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A Methodological Framework for Tailoring National Indicators to Regional Contexts

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Abstract

Innovation systems are made up of multiple entities within the quadruple helix model, including their interactions and connections. The role of smart technologies and ICT (Information and Communication Technology) is critical for the operational effectiveness of such systems. Additionally, the regional context is considered essential for the evaluation of the level of innovation within these systems. A significant barrier to this approach, is the absence of adequate data at a regional level. To address this gap, this paper presents a new methodology to adapt national level numerical indicators to regional contents. This methodological model-fit approach employs regression analysis to tailor national indicators to the regional level using comparable available data. The method is evaluated using data from Greek NUTS 2 (Nomenclature of Territorial Units for Statistics) regions, yielding regional-level estimates for four innovation indicators based on four existing indicators that are found to be significantly correlated to them. However, the same technique may be used to any EU (European Union) member country or the entire EU The findings, their implications for future research, and prospective applications are discussed. Overall, the provision of regional-level indicators is seen as critical for formulating effective development strategies.

Keywords: Innovation, Regionalization of Indicators, Regional Innovation Systems

1. Introduction

Innovation is typically examined within the framework of systems that encompass various organizations and the dynamics and linkages among them. Within such a system, innovation is propelled by factors including human capital, academic and research institutions, entities facilitating technology transfer, intermediary bodies like consultants and development organizations, financial entities, infrastructures for knowledge exchange and materials, market forces and consumers, and production companies (Cooke et al., 1997; Lundvall, 1993). Edquist and Hommen (1999) highlight that companies rarely innovate in solitude,

instead engaging in complex, often reciprocal interactions with other entities, marked by feedback mechanisms.

Innovative systems are described as the collaborative networks between public and private sector bodies, whose collective efforts lead to the generation, introduction, and spreading of innovations. They involve several actors including businesses, research and academic organizations, encompass broad scope of activities such as technology advancement and education, set within a wide range of conditions related to institutional, economic, social, and cultural conditions. This approach may lead to the evaluation of the impact of organizations and institutions on specific innovation processes at different levels and scales. Innovation systems include a wide spectrum of critical factors that may affect the impact of innovations, revealing the complex linkage between organizations which correspondingly affects the innovation process, outcomes, and the transformation of innovation ecosystems (Edquist, 1997).

Amid advancements in technology and the expanding reach of globalization, the concept of innovation systems anchored in specific geographic locations has gained prominence. These systems are now fundamental in assessing the efficacy of innovation and in the strategic deployment of innovation policies (Hollanders et al., 2014). This shift acknowledges that a company's potential for innovation is significantly shaped by its access to external knowledge and technology. Consequently, firms situated in diverse regions, each facing unique external challenges, can demonstrate varied levels of innovation success (Komninos, 2008), diversifying their business models accordingly (Kilintzis et al., 2020). This condition arises despite the potentially similar form of their internal operations and investments in R&D. This evolution has led to the partial abandonment of traditional economic theories, in favor of modern approaches that perceive innovation as a derivative of complicated interactions among firms and other stakeholders (McCann & Ortega-Argilés, 2013).

Extending the framework described above to a regional level, the Regional Innovation Systems (RIS) widely includes the network of institutional actors involved in the innovation process within a specific geographical area, (Chung, 2002). These actors, play a critical role in the generation and capitalization of new ideas and technologies, thereby directly affecting the system's overall ability to create innovation. This approach marks a departure from the earlier, more linear views of innovation that prevailed up until the 1980s. It underscores the importance of a holistic systems perspective, highlighting that investments in Research and Development (R&D) alone are insufficient for driving economic growth without the active engagement and collaboration of all system components to foster meaningful innovation. This perspective emphasizes the synergy between various stakeholders, including businesses, academic institutions, and government entities, in creating a conducive environment for innovation (Jucevičius et al., 2017). A process that could further specialize the RIS structure, transferring it from a regional to a local level, could well imprint the aforementioned synergies and depict a more detailed innovation paradigm.

2. Literature Review

The significance of innovation systems, highlighting the interplay between regionalization and globalization, and the role of regional networks in this context has been emphasized by the relevant literature (Lundvall, 1993). This has led to the development of a region-centric view among innovation system researchers, focusing on geographical areas within countries as critical for innovation. Despite the diminishing importance of physical distance due to advancements in information and communication technologies, the spatial concentration of

activities, such as those seen in Silicon Valley, remains crucial for fostering innovative ecosystems (Asheim & Gertler, 2009).

The concept of RIS introduces a focused lens on the intricacies and unique dynamics at the regional level, differentiating it significantly from National Innovation Systems (NIS) (Korres & Michailidis, 2021). This methodology explores in detail the organizational structure of businesses, the effects of public sector initiatives and policies, and the function of diverse institutional frameworks, which can vary significantly between geographic locations. Through focusing on the regional dimension, the RIS framework illuminates the subtleties of knowledge production, utilization, and diffusion within particular regions, providing insights into the diverse range of creative capacities and rates related to entrepreneurship and economic growth seen among regions (Kilintzis et al., 2023). According to Doloreux (2003), innovation is viewed as a cooperative network that unites a variety of public and private institutions, organizations, and entities in order to promote the development, application, and dissemination of creative skills, drives, and capacities locally.

In order to find distinctive development prospects through strategic networking, learning, and creative innovation, regions must adjust to the demands of modern society and the global market (Korres & Michailidis, 2021). Every region has unique resources, capacities, and rules that differentiate it. Smaller nations need to find ways to differentiate themselves in the market so they can compete globally. This entails looking for more funding, investigating creative answers to socioeconomic problems, identifying their advantages, and using them to realize their potential as smart areas (Sleuwaegen & Boiardi, 2014).

The implementation of Information and Communications Technology (ICT) nowadays is a key mean for countries aiming to distinguish themselves in the competitive global economic environment. This is critically important when the integration of ICT with other technologies is implemented as a mean to transform them into "smart technologies" (Meijer & Bolívar, 2016). This transformation allows regions to be categorized by their technology level. Effective development of ICT and smart technologies, followed by strategic long-term planning, is critical for a region’s development. (Samara et al., 2024) The exploitation of indicators to evaluate a region's progress and reveal its strengths and weaknesses is crucial for regional development planning (Muhammadi et al., 2015). This paper unveils ICT and smart technologies as key elements of RIS, pointing out an innovation perspective focused on these essential technologies. Ribeiro et al. (2020) stress the significance for policy makers to tailor ICT strategies to the unique characteristics of each region or sub-region, taking into account their distinct differences. These strategies should be based on local features and incorporate evaluation tools for their formulation. Despite the established significance of RIS in policy making, the lack of detailed regional data constitutes a challenge for a detailed analysis of regional activities and the implementation of effective policies. However, an ongoing improvement is recorded especially regarding the accessibility of key data for regional innovation assessment.

Innovation systems typically contain organizations and the interactions between them, regardless of their geographical extent, (Fagerberg et al., 2005). These systems are driven by the economic interplay of various actors and entities united in the goal of advancing technology development and innovation, including businesses, institutions, material assets, and human resources. The primary purpose of an innovation system is to encourage the creation, spread, and application of new ideas, with every activity aimed at this objective. RIS specifically involve networks of private, semi-private, and public organizations working within a supportive institutional environment. This setup facilitates the generation, application, and sharing of knowledge, thereby promoting innovative activities at a regional

level. Relevant literature contains numerous attempts to describe the research conducted within RIS (Asheim & Coenen, 2006; Cooke, 2004).

Doloreux and Parto (2005) have identified three core thematic areas of focus in RIS research:

- The first area examines the exchanges of knowledge between actors within the innovation system, such as organizations and institutions.
- The second area looks at the development and importance of institutions that facilitate knowledge exchange and innovation in a specific region.
- The third area investigates the influence of RIS on the formulation of regional innovation policies.

Autio's perspective (1998) on RIS encompasses:

- A subsystem dedicated to the application and commercialization of knowledge, characterized by innovative industries and businesses.
- A subsystem focused on the generation and spread of knowledge, involving higher education institutions, research centres, and other intermediaries.
- Active and extensive interactions between these subsystems, including the exchange of scientific and applied knowledge and human resources, as well as connections with other regional and national institutions.
- The presence of high-quality infrastructure and institutional frameworks, which include enough regional autonomy.
- Consideration of regional policy factors.

Komninos (2008) delineates the architecture of RIS as comprising an array of constituent components. Integral actors within this architecture include pioneering firms, supply chain participants, clientele, tertiary and other educational establishments, research institutions, entities dedicated to the transfer of technology, consultancy firms, incubators for new businesses, governmental bodies, and oversight organizations. These participants are interlinked through a set of institutions, conduits of knowledge exchange, and the fruits of innovative endeavors. Notably, knowledge, with a particular emphasis on tacit knowledge, exhibits a propensity for geographical aggregation, thereby catalyzing the colocation of innovative enterprises. At the zenith of this knowledge network, institutions assume a pivotal role, overseeing the allocation of funds and propelling the innovation process, thus bridging the gap between corporations and their consumer base. It is imperative to recognize that the configuration of these knowledge networks is subject to transformation contingent upon the ongoing processes of innovation, as novel innovation paradigms necessitate the formation of diverse partnerships and alliances (Komninos, 2008).

Literature has emphasized the noteworthy impact of specific national indicators on the performance of RIS, and vice versa. According to Barinova et al. (2015), regions in nations with robust economic indices typically have more active innovation ecosystems. Barinova et al. (2015) discovered a robust association between national measures such as R&D spending and the number of researchers, and regional innovation success in Russia. Additionally, the availability of trained personnel and the degree of education are essential for innovation. Stronger RIS are correlated with higher education levels (Karabayev et al., 2023). Moreover, national technological infrastructure – such as ICT – facilitates innovation by facilitating knowledge sharing and cooperation (Peshkov, 2019). Regional innovation capabilities are mostly determined by the amount of technical infrastructure and investment made in creative initiatives (Khadiullina et al., 2021), contributing to an increased level or responsibility in the

territorial policy making (Bidstrup et al., 2024). Moreover, specific indicators such as GDP (Gross Domestic Product) growth, investment in R&D, number of high-tech industries are vital for fostering a conducive environment for regional innovation (Popa, 2020).

Based on the initially conducted research, and in an effort to clarify RIS and the creative processes that occur within it before evaluating and examining the differences between Greek regional frameworks, this paper unfolds a theoretical approach that describes RIS as a combination of six discrete subsystems. These subsystems are made up of multiple components, each of which is represented by a separate variable that can be evaluated quantitatively. The characteristics of each variable are interdependent, influencing one another as the overarching system and its constituent subsystems manifest in a dynamic manner. The delineated subsystems include:

1. A subsystem encompassing the institutional architecture (inclusive of regional governance mechanisms).
2. A subsystem oriented towards regional development, indicative of innovation outcomes.
3. A subsystem dedicated to proficiency in information and communication technologies.
4. A subsystem for fostering knowledge networks.
5. A subsystem committed to the generation and dissemination of knowledge (incorporating universities and research institutions).
6. A subsystem focused on the application and commercialization of knowledge (encompassing enterprises and industrial clusters).

3. Methodology

The innovative regionalization methodology employed in this study is predicated on the concept of deriving estimates for indicators unavailable at the regional scale by utilizing alternative, accessible indicators that exhibit markedly congruent trends at the national scale. The regionalization process entailed the execution of correlation analyses between indicators available at the regional level and those that are not, followed by the application of regression models to generate estimates for the regional level predicated on pairs of indicators demonstrating significant correlations. A more comprehensive exposition of this method is provided in the subsequent sections. Furthermore, it is pertinent to acknowledge that this research did not engender any ethical concerns, as it was entirely predicated on the analysis of statistical data procured from a plethora of international databases, which are publicly accessible.

An array of indicators, amounting to 53 in total and aimed at evaluating the six subsystems of RIS as delineated in the literature review section, was employed to explore potential interrelations among them. These indicators were sourced from Eurostat, the World Bank, and an assortment of research studies cited in the scholarly literature. The selection of these indicators was guided by a comprehensive criterion aimed at encapsulating all facets of the regional innovation system that are pertinent to smart technologies and ICT, adhering to the model of the six subsystems introduced previously. The indicators were categorized into two groups based on their accessibility at the regional level. Out of the total 53 indicators, 29, identified as "Group A indicators," were accessible exclusively at the national level. The remaining 24, termed "Group B indicators," were available at both the national and regional levels.

The regionalization of the indicators involved five methodological phases. The initial step was identifying the target indicators that were not accessible at the regional level, referred to as "Group A indicators." Thus:

$$A_i = \textit{indices of high interest, where } i = 1, \ldots .n$$

$$A_{iN} = \textit{indices of high interest available in national level}$$

$$A_{iR} = \textit{indices of high interest not available, but required, in regional level}$$

The second phase involved identifying indicators linked to Group A indicators as per the literature, and accessible at both national and regional levels. These were referred to as "Group B indicators." Thus:

$$Bi = \textit{indices of high interest, where } i = 1, \ldots .n$$

$$B_{iN} = \textit{indices of high interest available at national level}$$

$$B_{iR} = \textit{indices of high interest available at regional level}$$

The third phase involved creating time series of national-level data for the indicators of Group A and Group B:

$$A_{iNt} = \textit{time series for indices of high interest available in national level}$$

$$B_{iNt} = \textit{time series for indices of high interest available in national level}$$

The fourth phase involved examining the correlations between each indicator in Group A (AiN) and all indicators in Group B (BiN) to reveal the links:

$$A_{iN} = a + bB_{iN} + \varepsilon_i, \textit{ where } \varepsilon_i \textit{ is the error variable}$$

Four pairs of indicators demonstrating a significant correlation with one another (specifically, an adjusted R-squared exceeding 0.8) were identified to possess a strong correlation, enabling the utilization of the indicators of Group B to derive regional-level estimates for Group A indicators. In the subsequent fifth step, the four robust correlations pinpointed in the fourth step were used to calculate regional-level estimates for the indicators of Group A (A_{iR}) from the regional-level data of Group B indicators (B_{iR}) through regression analyses. These models are presumed to be either unaffected or minimally affected by the geographic area of reference. Consequently, the regressions were conducted to approximate the regional-level values for Group A indicators. The outcomes derived from the regression models concerning the four focal indicators are delineated in the "results" section below and are subsequently analysed in the "discussion" section.

4. Results

Based on the model fit methodology described previously, a series of correlation analyses were conducted between variables in Group A and those in Group B. Among the 696 correlations performed, four exhibited particularly strong correlations, each with an adjusted R-squared value of 0.8 or higher, as detailed in Table 1. These correlations involved four unique variables from both Group A and Group B, selected for the regionalization process previously outlined. The selected indicators for regionalization all fall within the "competence in Information and Communication Technologies (ICT)" component of the regional innovation system. This was elaborated upon in the introduction, where the sub-systems of the RIS were discussed.

Table 1: Correlation estimations

	Dependent Variables			
	A1I (Employed ICT Specialists)	**A1W (Digitalization)**	**A1A (E-Commerce Sales)**	**A1F (Cloud Computing)**
Explanatory variables				
B1P (R&D expenditures in the public sector)	0.240 (6.03)			
B1F (GERD in the government sector)		0.327 (5.05)		
B1K (tertiary education)			0.032 (5.71)	
B1C (R&D personnel in higher education)				0.002 (18.05)
No. of observations	6	5	7	4
R-squared	0.901	0.895	0.867	0.994

Notes: Constant included numbers in parentheses denote t-statistics (i.e., the size of the difference relative to the variation in the sample data).

The four primary indicators chosen for regional analysis, along with their corresponding strongly correlated indicator, are outlined as follows:

- The indicator "Employed ICT specialists" (A1I), sourced from the World Bank at the national level, exhibited a strong correlation (with an adjusted R-squared value of 0.901) with "Gross Domestic Expenditure on R&D (all sectors)" (B1P), which is accessible at both national and regional levels via Eurostat. The established correlation formula is:

$$A1I = 0.239 \times B1P + 0.28$$

- The "Digitalisation" indicator (A1W), obtained at the national level from the European Innovation Scoreboard, showed a significant correlation (with an adjusted R-squared value of 0.895) with "Gross Domestic Expenditure on R&D in the government sector" (B1F), available from Eurostat for both national and regional levels. The correlation derived is:

$$A1W = 0.327 \times B1F$$

- "Enterprises with e-commerce as a percentage of total enterprises" (A1A), available at the national level from Eurostat, was found to have a strong correlation (with an adjusted R-squared value of 0.867) with the "percentage of the population aged 25–64 years with tertiary education" (B1K), accessible at both the national and regional levels via Eurostat. The resulting correlation equation is:

$$A1A = 0.032 \times B1K$$

- "Enterprises using cloud computing as a percentage of total enterprises" (A1F), sourced from Eurostat at the national level, demonstrated a highly significant

correlation (with an adjusted R-squared of 0.994) with "R&D personnel and researchers in the tertiary education sector" (B1C), available at both national and regional levels from Eurostat. The correlation formula derived is:

$$A1F = 0.002 \times B1C + 33.24$$

These correlations provide valuable insights for regionalization, demonstrating the interconnections between ICT specialization, digitalization, e-commerce, cloud computing adoption, and R&D expenditure and personnel across different sectors.

5. Conclusion

According to the study's findings, four distinct pairings of the 53 indicators that were investigated to evaluate RIS in terms of smart technologies were shown to be strongly corelated. Web sales are linked to the prevalence of tertiary education, cloud computing is linked to R&D personnel in tertiary education, ICT expertise in enterprises is linked to R&D expenditures in the public sector, and public R&D allocations are linked to increased digitalization. The assessment of those indicators that are unavailable at the regional level is made possible by these links, which are supported by the literature.

The literature's emphasis on the regional level is reinforced by the complexity of national systems and the degree of diversification within particular regional production systems. Furthermore, the scholarly literature usually emphasizes the idea that a distinct regional system might successfully function as a counterbalance in an era of increasing globalization. These phenomena highlight the tendency for cultural homogenization and the convergence of techniques and solutions (Hollanders et al., 2014). Economies continue to display a consistent preference for regional integration. As a result, it is critical to understand globalisation, the dominant narrative of our era, in connection with a lesser-known phenomena known as "global regionalization" (Malerba, 2002).

The availability of comparable and reliable data at the regional level is critical to assessing the effectiveness of a regional innovation system. The Sustainable Development Goals (SDGs) not only underscore the significance of data but also urge countries to improve the availability of de-identified data as part of the goal to strengthen data surveillance and accountability (SDG target 17.18). Subnational data is desperately needed in many areas, such as smart technologies, (Samara et al., 2024), business innovation capacity (Giourka et al., 2021), employment implications (Moktan, 2019), Smart Education (Samara et al., 2021) and so on, as data accessibility is seen as a crucial factor for assessing regional growth.

Efficient smart specialization strategies (RIS3) should result in complex and well-coordinated interactions among regional data sets, methodologies, and elements, with each component making unique contributions to strategic growth. The dynamic model outlined above, which includes several measurable indicators that can now be applied at the regional level, has the potential to significantly improve the effectiveness of RIS3 planning processes.

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