeter tradition* in innovation measurement. Schumpeter's "creative destruction" continually deconstructs the old economic structure and replaces it with a new one (Schumpeter 1950). Furthermore, it is not only economic structure that changes, but in "co-evolution" with it, also the infrastructural environment, social relations, interest representation mechanisms and the relation of economy and the natural environment (Polányi 1944, Witt 2003, Kemp et al 1998). One consequence deriving from this process of creative destruction lies in the fact that innovation inevitably has its losers – at least in the short run. Moreover, it makes sense to assume that winners and losers also have different positions in terms of space.

The other fundamental criterion is that the innovation process – since it causes changes in the economy, society and the natural environment simultaneously – requires a great level of continual adaptation from the involved parties. In this case, however, the pace of change is not at all marginal, that is, in a given case, too fast change (outstanding innovation performance) can even result in catastrophic economic and environmental effects.

All this means that in measuring the innovation capacity of territorial units, the application of an approach much more complex than earlier ones seems efficient: integrating social and environmental effects into the measurement and grasping the "manageable" pace of change.

## 6. Summary

The present paper describes a complex analysis of the innovation capacity of national subregions based on multiple indicators, in the course of which we regarded the concept of regional innovation systems as a point of departure. Based on the complex system of indicators classified in three categories, the analysis goes beyond the approaches that emphasise solely research and development. Beyond knowledge creation, we also reviewed the performance of knowledge exploitation and the "smart" infrastructure necessary for the maintenance of all these.

Based on the results, it becomes apparent that the *territorial distribution of innovation capacity carries enormous disproportions in Hungary*. Innovation capacity is concentrated in few subregions. Besides the few subregions with strong innovation capacity, the group of those with medium innovation capacity is not wide either. This latter one characteristically embraces subregions with centres that have more population, although there are some exceptions to this.

It is highly important that *knowledge production and knowledge exploitation are spatially differentiated in Hungary*. The number of subregions that excel in both categories is rather small. The effect of knowledge creation typically does not go beyond subregional boundaries, and is only rarely accompanied by local knowledge exploitation. At the same time, knowledge exploitation capacity shows characteristic spatial patterns. In this respect, various subregions are interconnected organically in the surroundings of Budapest.

In the final chapter, we pointed out that the approaches aiming to measure the innovation capacity of territorial units have several limitations that suggest the necessity of reconsidering generally used schemes. Beyond economic indicators, grasping social and environmental changes induced by innovation at the same time seems efficient, since only the joint analysis of the three dimensions could provide a real basis for (the practice of) linking innovation capacity and the desired direction of change in subregions.

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