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Digital Futures

Analysis of Global Innovation Index (GII) and European Innovation Scoreboard (EIS)

Executive Summary

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Analysis of Global Innovation Index (GII) and European Innovation Scoreboard (EIS) – Executive Summary

This paper is a brief summary of the Hungarian-language study.

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The study was prepared within the framework of the Digital futures research, but it is also related to the results of the Future Potentials project and a deeper understanding of the indicators examined in the Future Potential Index (FPI), primarily in connection with the national innovation performance.

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The study presents the two most well-known innovation indices, the European Innovation Scoreboard (EIS) and the Global Innovation Index (GII). The analysis reviews 185 open science papers referring to the Global Innovation Index and/or the European Innovation Scoreboard. This can help identify the aspects of these indices and guide the definition of the scope of analyses that can be carried out later (further research directions).

In the study, the results of the two indices are compared based on several aspects, such as composite index level and separated by input and output indicators. In addition to comparing the results of the two measurement systems, we also attempt to examine the sensitivity of the European Innovation Scoreboard results. During the analyses, special attention was paid to exploring the results of Hungary.

A thorough understanding of innovation measurements is particularly important because, according to a survey, 70 percent of WIPO (World Intellectual Property Organization) member states use the GII to improve innovation ecosystems or as an international benchmark. The cooperation between statisticians, innovation actors, and policymakers could be important to understand countries' innovation performance, followed by a policy debate on exploiting innovation opportunities and overcoming weaknesses (WIPO, 2023). With our study, on the one hand, we would like to contribute to a deeper understanding of the results, and on the other hand we would like to provide a basis for further analysis.

1 Systematic literature analysis of relevant publications

The selection of scientific papers published concerning the EIS and GII measuring systems was carried out based on the PRISMA protocol (Moher et al., 2009). The bibliographic data were obtained from the Web of Science Core Collection database, for EIS and GII separately, by entering the search conditions Topic = "global innovation index" and Topic = "European innovation scoreboard". The search was performed in the titles, keywords, and abstracts. By setting the filter according to language (English) and document access (Open Access), 54 publications were selected for the EIS and 131 for the GII. As a result of screening the titles, abstracts, and keywords of the publications, nine publications were found to be relevant to the EIS, and 26 to the GII. There was one publication on both lists, so after excluding the duplicate, the systematic literature review was conducted on a total of 34 publications.

The systematic literature review has revealed that the EIS is used to evaluate and compare the innovation performance of EU member states (Filippetti et al., 2011; van Hemert & Nijkamp, 2010), to analyze the diffusion of innovation (Anderson & Stejskal, 2019), as well as to develop innovation policies and optimize resource allocation (Kuzior et al., 2022; Coutinho & Au-Yong-Oliveira 2023). Onea (2020) combines the analysis of innovation processes at the company and national levels by comparing company investments and employment to national innovation performance measured based on the EIS. According to some researchers (Kaynak et al., 2017; Kuzior et al., 2022), innovation performance values measured with the EIS can be used as reference values to evaluate innovation performance in non-EU countries.

The GII provides a comprehensive and standardized set of indicators that allows reliable international comparison of innovation performance (Barbero et al., 2021; Kuzior et al., 2022), the analysis of the effects of different innovation elements such as cultural dimensions and economic factors (Marti & Puertas, 2023; Kraftova et al., 2016), as well as the examination of the countries' innovation environment and the identification of the main influencing factors (Kraftova et al., 2016; Jankowska et al., 2017). GII data is widely used in empirical research, for example, in examining the correlations between 82 indicators related to innovation and GDP and research and development expenditures (Pençe et al., 2019; Dritsaki & Dritsaki 2023). Stefko et al. (2019) examine the relationship between innovation performance as measured by the GII and health satisfaction and the general human development index (HDI). Silva et al. (2020) use GII innovation performance values in a multi-criteria decision support approach to inform investment decisions in upper-middle-income countries.

The criticisms of the two measurement systems can be summarized as follows.

The complexity of the EIS indicator system and the equal weighting of individual indicators can lead to misleading information and do not necessarily cover a wider spectrum of innovation activities (van Hemert & Nijkamp, 2010, Bielinska-Dusza & Hamerska, 2021). The EIS does not consider the proximity of countries and their economic relations (Filippetti et al., 2011). The EIS methodology does not sufficiently take into account the dynamic and changing nature of innovation processes (van Hemert & Nijkamp, 2010). The EIS does not consider the interactions between different innovation dimensions, which can potentially distort the value of the composite indicator (Corrente et al., 2023).

Bielinska-Dusza and Hamerska (2021) attempted to reduce the number of indicators of the European Innovation Scoreboard (EIS). The 27 indicators used in the 2019 EIS report were reduced to 22 using a regression procedure. However, the reduced set of indicators ensured that the national ranking remained similar to the ranking according to the original indicator system. Through the involvement of experts from different European countries with knowledge and professional experience related to innovation, Corrente et al. (2023) attempted to weigh the dimensions of the EIS according to the importance of universities, industry, and government actors.

Several researchers (Barbero et al., 2021; Marino & Pariso, 2021) point out that the GII value is determined by simple arithmetic averaging sub-pillars, pillars, and sub-indices. However, they argue that this approach may oversimplify the complex nature of innovation systems. Tziogkidis et al. (2020) also state that the GII does not have an adequate weighting system for the indicators included, making it difficult to determine the relative importance of the latter. Roszko-Wójtowicz and Białek (2018) draw attention to the fact that the use of too many indicators in the GII indicator system can lead to possible redundancy and multicollinearity problems. Alidrisi (2021) refers to the underrepresentation of environmental protection aspects within the GII indicator system, which limits the measurement of innovation performance holistically. According to several researchers (Cvetanovic et al., 2014; Marti & Puertas, 2023; Voronenko et al., 2022), the GII ignores country-specific contexts and oversimplifies the complexity of innovation ecosystems by focusing primarily on R&D and technology-based innovations. Several researchers (Kraftova et al., 2016; Kowalska et al., 2018) also point out that the GII does not fully reflect the specific relationships of industrial structures or the unique innovation dynamics within each country. Various studies (Bulut, 2020; Nazarov et al., 2022; Rindasu et al., 2023; Petkovski, 2023; Costa Cavalcante, 2024) point out that the GII focuses heavily on quantitative indicators, which may mask qualitative aspects of innovation systems. Some researchers (Lee et al., 2022; Lourenço & Santos, 2023) emphasize the importance of considering the cultural factors of innovation. Havas (2016) emphasizes the importance of taking into account the unique characteristics of social innovations. One criticism of the GII is that it does not account for regional differences (Lee et al., 2022; Strielkowski et al., 2023). Van Hemert and Nijkamp (2010) point out that the indicators used by the GII are often static and do not necessarily reflect changes in innovation systems over time.

The input-output approach is used in various aspects to analyze innovation performance in studies. Below is a summary of the contexts and how this approach is applied to the EIS and GII measurement systems.

Concerning the EIS measurement system, Filippetti et al. (2011) distinguish between innovation inputs (e.g. business research and development expenditures, IT expenditures) and outputs (e.g. sales of new products, patents) when analyzing their relationship with internationalization indicators. Van Hemert & Nijkamp (2010) use the input-output approach to analyze innovation performance, especially to examine the relationships between the various factors contributing to innovation and the results of innovation activities. Kuzior et al. (2022) use the input-output approach in the regression model to show the effects of different input parameters on national innovation performance.

Regarding the GII measurement system, Barbero et al. (2021) use the input-output approach to analyze the quantity of innovation inputs and their efficiency concerning outputs, using Data envelopment analysis (DEA), a method suitable for measuring relative efficiency. Tziogkidis et al. (2020) evaluate the input and output indicators to determine the efficiency of the innovation. Duarte & Carvalho (2021) and Dritsaki & Dritsaki (2023) use the input-output approach to analyze the relationships between research and development expenditures and innovation results.

2 Comparison of the results of the two indices (GII-EIS) for the Member States of the European Union

The examined innovation indices (EIS, GII) use a similar methodology, but we can still find some differences, which can also influence the results (Table 1). Among these, the indicators' number and structure should be highlighted. These can fundamentally affect the results, but there may also be additional important factors.

Comparison criterion	EIS	GII
Number of countries examined	49 (27 EU Member States, 11 neighboring countries, 11 global competitors)	132
Number of indicators	32	80
The role of sub-indices/subdimensions in calculating the index	It is not significant, the index is the average of the normalized values of indicators	Important, these are the basis of the index
Handling of outliers	Yes	Yes
Kurtosis consideration	No	Yes
Skewness consideration	Yes	Yes
Method of normalization	Min-Max method (*min* and *max* values are determined taking into account data from several years)	Min-Max method (*min* and *max* values are taken from the data of the given year)
Aggregation	Arithmetic mean	Arithmetic mean
Weighting	No	By default, the weight of the indicators is 1, but for 2 indicators and 2 subdimensions, a weight of 0.5 was used during aggregation

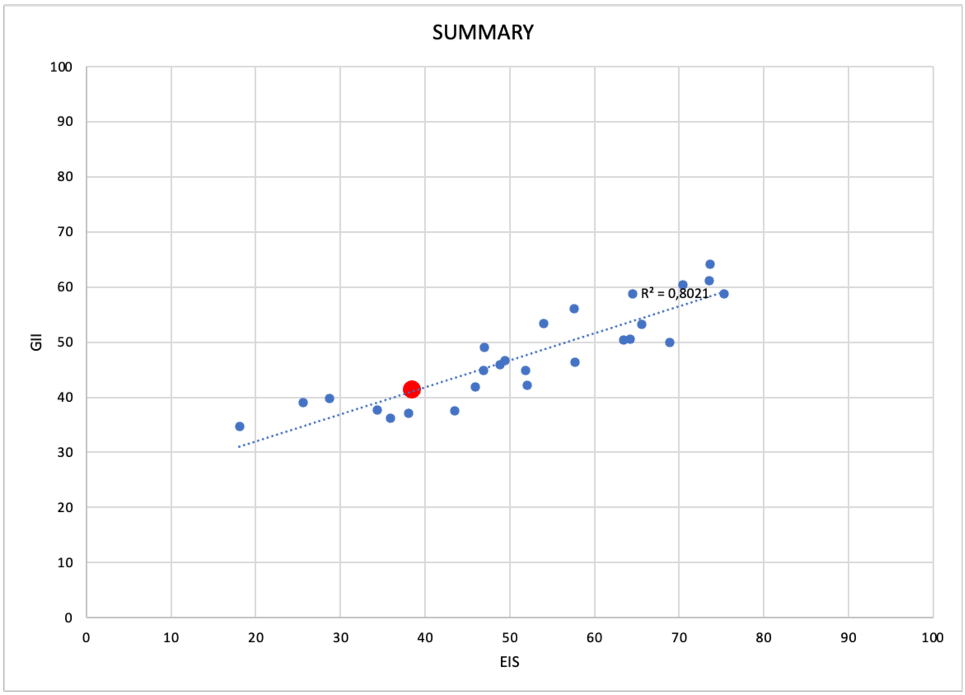
Table 1. - Comparison of some methodological steps of the GII and EIS (Source: own editing)

The methodological differences described above may affect the results. In addition, the measurement areas must be different for the two indices, therefore the results do not necessarily coincide with each other.

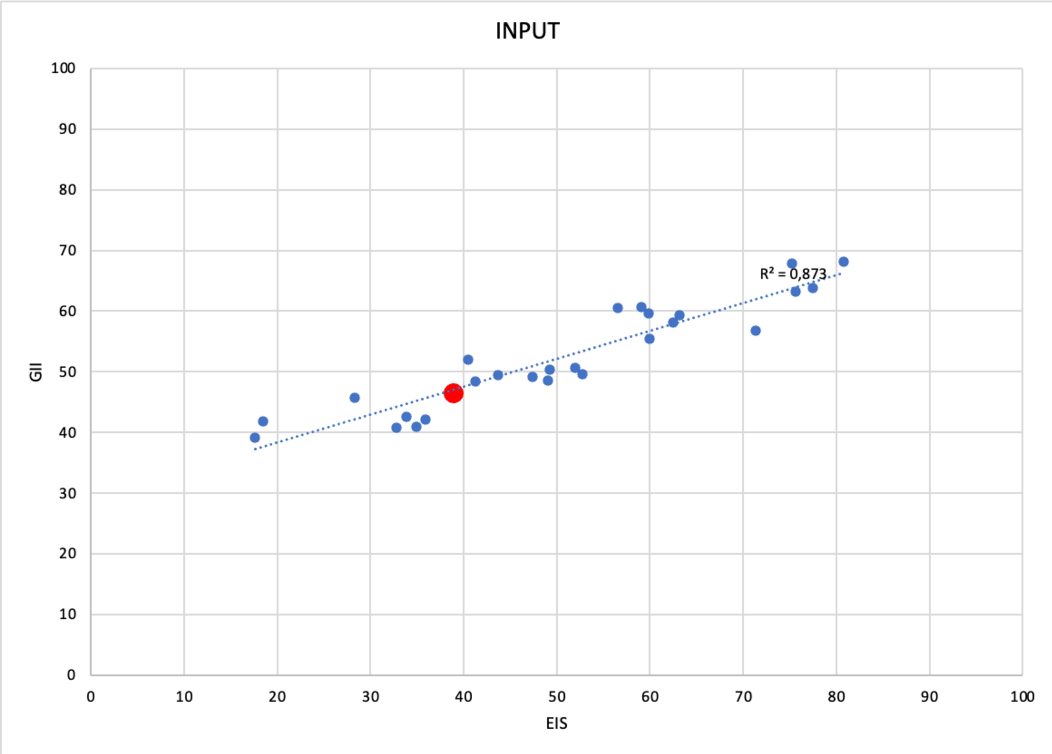
In the methodology of the Global Innovation Index, input and output factors are separated, but not in the European Innovation Scoreboard. To compare the results on several levels, an attempt was made to distinguish between input and output areas in the case of EIS dimensions. In the literature, input and output indicators and their relationship have been examined in various ways (e.g. Hollanders & Celikel-Esser, 2007; Filippetti et al., 2011; Edquist & Zabala-Iturriagagoitia, 2015). However, due to the regular changes in the set of indicators, it is worth reviewing the grouping of indicators every year. In the present study, we opted for a simple grouping of all indicators, and from the dimensions presented earlier, indicators belonging to the Framework Conditions and Investments dimensions were classified as input areas, while the indicators of the Innovation Activities and Impacts dimensions were classified as outputs. In this approach, outcome and impact indicators are also included among the outputs, but we emphasize that it is worth examining this separately later.

The GII publishes each country's results separately based on their results in input and output areas. For comparability, we calculated the composite values of Inputs and Outputs separately for each input and output areas of the EIS. The composite value is the unweighted arithmetic average of the normalized values of the indicators for specific dimensions, which is the same as the EIS calculation method. The difference is only in the number of indicators, since this time we worked with an unweighted arithmetic average of 16-16 values, not 32.

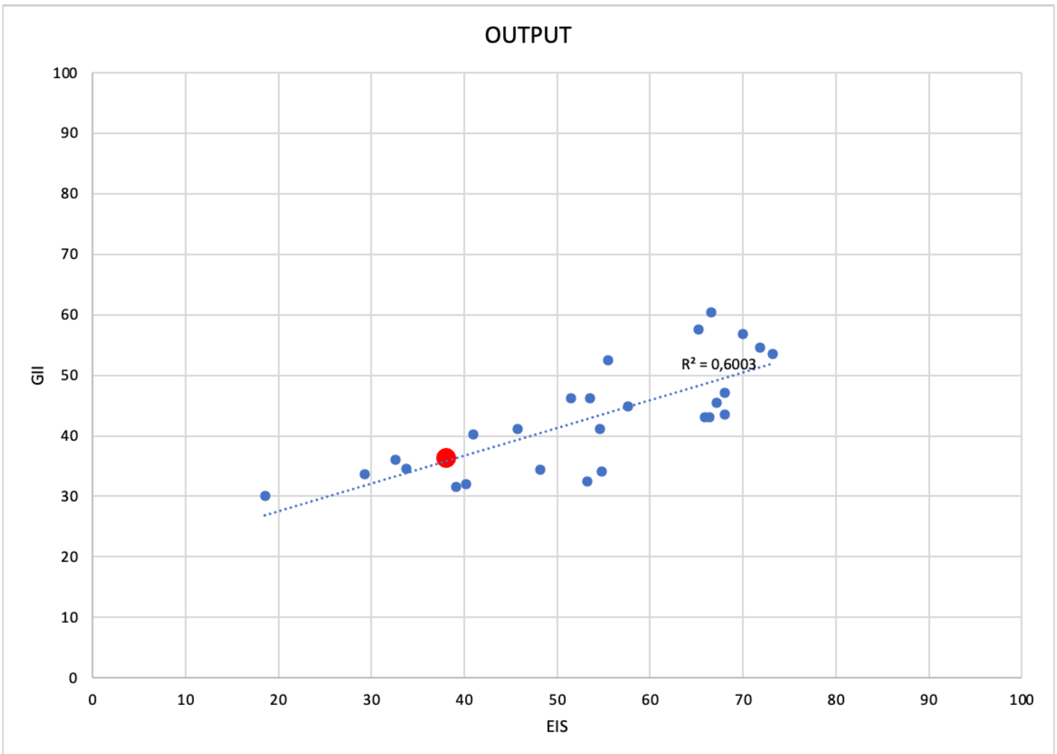
The results of the comparison are presented using scatter plots (Figures 1-5), Hungary has been highlighted in red).



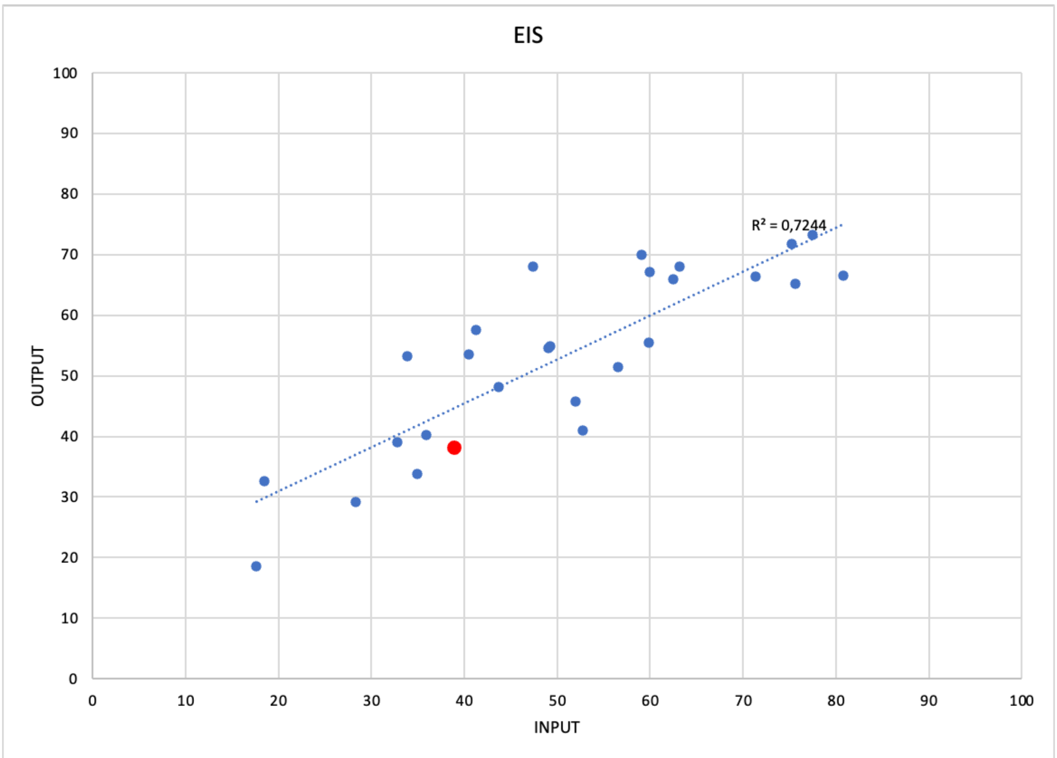
1. Figure - Comparison of combined index values of EIS and GII in EU countries (Source: own editing based on EIS and GII data)



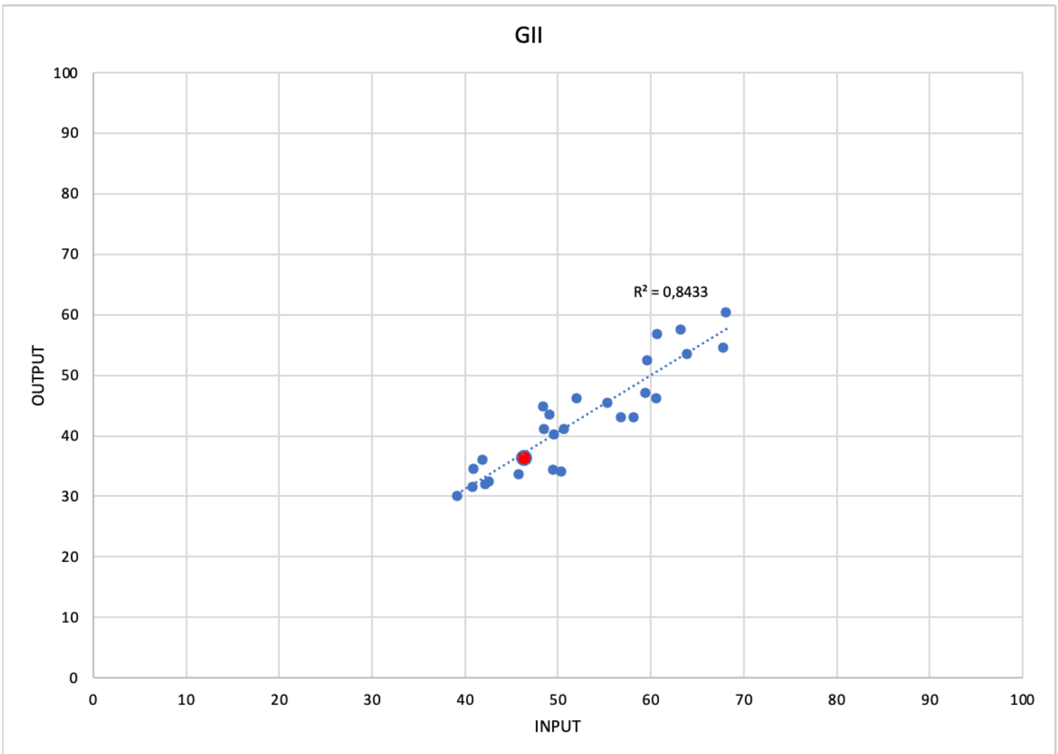
2. Figure - Comparison of results in EIS and GII input areas in EU Member States (Source: own editing based on EIS and GII data)



3. Figure - Comparison of results in EIS and GII output areas in EU Member States (Source: own editing based on EIS and GII data)



4. Figure - Comparison of results in EIS input and output areas in EU Member States (Source: own editing based on EIS data)



5. Figure - Comparison of results in GII input and output areas in EU Member States (Source: own editing based on GII data)

There is a fairly strong positive linear relationship (r=0.90) between the composite innovation index values set out in the European Innovation Scoreboard 2023 (EIS) and the Innovation Index values reported in the Global Innovation Index 2023 (GII) report (Figure 1). This means that the innovation performance of one measurement system can be used to estimate more than 80% of the performance value of the other system. The strongest positive linear relationship (r=0.93) can be determined between the input dimensions of the two indices (Figure 2), and the weakest between the output values (Figure 3) of the two systems (r=0.77). This suggests that there is greater consistency between the two indices in measuring innovation performance related to inputs, but there are more significant differences on the output side. This information may be useful, for example, in determining how similar or different the two systems are and where there may be differences in indicator systems or weighting mechanisms.

In the case of GII, there is a stronger correlation (r=0.92) between the combined values of the input and output dimensions (Figure 5) compared to the EIS (r=0.85) (Figure 4). However, for both indices, there is a strong positive correlation between the results measured in the input and output areas, which means that higher results in input indicators can be associated with higher results measured by output indicators.

For Hungary, both for the aggregate values of innovation indices and for the values of inputs and outputs, the value under one system is consistent with that determined by the other. In the case of the GII, based on the aggregate value of the input dimension, the observed output value of Hungary is close to the estimated value. However, in the case of the EIS, the observed output value of Hungary is lower than the value estimated based on the result of the input dimension.

3 Sensitivity of EIS results to developments and changes in the set of indicators – the case of Hungary

We also attempted to examine the sensitivity of the results on several levels. During the analysis, the sensitivity of the composite index to the effect of the improvement of certain indicator values is examined, as well as to changes in the set of indicators (leaving out each individual indicator from aggregation). The following calculations are carried out on an experimental basis for Hungary and the results of the 2023 EIS report. The calculations can subsequently be extended to more countries and periods.

Sensitivity to 5% improvement in indicator value

Each policy measure may have a different impact on countries' Summary Innovation Index (SII). We tested the expected impact of the measures on a point-by-indicator basis using a simple, easy-to-understand methodology. Based on the 2023 EIS data, we examined the impact of a 5% increase in the indicator value for one indicator on Hungary overall index value, while the values of the other indicators remain unchanged. In case of ‘4.3.2. Air emissions by fine particulates PM2.5 in Industry indicator, we expected a 5% decrease in the indicator value, because in this case the development is indicated by a decrease in the value of the indicator.

The result of the calculations shows that the change in the aggregate index ranges from 0.04% to 0.47%. Although the resource and time requirements of developments and measures implemented to improve the value of each indicator by 5% can vary enormously, it can still be interesting to compare the expected impact of the hypothetical developments.

Table 2 summarises the impact of a 5% improvement on the Summary Innovation Index (SII) for each indicator.

Indicator	Original indicator value	SII value expected in case of 5% improvement in indicator value	% change of SII value
4.2.1. Medium and high technology product exports	65.5	0.3871	100.47
1.1.2. Percentage population aged 25-34 having completed tertiary education	31.9	0.3866	100.34
4.1.1. Employment in knowledge-intensive activities	13.9	0.3865	100.33
4.1.2. Employment in innovative enterprises	39.2	0.3865	100.31
2.1.3. Direct government funding and government tax support for business R&D	0.23	0.3864	100.29
2.3.2. ICT specialists	4.1	0.3864	100.29
3.2.3. Job-to-job mobility of Human Resources in Science &Technology	6.7	0.3863	100.28
4.2.2. Knowledge-intensive services export	55.5	0.3863	100.28
1.3.1. Broadband penetration	43.3	0.3863	100.27
2.2.1. R&D expenditure in the business sector	1.24	0.3861	100.23
3.1.2. SMEs introducing business process innovations	23.5	0.3861	100.23
2.3.1. Enterprises providing training to develop or upgrade ICT skills of their personnel	18.2	0.3861	100.23
4.3.1. Resource productivity	1.59	0.3860	100.20
3.1.1. SMEs introducing product innovations	19.9	0.3860	100.20
1.3.2. Individuals who have above basic overall digital skills	21.5	0.3860	100.20
1.2.3. Foreign doctorate students	25.5	0.3860	100.19
2.1.1. R&D expenditure in the public sector	0.4	0.3859	100.17
4.3.3. Development of environment-related technologies	7.7	0.3859	100.17
3.2.1. Innovative SMEs collaborating with others	9.9	0.3859	100.16

1.2.2. Top 10% most cited publications	5.9	0.3859	100.16
2.2.3. Innovation expenditure per person employed	4169	0.3859	100.16
4.2.3. Sales of new-to-market and new-to-enterprise innovations	7.8	0.3858	100.15
1.1.3. Percentage population aged 25-64 participating in lifelong learning	7.9	0.3857	100.12
2.1.2. Venture capital expenditures	0.11	0.3857	100.11
2.2.2. Non-R&D innovation expenditures	0.64	0.3857	100.11
3.2.2. Public-private co-publications	157.1	0.3857	100.10
1.2.1. International scientific co-publications per million population	757	0.3856	100.09
4.3.2. Air emissions by fine particulates (PM2.5) in Industry	0.09	0.3856	100.09
3.3.2. Trademark applications	3.69	0.3856	100.09
3.3.1. PCT patent applications	1.09	0.3856	100.08
1.1.1. New doctorate graduates in STEM	0.3	0.3856	100.08
3.3.3. Design applications	3.0	0.3854	100.04
original SII value		0.3853	

Table 2. - Sensitivity of Hungary indicators to a 5% improvement in indicator value (own calculation based on EIS data)

Sensitivity to changes in the set of indicators

We also examined how sensitive the results are to changes in the set of indicators. In the course of the study, the aggregate index value (SII) of Hungary was calculated by excluding the indicators individually from aggregation[1], so the aggregate index value this time is not the unweighted arithmetic average of the normalized values of 32 but 31 indicators. The following table shows how the index value changes if one of the indicators has been left out. The results show that, for example, while leaving out indicator 4.2.1 can decrease the index value by almost 4.5%, leaving out indicator 3.3.3 increases the index value by almost 2.5%. For indicators where we get a value above 100, we can also assess that the normalized value of Hungary in this area is below the average index value (SII), so it underperforms 'relative to itself', compared to the average level of innovation performance measured based on all indicators. And if it's below 100, it scored better than its average performance.

[1] When analyzing indices, the JRC (Joint Research Centre) uses a similar methodology (Leave-out scores). The analysis tool is available at: https://knowledge4policy.ec.europa.eu/composite-indicators/coin-tool_en

The following table summarises the impact of leaving out an indicator from the indicator set on the Summary Innovation Index (SII).

Indicator	Normalized value	SII value expected if indicator left out	% change of SII value
3.3.3. Design applications	0.365	0.3949	102.49
1.1.1. New doctorate graduates in STEM	0.186	0.3917	101.67
1.1.2. Percentage population aged 25-34 having completed tertiary education	0.190	0.3916	101.64
4.1.2. Employment in innovative enterprises	0.195	0.3914	101.60
3.1.2. SMEs introducing business process innovations	0.205	0.3911	101.51
1.2.1. International scientific co-publications per million population	0.206	0.3910	101.50
1.1.3. Percentage population aged 25-64 participating in lifelong learning	0.237	0.3901	101.24
3.2.2. Public-private co-publications	0.244	0.3898	101.18
4.3.3. Development of environment-related technologies	0.246	0.3898	101.17
2.1.1. R&D expenditure in the public sector	0.295	0.3882	100.76
4.3.1. Resource productivity	0.302	0.3880	100.70
3.3.2. Trademark applications	0.329	0.3871	100.47
4.2.3. Sales of new-to-market and new-to-enterprise innovations	0.335	0.3869	100.42
1.2.2. Top 10% most cited publications	0.335	0.3869	100.42
3.2.1. Innovative SMEs collaborating with others	0.340	0.3867	100.38
3.3.1. PCT patent applications	0.355	0.3862	100.26
2.2.3. Innovation expenditure per person employed	0.365	0.3859	100.17
3.1.1. SMEs introducing product innovations	0.384	0.3853	100.01
1.3.2. Individuals who have above basic overall digital skills	0.397	0.3849	99.90
2.3.1. Enterprises providing training to develop or upgrade ICT skills of their personnel	0.404	0.3847	99.85
2.3.2. ICT specialists	0.431	0.3838	99.62
1.2.3. Foreign doctorate students	0.443	0.3834	99.52
4.1.1. Employment in knowledge-intensive activities	0.445	0.3833	99.50
1.3.1. Broadband penetration	0.478	0.3823	99.23
2.2.2. Non-R&D innovation expenditures	0.487	0.3820	99.15

3.2.3. Job-to-job mobility of Human Resources in Science & Technology	0.490	0.3819	99.13
4.2.2. Knowledge-intensive services export	0.516	0.3810	98.90
2.1.2. Venture capital expenditures	0.525	0.3808	98.83
2.2.1. R&D expenditure in the business sector	0.538	0.3803	98.72
4.3.2. Air emissions by fine particulates (PM2.5) in Industry	0.714	0.3747	97.25
2.1.3. Direct government funding and government tax support for business R&D	0.719	0.3745	97.20
4.2.1. Medium and high technology product exports	0.906	0.3685	95.64
original SII value		0.3853	

Table 3. - Sensitivity of Hungary indicators to changes in the set of indicators (own calculation based on EIS data)

4 Conclusions

In the study, we presented the main methodological steps of the two most well-known innovation indices (European Innovation Scoreboard - EIS, Global Innovation Index - GII), and pointed out the differences during the calculation of the composite indicator. In addition to comparing the two methodologies, we also compared the measurement results, and we found that there is a strong positive linear relationship between the two indices, so based on one measurement system, the result according to the other system can be estimated in more than 80%. The results were also examined separately into input-output areas. The relationship between the input dimensions of the two indices was stronger than between the output dimensions, suggesting that there is more consistency between the two indices when measuring input areas than in the case of output areas. It should also be pointed out that Hungary performance is very similar based on the two indices.

We also pointed out that improvements in indicator values (5%) for each indicator improve Hungary aggregate index value to varying degrees. However, developments may require different resources and time, which should be taken into account during planning. It should also be added that results can also be influenced by the results of other countries and their improvements.

In our view, the results of the analysis can help understand the characteristics of innovation measurements. This study can contribute to the strategy needed for progress, but it is not sufficient in itself, because, for example, the expected impact of individual measures also needs to be examined, especially considering that measures may have an impact on several indicators at the same time.

It is also important to keep in mind the recommendations presented at the beginning of the study, which are included in the GII publication (WIPO, 2023), i.e. do not to set over-ambitious targets; should be taken into account there are lags between policy making, execution and impact; it is not worth treating the indices as a mathematical problem and focusing on a particular indicator or area to climb the ranking, because measurement systems can change over the years. As a consequence, it is advisable to find those development directions that can sustainably support the innovation performance of countries in the long run.

5 Limitations and future research directions

The quality and completeness of the data used for EIS and GII measurements are not always guaranteed.

The data used in the EIS is often years behind the publication date of the report. This can cause difficulty in accurately assessing the current situation and identifying the effects of interventions. The two systems use different methodologies for handling outliers and normalization, which affects the comparability of the results. The EIS normalizes the data with the average of several years, while the GII is based on the data of the given year. In the EIS, all indicators are given the same weight, while the GII applies a reduced weight to certain indicators. This difference may bias comparisons and rankings. Due to the complexity of the EIS and GII systems, interactions between individual dimensions and indicators cannot always be handled well. These measurement systems do not take into account the interactions between different innovation dimensions (subpillars, pillars), which can distort the value of the aggregated (composite) indicator. The innovation systems of countries may differ. The EIS and GII do not always reflect the specific strengths of countries, for example, some are strong in technological and others in social innovation. In the case of EIS and GII, the number of countries examined is different. In addition to these factors, Csath (2022) formulates additional limitations in relation to the evaluation of the results of innovation measurements. Among other things, it is necessary to take into account where the ‘innovation content’ of an innovative product was created, locally generated or originated from abroad, the result of its own development or purchased by the company. Furthermore, when examining certain indicators, their limitations should also be considered, for example, when assessing inward direct investments (FDI), the area in which the given investment arrives and what kind of activity it deploys in the given country (Csath, 2020). This is closely linked to the role and length of global value chains, the diversification of the economy and many other factors that need to be taken into account when assessing innovation performance.

Further research directions can be formulated to solve the problems arising from the methodological limitations of the two innovation measurement systems:

1. A detailed analysis of individual input and output indicators can help identify strengths and weaknesses.

2. The analysis of time trends can help to reveal long-term development patterns.

3. A detailed analysis of the relationships between inputs and outputs can help determine the factors that most contribute to successful national innovation systems.

4. Comparing the results of different countries provides an opportunity to identify best practices.

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