EXPLORING THE LINK BETWEEN INNOVATION AND ICT READINESS. A COMPARATIVE ANALYSIS OF ESTONIA AND ROMANIA

Daniela Alexandra CRIȘAN[1]

Justina Lavinia STĂNICĂ[2]

Abstract

This paper examines the relationship between the Summary Innovation Index (SII) and certain ICT readiness indicators, including the Network Readiness Index (NRI) and the Human Resources in Science and Technology (HRST) Index, across the EU-27 countries. The objective is to gain a deeper understanding of how digital infrastructure and human capital contribute to innovation performance within the region. The results obtained confirm the previous research of the authors of this paper regarding the close connection between innovation and ICT.

In the second part of the paper, we conducted a case study in which we analyzed the innovation and ICT readiness landscapes in Estonia and Romania, two countries that present a clear contrast.

Keywords: ICT, innovation performance, correlation, Summary Innovation Index (SII), Network Readiness Index (NRI), Human Resources Science and Technology (HRST) Index

JEL Classification: M15

1. Introduction

The European Union has long recognized that fostering innovation is key to driving economic growth, enhancing global competitiveness, and addressing societal challenges. Therefore, at the EU level, innovation-driven growth has become a key priority, focusing on directing resources to foster research and development. Investments in research, development, education, and skills are crucial policy areas for the EU, as they play a vital role in driving economic growth and establishing a knowledge-based economy.

This paper examines the relationship between different indicators of innovation and ICT readiness. Recent studies have highlighted the importance of aligning innovation strategies

[1]Associate Professor, PhD, School of Computer Science for Business Management, Romanian-American University, e-mail: daniela.alexandra.crisan@rau.ro, corresponding author

[2]Lecturer, PhD, School of Computer Science for Business Management, Romanian-American University, lavini.stanica@rau.ro

with ICT readiness frameworks across European nations [1]. Also, the role of digital transformation in enhancing innovation performance is analyzed in [2]. In addition, previous research conducted by the authors shown a strong linkage between innovation and ICT, considering various indicators, such are: the Summary Innovation Index (SII) and the the Global Innovation Index (GII), for the innovation, and, respectively the Networked Readiness Index (NRI), the ICT Development Index (IDI), and various EUROSTAT indicators, for ICT [3][4]. Therefore, by analyzing the models provided, we aim to better understand the demand for and supply of highly qualified individuals in science and technology, alongside the essential need for continued investments in R&D.

Materials and methods

For the materials and methodology, all charts and graphics included in this paper were created by the authors using Microsoft Excel (including ANOVA analysis), with data sourced from the European Innovation Scoreboard (EIS) 2024, the Global Information Technology Report 2024, and Eurostat. The HRST indicator values were updated on 13 December 2024.

The Summary Innovation Index (SII)

The **European Innovation Scoreboard (EIS)** is an initiative launched by the European Commission to provide a comparative analysis of innovation performance across European countries, both at national and regional levels. EIS is published annually, and it measures and ranks countries based on their innovation capabilities and outcomes, helping to identify trends and gaps in innovation across Europe.

The purpose of the EIS is to assess different aspects of innovation, through a variety of indicators:

1. **Human Resources** – the availability of skilled individuals in science and technology.
2. **Research Systems** – the performance of research institutions and public research expenditure.
3. **Innovation-Related Investments** – private sector investments in innovation and R&D.
4. **Enterprise and Innovation Activities** – the presence and performance of innovative companies and startups.
5. **Intellectual Assets** – indicators like patents, trademarks, and designs.
6. **Market and Economic Impact** – the contribution of innovation to economic performance, including productivity and job creation.

The initiative came to life in 2001, but over time, it has undergone changes. At the beginning, the report was published under the name "Innovation Union initiative". The current name of EIS was acquired in 2015. In addition, the indicators in the early versions

of the EIS focused on more traditional aspects of innovation, such as R&D investment, patents, and scientific publications. Their structure has changed over, in order to reflect more accurately the changes of the economies. One of the most recent, important updates of EIS happen in 2021, they were meant to better reflect evolving trends in innovation. Some of the key changes introduced in 2021 include: (1) Expanding Indicators on Digital Transformation, (2) Introduction of the "Green Innovation" Dimension, (3) New Methodology for Composite Indicator.

In recent editions, the methodological framework of the scoreboard is based on a total of 32 indicators, divided into four main categories and 12 dimensions, to assess the innovation performance of the EU, its Member States and selected third countries (EIS, 2024). Based on these indicators, a composite index, **Summary Innovation Index (SII)** is calculated yearly for every country:

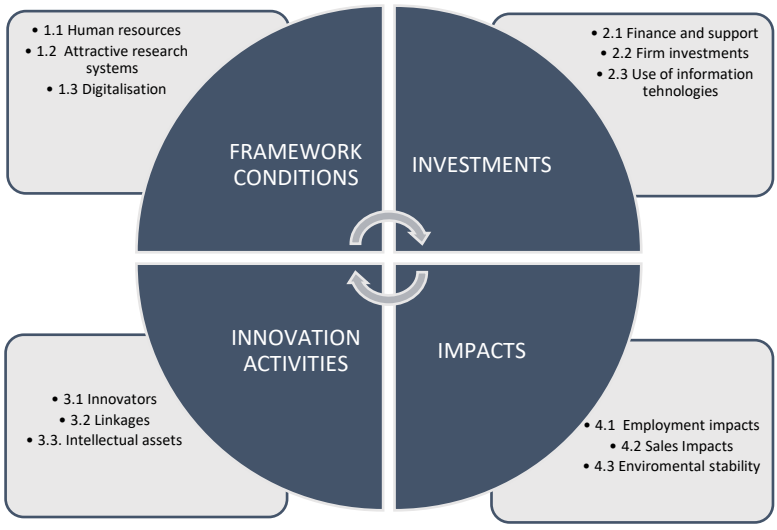


Figure 1. The structure of the Summary Innovation Index (SII) in 2024
(chart made with Ms. Excel, by authors)

Based on their SII index values, the 27 Member States are categorized into four performance groups (Figure 2):

- **Innovation leaders** (Denmark, Sweden, Finland, and the Netherlands) – perform in innovation well above the EU average (above 125% than EU average);
- **Strong Innovators** (Belgium, Austria, Ireland, Luxembourg, Germany, Cyprus, Estonia, and France) – innovate below the leaders, but above the EU average;
- **Moderate innovators** (Slovenia, Spain, Czechia, Italy, Malta, Lithuania, Portugal, Greece and Hungary) – perform in innovation below or equal to the EU average (at least 70% of EU average);
- **Emerging innovators** (Croatia, Poland, Slovakia, Latvia, Bulgaria and Romania) – innovate well below the EU average.

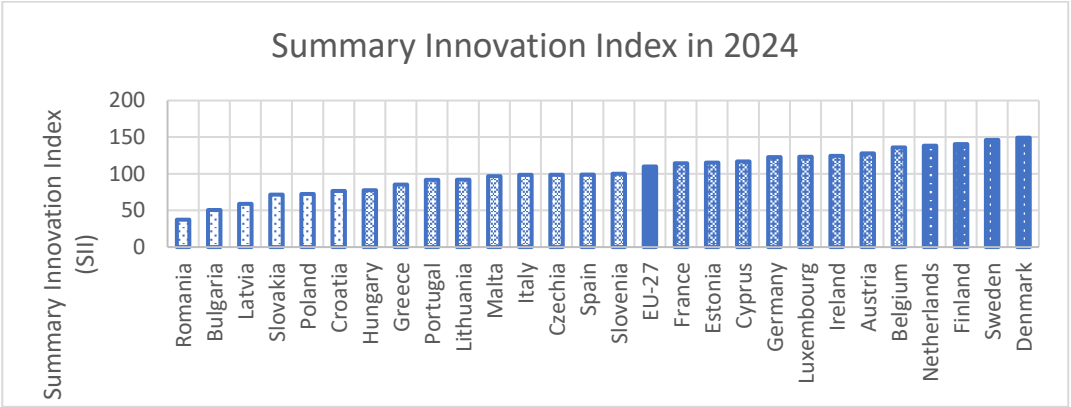


Figure 2: The four groups of EU-27 countries by their innovation performance (SII) relative to EU scores, in 2024
(chart made with Ms. Excel, by authors)

We note that, according to EIS 2024: "All performance scores described in this report are relative to that of the EU in 2017 to facilitate the tracking of progress and trends that enable policymakers to identify specific areas requiring attention through strategies and programmes at national level." [5, pg. 9].

Measuring the ICT readiness

In order to assess the ICT readiness of a country, we have used two indicators:

1. **HRST Index** measures **the availability and quality of human capital** in science, technology, engineering, and mathematics (STEM) fields.
2. **NRI** assesses a country's **overall readiness to leverage information and communication technologies (ICT)** for economic and social development.

The **Human Resources in Science and Technology (HRST) Index** is a key measure used by Eurostat to assess the availability of skilled labour in science and technology fields across European countries. It includes people with higher education qualifications in science and technology fields, such as those with degrees in engineering, life sciences, physical sciences, and information technology [6].

In our analysis, we have used the HRST indicator with the following dimensions:

- Unit of measure: Percentage of population in the labour force (PC_ACT)
- Category: Persons with tertiary education (ISCED) and/or employed in science and technology (HRST)
- Age class: From 15 to 24 years and 65 to 74 years (Y15-24_Y65-74)

Using the HRST Index, we can rank the 27 Member States as follows:

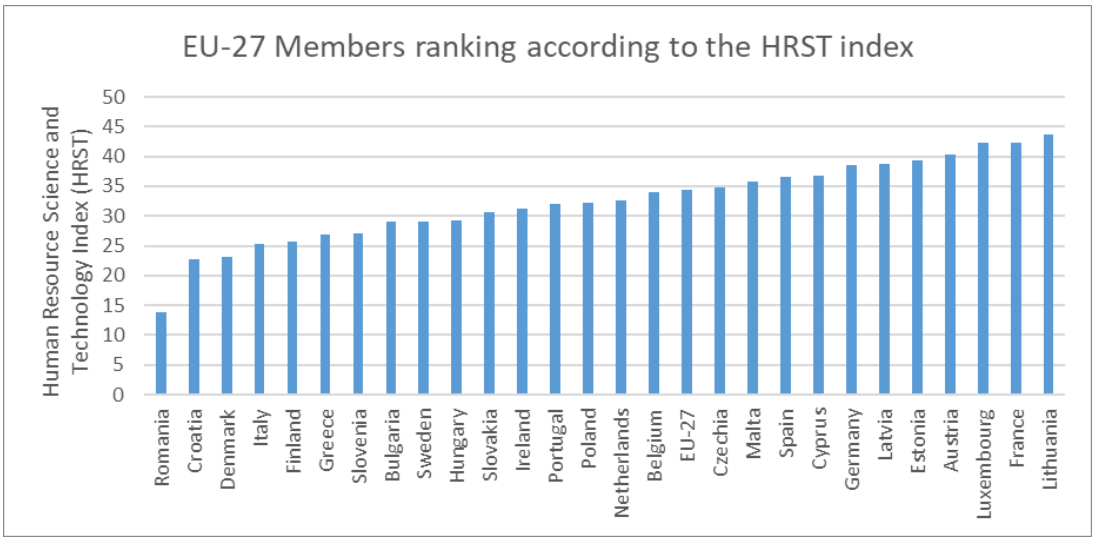


Figure 3: The EU-27 countries ranked by their S&T performance (HRST Index 2023)
(chart made with Ms. Excel, by authors)

The **Network Readiness Index (NRI)** is also a composite index meant to offer a description of the digital economy of a country. It is published as part of the Global Information Technology Report [7], as a result of collaboration between various partners, including the World Economic Forum (WEF) and INSEAD. The 2024 version was published under the motto "Building a Digital Tomorrow: Public-Private Investments and Global Collaboration for Digital Readiness", by the Portulans Institute in collaboration with Saïd Business School, University of Oxford.

The NRI is built around four main pillars, each of which is broken down into sub-pillars and indicators:

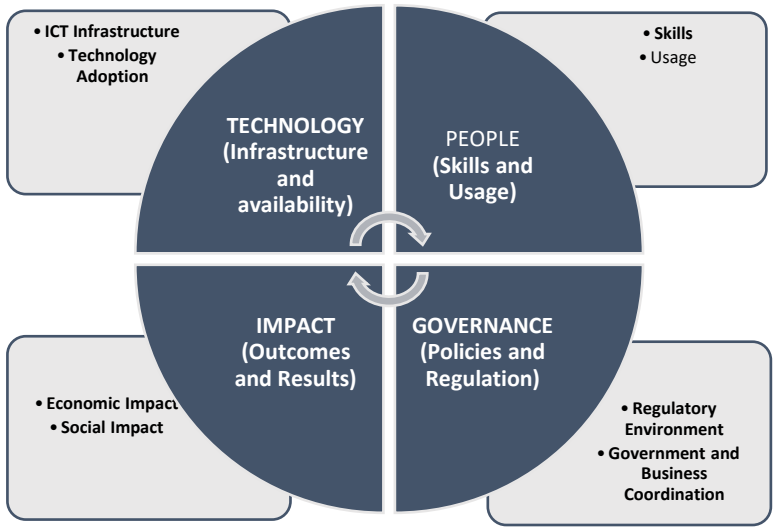


Figure 4. The structure of the Network Readiness Index (NRI) in 2024
(chart made with Ms. Excel, by authors)

In the next graphic the ranking of the 27 EU members, according to their NRI values. The four pillars Technology, People, Governance and Impact are also represented:

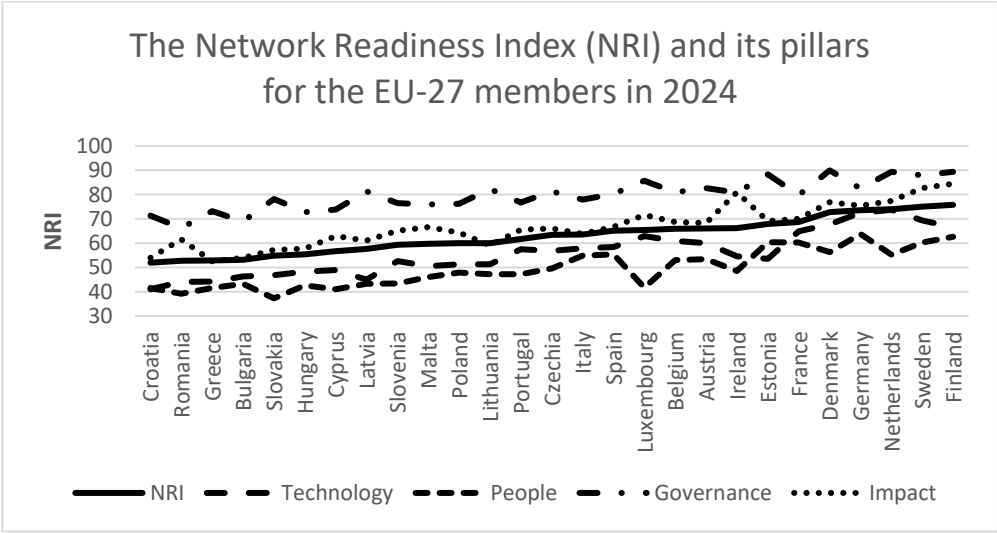


Figure 5. The Network Readiness Index (NRI) and its pillars for the EU-27 members in 2024
(chart made with Ms. Excel, by authors)

2. Correlations between innovation and ICT for the EU-27 Member States

In this section, we aim to examine the correlation between the SII and ICT readiness indicators, such as the NRI and HRST Index, for the EU countries in order to better understand how digital infrastructure and human capital influence innovation performance across the region.

2.1 Summary Innovation Index (SII) vs Network Readiness Index (NRI)

The next diagram illustrates the Summary Innovation Index (SII) and Network Readiness Index (NRI) indexes for the 27 EU Member States in 2024 suggesting that a linkage exists between them. This visual representation indicates that countries with higher NRI scores tend to have stronger innovation performance, as reflected by their SII:

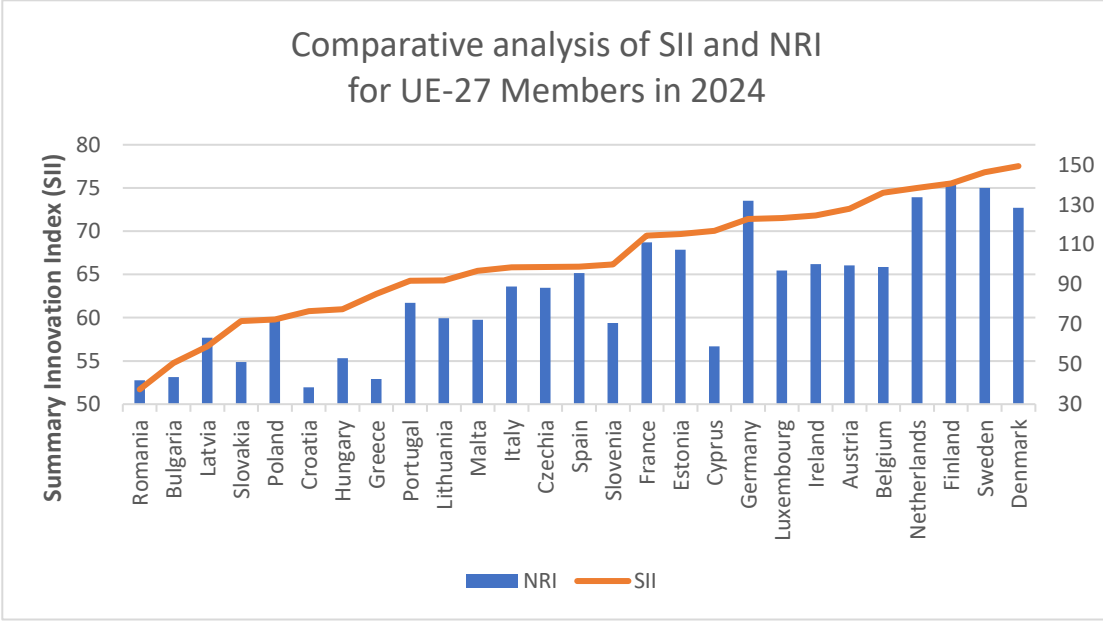


Figure 6. Comparative analysis of SII and NRI for UE-27 Members in 2024
(chart made with Ms. Excel, by authors)

Our next step was to describe this relationship using a linear model. The figure below shows that the two composite indexes for 2024 are linearly correlated:

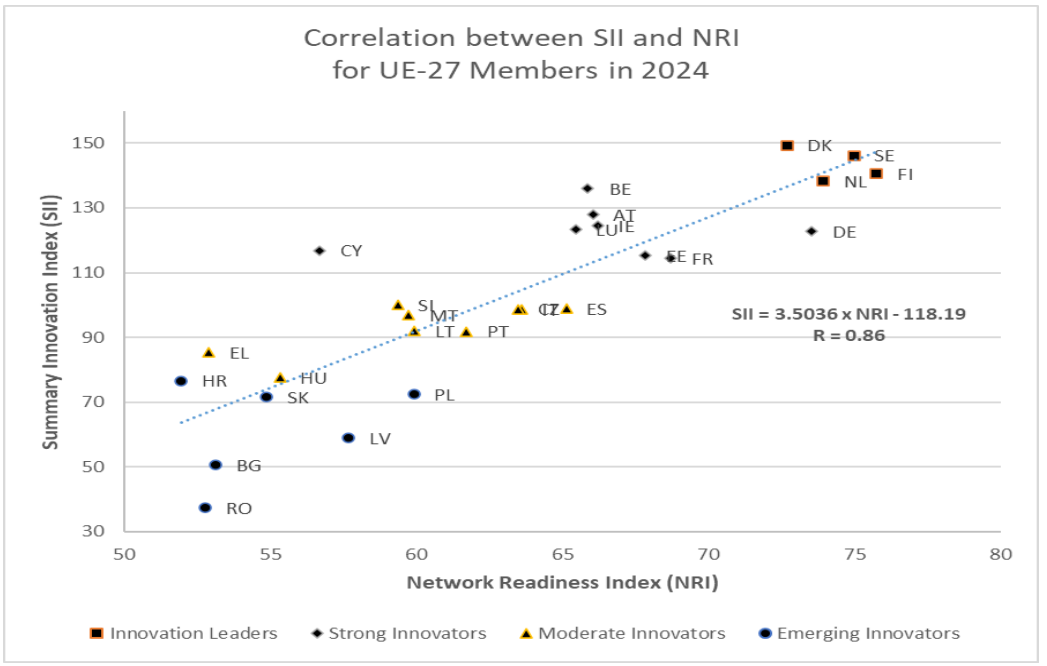


Figure 7. Correlation between SII and NRI for UE-27 Members in 2024
(chart made with Ms. Excel, by authors)

The equation of the linear regression is provided:

$$SII = 3.50 \times NRI - 118.19$$
$$R = 0.86$$

further demonstrating the strength of this correlation and offering a quantitative basis for understanding the connection between human capital in science and technology and innovation performance across EU Member States.

2.1 Summary Innovation Index (SII) vs. the Human Resources in Science and Technology (HRST) Index

Our next investigation referred to the relationship between the Summary Innovation Index (SII) and the Human Resources in Science and Technology (HRST) Index for the EU-27, at the global level, for the period 2017 to 2024:

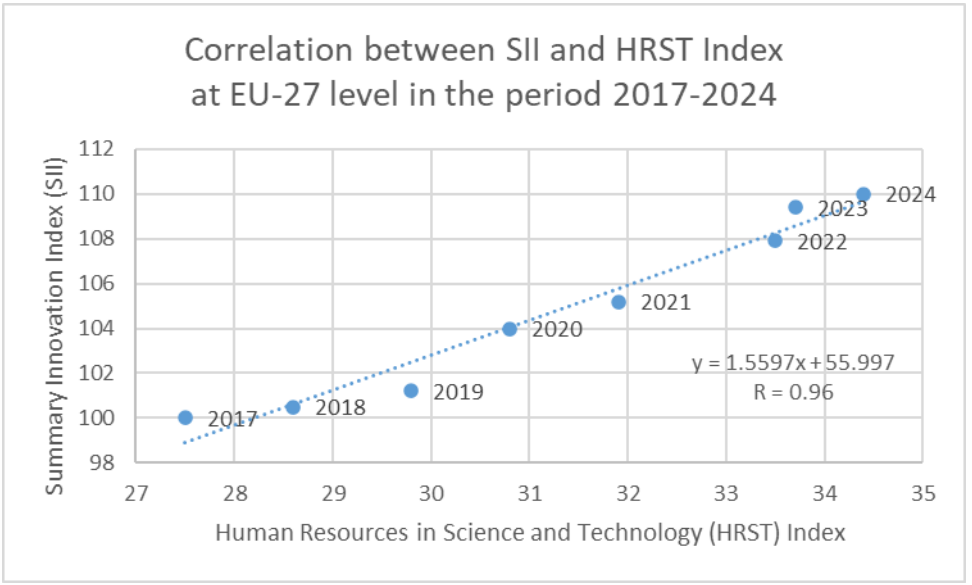


Figure 8. Correlation between SII and HRST Index at EU-27 level in 2024
(chart made with Ms. Excel, by authors)

As expected, they are also strongly correlated because both indicators reflect key drivers of innovation. The HRST Index measures the availability of a skilled workforce in science and technology, which is essential for fostering research, development, and technological advancements.

3. Comparative analysis between Romania and Estonia in terms of innovation and ITC readiness

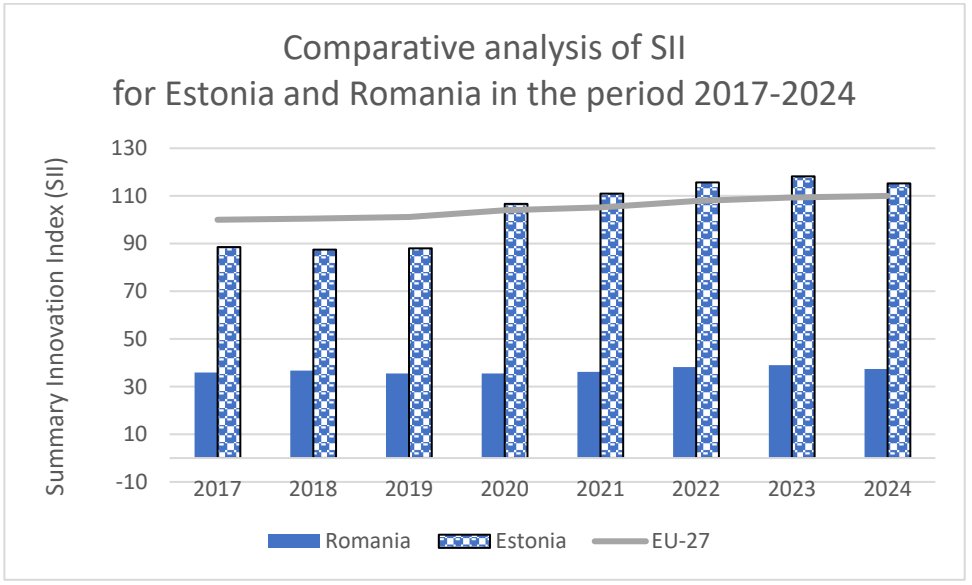
Romania faces significant challenges in terms of innovation, which have hindered its progress in the global digital economy. Despite having a relatively young and educated workforce, the country struggles with inadequate infrastructure and limited access to high-speed internet, particularly in rural areas. This digital divide hampers the widespread adoption of new technologies and stifles the growth of digital businesses. Moreover, while the country has made strides in some sectors, the public and private sectors are often slow to embrace digital transformation, with outdated governance structures and regulatory frameworks that do not fully support innovation.

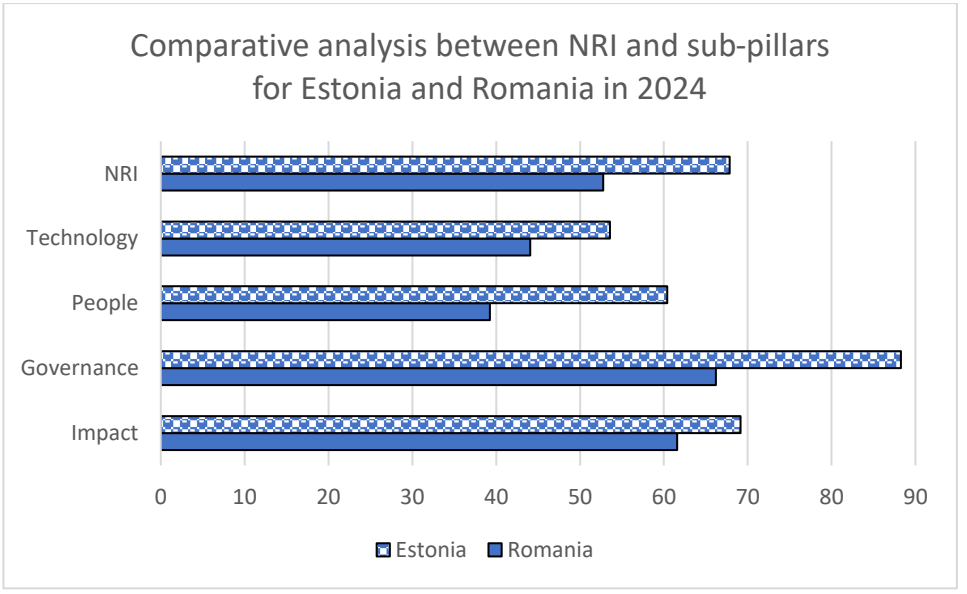
Additionally, Romania's education system, though improving, still falls short in providing the necessary digital skills to equip the workforce for the demands of the modern economy. As a result, Romania's innovation ecosystem remains underdeveloped, with limited investment in research and development, low rates of collaboration between businesses and academia, and insufficient support for startups and digital entrepreneurship.

These factors contribute to Romania's relatively low ranking in global innovation indices, hindering its competitiveness in an increasingly digital world.

In contrast, Estonia stands out as a leader in innovation. Estonia's regulatory frameworks are designed to encourage investment in research and development, collaboration between businesses and academic institutions, and the growth of digital entrepreneurship.

As a result, Estonia consistently ranks among the top performers in global innovation and ICT readiness indices, contrasting sharply with Romania's situation:





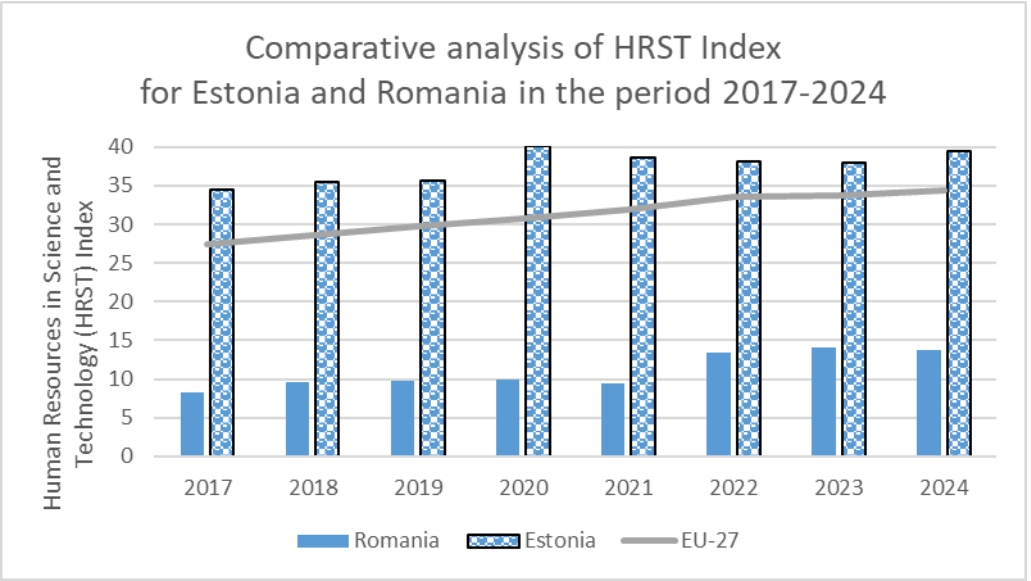
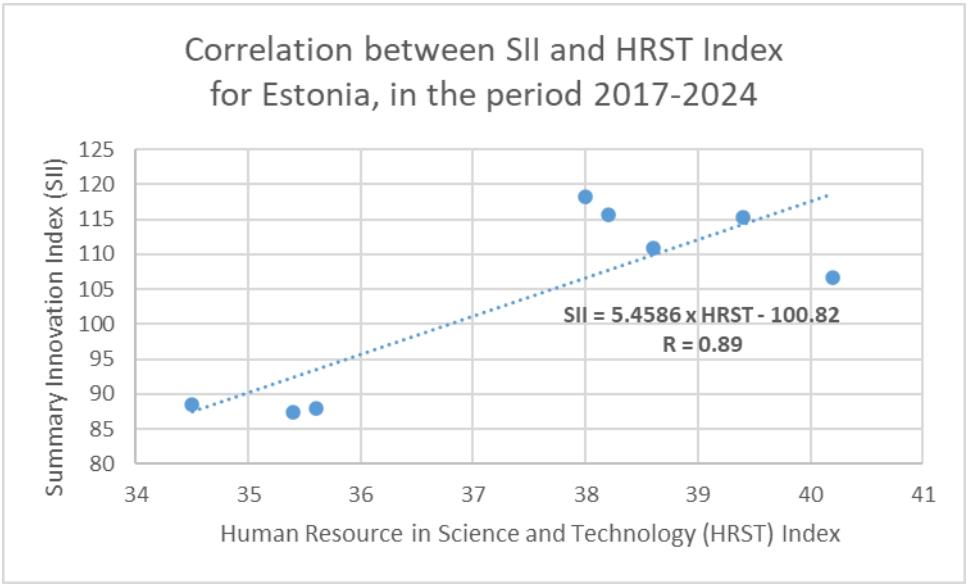


Figure 9. Comparative analyses using SII, NRI and HRST Indicators for Estonia and Romania

(chart made with Ms. Excel, by authors)

Examining the relationship between innovation and the Human Resources in Science and Technology (HRST) Index, for both Estonia and Romania, we have found a strong link, that suggests that the availability and quality of skilled labor in science and technology plays a crucial role in fostering innovation in both countries:



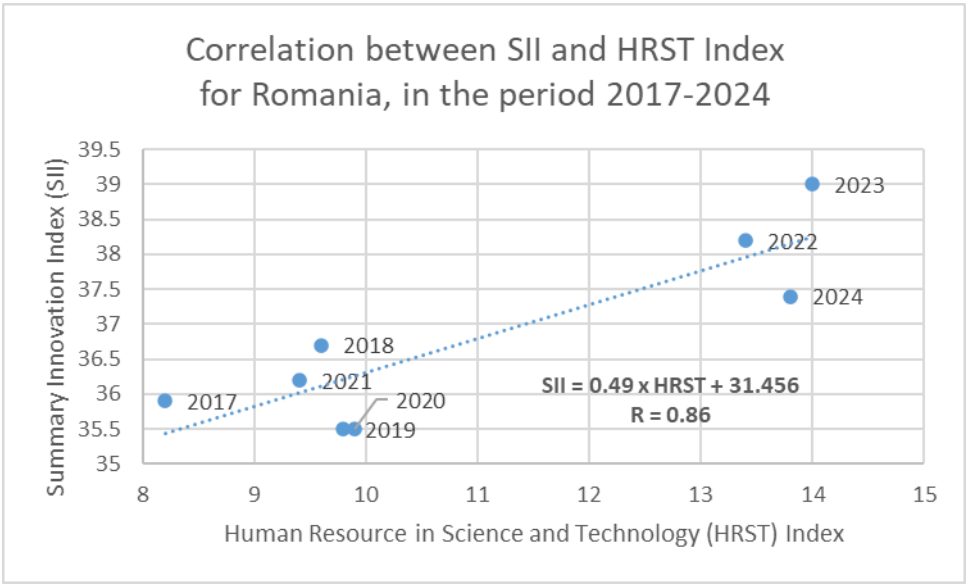


Figure 10. Correlation between SII and NRI for Estonia and Romania (bottom) in the period 2017-2024

(chart made with Ms. Excel, by authors)

For Estonia, this strong connection indicates that the country's investment in developing a highly skilled workforce in science, technology, engineering, and mathematics (STEM) has directly contributed to its innovation success. Estonia's high HRST score reflects a well-educated, digitally literate population that is prepared to drive innovation in emerging technologies.

Romania's lower HRST score suggests that there are still gaps in terms of the quantity and quality of its skilled workforce in STEM fields. Despite having a relatively high level of education, Romania faces challenges in producing enough highly skilled individuals with specialized knowledge in science and technology, which could be stifling its innovation potential. A lack of investment in education and research, coupled with an underdeveloped R&D sector, limits the country's ability to generate and implement innovative solutions. Improving the HRST index by investing in STEM education, skills development, and research infrastructure could significantly boost Romania's innovation capacity, helping it better compete in the global digital economy.

In summary, the strong relationship between HRST and innovation in both countries underlines the importance of a highly skilled workforce in driving technological advancements and fostering a vibrant innovation ecosystem. Estonia's success shows how a strong HRST index can be a major driver of innovation, while Romania's situation suggests that enhancing its HRST capacity is key to unlocking its innovation potential.

4. Conclusions

In conclusion, the analysis of the correlation between the Summary Innovation Index (SII), Network Readiness Index (NRI), and the Human Resources in Science and Technology (HRST) Index reveals a clear and significant relationship between digital infrastructure, human capital, and innovation performance across the EU countries. The findings show that countries with higher HRST and NRI scores tend to perform better in innovation, suggesting that investments in digital readiness and a skilled workforce are crucial factors for fostering innovation.

Romania and Estonia are at different poles in terms of innovation, digitalization and innovation. The analyses carried out reinforce the idea that a highly skilled workforce and a strong digital infrastructure led to better performance in innovation, emphasizing the need for strategic investments in education, research, and digitalization in Romania's case, in order to bridge the gap with leading innovators in the EU.

Acknowledgment: The research was carried out in part within the Center for Computational Science and Machine Intelligence (CSMI) of the Romanian-American University's School of Computer Science for Business Management".

References

[1] Sfetcu N. (2024), "ICT in the EU: Driving Digital Transformation and Innovation," *IT & C*, 4:1, pp. 41-57, DOI: 10.58679/IT96537, available at: https://www.internetmobile.ro/ict-in-the-eu-driving-digital-transformation-and-innovation/

[2] Varzaru A.A., Bocean C.G. (2024), "Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation," *MDPI Open Access Journals*, available at: https://www.mdpi.com/2079-8954/12/9/359

[3] Crișan D.A., Stănică J.L. (2022), "Analysis of the correlation between Innovation and ICT Readiness for the EU-27 Member States," *Journal of Information Systems and Operations Management (JISOM)*, Vol. 16 No. 2 / Dec 2022, pp. 35-45

[4] Preda A.M., Crișan D. A., Stănică J.L. (2014), "The Impact of ICT on Innovation Performance in Europe. Case of Romania," *Journal of Information Systems and Operations Management (JISOM)*, Vol 8 No 1, 2014, pp. 1-12, Ed. Universitara

[5] European Innovation Scoreboard 2024, available at: https://op.europa.eu/en/publication-detail/-/publication/8a4a4a1f-3e68-11ef-ab8f-01aa75ed71a1/language-en

[6] EuroSTAT, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Human_resources_in_science_and_technology_(HRST)

[7] Global Information Technology Report, available at: https://kpmg.com/xx/en/our-insights/transformation/kpmg-global-tech-report-2024.html

Bibliography

[1] Crișan D.A., Stănică J.L. (2022), "Analysis of the correlation between Innovation and ICT Readiness for the EU-27 Member States," *Journal of Information Systems and Operations Management (JISOM)*, Vol. 16 No. 2 / Dec 2022, pp. 35-45

[2] European Innovation Scoreboard 2024 Report, available at: https://op.europa.eu/en/publication-detail/-/publication/8a4a4a1f-3e68-11ef-ab8f-01aa75ed71a1/language-en

[3] Global Information Technology Report, available at: https://kpmg.com/xx/en/our-insights/transformation/kpmg-global-tech-report-2024.html

[4] Preda A.M., Crișan D. A., Stănică J.L. (2014), "The Impact of ICT on Innovation Performance in Europe. Case of Romania," *Journal of Information Systems and Operations Management (JISOM)*, Vol 8 No 1, 2014, pp. 1-12, Ed. Universitara

[5] Sfetcu N. (2024), "ICT in the EU: Driving Digital Transformation and Innovation," *IT & C*, 4:1, pp. 41-57, DOI: 10.58679/IT96537, available at: https://www.internetmobile.ro/ict-in-the-eu-driving-digital-transformation-and-innovation/

[6] Varzaru A.A., Bocean C.G. (2024), "Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation," *MDPI Open Access Journals*, available at: https://www.mdpi.com/2079-8954/12/9/359

[7] EuroSTAT, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Human_resources_in_science_and_technology_(HRST)