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Article

Assessment of Smart Technologies in Regional Innovation Systems: A Novel Methodological Approach to the Regionalisation of National Indicators

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Abstract: Innovation systems consist of different organisations from the quadruple helix, as well as the interactions and linkages between them. Smart technologies and ICT play a key role in the efficiency of systems. At the same time, regional scale is considered crucial for studying innovation in systems. However, the lack of many important data at the regional level compounds the efforts to study them. The paper proposes a novel methodological approach to the regionalisation of national-level indicators in order to address this issue. This is based on the model fit approach, using regressions to "regionalise" national-level indicators based on similar indicators that are available. The approach is tested on the data for Greek NUTS 2 regions and produces regional-level estimates for four innovation indicators, based on four available indicators that are found to be strongly correlated to them. However, the same approach can be used for any EU country or the whole of the EU. The results, their prospects for future research, and potential applications are considered. Overall, the availability of regional-level indicators is considered crucial for the formulation of impactful development policies.

Keywords: regional innovation systems; regionalisation of indicators; innovation

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1. Introduction

1.1. Terminology and Context

Innovation is usually studied in the context of systems, consisting of different organisations and the relationships and connections between them. In an innovation system, the drivers of innovation are human capital, research institutes and universities, the technology transfer organisations and other intermediary organisations, consultants, development organisations, financial and investment organisations, knowledge and material infrastructures, markets and consumers, and, finally, production businesses [1,2]. According to Edquist and Hommen, "firms... almost never innovate in isolation but interact more or less closely with other organisations, through complex relationships often characterised by reciprocity and mechanisms feedback..." [3].

In all cases, the innovative systems are referred to as interconnections of public and private sector institutions, whose activities and interactions create, introduce, and diffuse innovations. In essence, the innovation system includes a number of subjects such as enterprises, research centres, and educational institutions, a number of activities such as technological research and education, and a number of broader conditions such as institutional, economic, social, and also cultural. Therefore, it is one way of studying the effect of organisations and institutions on the national, regional, or local innovation activity.

Using one of the many definitions, we could say that an innovation system is defined according to [4] as: “the set of important economic, social, political, organisational and other factors that influence creation, diffusion and use of innovations”. In general, there is a complex two-way relationship between organisations and institutions, and this relationship affects innovation processes, and, thus, also performance, and changes the innovation systems [5].

Despite technological advancements and globalisation, geographically based innovation systems have become increasingly important. They have become the standard used to evaluate innovation performance and implement innovation policies [6]. It was recognised that a firm’s ability to innovate is influenced by external sources of knowledge and technology. As a result, firms located in different regions, exposed to distinct external conditions, can exhibit wide differences in innovative performance, even if their internal conditions and R&D expenditures are similar [7]. This understanding led to the replacement of neo-classical frameworks with evolutionary approaches [8], which viewed innovation as a systemic phenomenon dependent on meso-level interactions between firms and other actors, as well as micro-level interactions within the firms themselves [9].

Christopher Freeman [10], a Schumpeterian economist, was the first to introduce the term “National Innovation Systems” in this context. It is considered by many the most studied form of innovation systems [1,9,10]. In this approach, the country is the main unit of analysis. The national differences in the institutional organisation and structure of production and consumption are considered as explanatory factors, because some countries succeed in creating economic growth from innovation while others do not [1,10,11]. This approach is now widely adopted by transnational governing bodies to analyse and to structure political initiatives (OECD, EU, UN, etc.).

As the concept of innovation systems evolved, it became clear that factors beyond national character and boundaries played a crucial role in shaping innovation. Certain competences and features tended to be locally accumulated, leading to the definition of other systems of innovation, such as cluster-type or sectoral innovation systems, which focused on specific industrial sectors, and regional systems of innovation (RSI), which operated in specific areas with geographical proximity enabling the exchange of information [12].

Other scholars focus on one part of the national innovation system, namely, those who study regional innovation systems [13–16] and the sectoral innovation systems [17]. Local cultures and sectoral characteristics contribute to differences in structure, dynamics, and performance of these innovation systems. Regional focus is enhanced if one locates the complexity of national systems and their level of differentiation of individual regional production systems [18]. Furthermore, the literature often shows that the concept of a distinctive regional system can play a role in increasing the levels globalisation, which demonstrates the tendency towards homogenisation of culture and directions in strategies and in solutions [19].

1.2. Regional Innovation Systems and Smart Technologies

The concept of regional innovation systems (RIS) does not have a generally accepted definition [20], but a broad definition usually includes all interrelated institutional actors that create, diffuse, and exploit innovations in a specific geographical region [21], and all of which impact the RIS’s performance in producing innovation [22]. The concept of the RIS represents a shift from a linear perception of innovation that was dominant until the 1980s towards a systems theory in which investments in research and development (R&D) cannot stimulate economic growth unless they are appropriated by the different actors of the system to produce meaningful innovation [23].

Lundvall [1] is one of the first authors who promoted thinking about the systems of innovation, the mentioned regionalisation in relation to globalisation, and he also refers to regional networks as well. Innovation systems researchers and scholars have developed a regionally based approach to innovation system thinking, with ‘regions’ usually referring to a geographical area within a country. This spatial concentration remains important for the development of innovative activities, despite the fact that modern information and communication technologies make spatial distances insignificant between different partners [24]. Silicon Valley is the typical example used for a region with great innovative potential.

Although many aspects of the national innovation systems (NIS) approach can also be applied at the regional level, the approach of regional innovation systems (RIS) is crucially different from that of NIS [25,26]. The internal organisation of businesses, the relationships between businesses, the role of the public sector and public policy, as well as institutional organisations, for example, the financial sector, are among the various characteristics that may be explored in detail at the regional level. At the national level, these aspects could vary greatly. The RIS approach, thus, emphasises the regional dimension of the production and exploitation of new knowledge, thereby helping to explain regional differences in innovative capacity and economic growth. It is perceived as a network of public and private actors, institutions, and organisations whose activities and interactions create local channels of use, development, and diffusion of available skills, motivation, and innovative capabilities [27].

Regions must respond to the needs of modern society and of the world market and find their own opportunities to develop their intelligence (goal seeking, networking, participation, learning, innovation, creativity, intelligence, etc.) [17,24,25]. Each region "has specific assets, unique capabilities and industrial policies that differentiate it from other regions" [28]. The regions of a small country must find their own field of competitive advantage to participate in a global market. Therefore, they seek access to additional resources, try non-traditional ways of solving socio-economic problems, they identify their advantages and use them to find innovation potential to become smart regions.

Today, grasping and utilising ICT is one of the methods by which countries can be developed in the global economy. This is particularly true for the application of ICT in other technologies, which previously did not have such capabilities, to upgrade them to "smart technologies" [29]. In this context, geographical areas and regions can be ranked according to the level of their development in technology. As a result, the optimal development of ICT and smart technologies can become a key in the development of a country, if correct long-term planning is used [30–32]. The use of indicators to assess and explain the level of development of a region, as well as to identify its strengths and weaknesses, is a prerequisite during developmental planning on a regional level [30]. Due to these reasons, this paper considers ICT and smart technologies as a key aspect of regional innovation systems and adopts a view of innovation systems through the approach of these key technologies.

There is a wide variety of tools on a regional level facilitating the assessment of the local ICT framework via the systematic comparison of regional output in several aspects of the development of an information society. Various scoreboards feature indicators for ICT, which compare the performance of a region with other regions in the same country or different countries [33,34].

For example, the European Innovation Scoreboard provides a comparative assessment of the research and innovation performance of EU member states, other European countries, and regional neighbours. It helps countries assess the relative strengths and weaknesses of their national innovation systems and identify challenges that they need to address. It consists of 32 indicators grouped under 12 dimensions out of which only 4 are referring to smart technologies [35]. Similarly, the Regional Innovation Scoreboard (RIS) serves as an extension of the European Innovation Scoreboard (EIS) and is specifically designed to evaluate the innovation performance of European regions. This assessment is conducted using a selected set of indicators. The Regional Innovation Scoreboard 2023 adheres to the approach of the European Innovation Scoreboard 2023EN, utilising data from 239 regions in Europe. This data encompasses 21 of the 32 indicators utilised in the European Innovation Scoreboard 2023. There are just two indicators that are associated with smart technologies [36].

According to Ribeiro et al. [37], when formulating public policies regarding the use of ICTs, decision makers should take into account the unique characteristics of a region, or even of different areas within a region, and how these differ from each other. Therefore, public policies should be designed, based on local peculiarities and features, and should take assessment tools into account. Overall, however, although the regional system is considered crucial, capitalising on its importance is restricted by a lack of data on the regional level [6]. This complicates the process of accurately assessing the processes taking place in the regional system, which, in turn, hinders the drafting and implementation of suitable policies to support the system. Several key indicators for regional innovation are not available on a regional level, although the situation is gradually improving [6].

1.3. Major Features of Regional Innovation Systems

Regardless of their geographical scale, systems of innovation are composed of organisations and institutions, along with the relationships and linkages between them [38]. These systems are shaped by the economic dynamics of complex relationships among various actors and entities with the common goal of promoting technology development and innovation. This includes firms, institutions, material resources, and human capital [39]. The ultimate objective of a system of innovation is to foster the development, diffusion, and utilisation of innovations, and all its activities are oriented towards achieving this goal in one way or another [38].

Regional innovation systems usually consist of a set of interacting private, semi-private, and public organisations, which interact within an institutional framework. This framework supports the creation, exploitation, and dissemination of knowledge and, thus, supports the creation of innovative activities at the regional level [27,40,41]. There are many attempts in the literature that try to capture the research that is carried out in a regional innovation system.

According to Doloreux and Parto [42], the research of RISs focuses on three main dimensions:

- First, in the interactions between the innovation system's actors (organisations and institutions) that are related to knowledge exchange;
- Second, in the creation and role of institutions that support knowledge exchange and innovation within a region;
- Thirdly, in the role of RIS in drawing up regional innovation policies.

According to Autio [43], the RIS includes:

- The "knowledge application and exploitation subsystem": innovative industries/ businesses;
- The "knowledge production and dissemination subsystem": tertiary education, research centres and other 'intermediaries' (e.g., [44]);
- Intensive interactions between subsystems in terms of scientific/applied knowledge and human resource flows, including relations with other regional and national institutions;
- High-quality infrastructure and institutional arrangements, including sufficient 'regional' autonomy [45];
- Regional policy factors [46].

Studying innovation, the regional system emerges as a pivotal factor, striking a balance between cluster-type and sectoral innovation systems, as well as national innovation systems. While cluster and sectoral systems tend to be too specialised and overlook the broader network of interactions among actors, national systems, particularly in larger countries, may be too extensive to consider local interactions adequately.

It is evident that regions merit individual attention, given the considerable diversity in regional economic specialisation patterns and innovation performances within countries [47]. Moreover, certain knowledge spill overs are confined to the regional level, as they depend on trust-based relationships that require geographical proximity, making transfer over long distances challenging. This is particularly true for tacit knowledge, which involves skills, ideas, and experiences that are not easily expressed or codified, making them challenging to access [47].

Regional innovation systems usually consist of a number of private, "semi-private", or public organisations, coming from academia, public administration, entrepreneurship, and society according to the quadruple helix model [48]. The quadruple helix expands on the triple helix concept, which views innovation as the product of the dynamic interactions between academia, industry, and government [49]. Public or civil society is added as a fourth helix to the model to respond to the changing nature of knowledge society [50]. All actors belonging to the helixes interact within an existing institutional framework. This framework supports the creation, valorisation, and spread of knowledge, contributing to the implementation of innovative activities at a regional level [27,40].

According to Doloreaux and Parto [42], the interactions and research taking place within innovation systems are focused mainly on three dimensions:

- The interactions between the innovation system components (organisations and institutions that take part in knowledge exchange processes);
- The formation and role of institutions that support the knowledge exchange process within the system;
- The role played by the regional innovation system in drafting innovation policies.

Autio [43] states that a regional system consists of a number of different subsystems and the interactions between them. A subsystem of knowledge production and diffusion includes universities and research centres, while a subsystem of knowledge implementation and capitalisation includes innovative industries and businesses. The regional system consists of the interaction between these two subsystems in terms of human resources and applied knowledge, as well as between them and existing regional infrastructures and institutions, and the factors that determine regional policies [44,46].

For Komninos [51], the structure of regional innovation systems includes various components. Organisations with a key role are innovative companies, suppliers, clients, universities, other educational institutions, research organisations, technology transfer organisations, consultants, business incubators, government agencies, and monitoring agencies. These are connected by institutions, knowledge networks, and innovation outputs. Knowledge, and especially tacit knowledge, tends to accumulate spatially, bringing innovative businesses in geographical proximity. Institutions, by being responsible for approval of funding and mobilising the process of innovation, have a place at the top of the knowledge network, connecting companies with clients. Finally, the architecture of knowledge networks changes according to the innovation processes taking place, as new types of innovations require different partnerships and alliances [51].

Based on the brief review above, and in order to focus on regional innovation systems and the innovative processes taking place within them before estimating and examining the differences between the Greek regional systems, the paper follows a conceptualisation of the regional innovation system as consisting of six subsystems. The subsystems, in turn, consist of different components, captured by different factors that can be quantitatively assessed. The properties of each factor affect the others as the system and its subsystems operate dynamically. The sub-systems are:

- A sub-system of competence in information and communication technologies (ICT);
- A sub-system of regional development, reflecting innovation outputs;
- A sub-system of institutional framework (including regional governance);
- A sub-system of knowledge implementation and capitalisation (enterprises and clusters);
- A sub-system of knowledge networking;
- A sub-system of knowledge production and dissemination (universities and research centres).

1.4. Aim of the Paper

The brief literature review conducted in the introduction section above has outlined the major importance of the regional scale of innovation systems, and, at the same time, the disconcerting lack of data at that level. To compensate for this, the present paper implements and demonstrates a novel methodological approach to the "regionalisation" of national-level indicators. It has followed a "model fit" methodology using correlations and regressions [52] to provide estimates of regional-level values for four indicators that are not available on the regional level, based on the values of four other indicators that are closely connected to the former group and are available in the regional level.

The estimations have been conducted utilising numerical data pertaining to the 13 NUTS 2-level regions of Greece. However, the same process can be reproduced equally well and is equally valid for any other EU country, as all have the same administrative divisions in the NUTS scale and a similar availability of data in the international databases used (see below in Section 2.1). It is, therefore, intended that further research can be used in applying this "regionalisation" approach on a European level, producing reliable regional-level data estimates for all indicators that are currently missing on a regional level. The main aim of the paper is to test and present this approach, and, therefore, help address the issues caused by the lack of regional-level data.

The methodological approach followed is presented in the "material and methods" section, below. The resulting statistical estimates are presented in the "results" section. The "discussion" section considers how the existing literature substantiates the connections between indicators revealed by the model fit methodology. It also includes a consideration of the results and their implication for further research, together with the prospects of the methodological approach being used on other indicators in order to improve the ability to assess regional innovation systems.

2. Materials and Methods

The novel regionalisation approach used in the present paper is based on the idea of estimating indicators that are not available at the regional level based on other, available indicators that show strongly similar tendencies at the national level. The regionalisation was conducted by running correlations between indicators that are available at regional level and those that are not and running regression models to produce regional-level estimates based on pairs of indicators showing strong correlations. This is described in more detail below.

It should also be noted that there were no ethical issues raised in the research, as it was completely based on statistical data that were openly available from a number of international databases.

2.1. Measures and Indicators

A number of indicators assessing the six sub-systems of regional innovation systems, as these were outlined in the introduction above, were used to look for potential correlations among them. In total, this included 53 indicators, which were taken from Eurostat, the World Bank, and various research studies listed in the literature. The indicators were selected with the overall criterion of encompassing all aspects of the regional innovation system that are connected to smart technologies and ICT, following the model of the six sub-systems outlined in the introduction. Similar approaches to the assessment of these indicators have been used in the existing literature reviewed above.

The indicators were divided in two groups according to their availability on a regional level. Of the total of 53, 29, listed as "Group A indicators" were only available on the national level. Another 24, listed as "Group B indicators", were available on both national and regional level. This is further described below. A full list of the indicators is provided in Appendix A.

As mentioned above, the data for these 53 indicators were taken from the relevant data sources for the 13 NUTS 2-level regions of Greece. This was executed as the authors have greater familiarity and experience with Greek regions and the Greek setting. However, as already mentioned, the same process can be reproduced equally well and is equally valid for any other EU country, as all have the same administrative divisions in the NUTS scale and a similar availability of data in databases. Running the model on Greek regions represents a smaller-scale test of the model.

2.2. Procedure

The procedure for regionalisation of the indicators consisted of five methodological steps. The first step was to identify the target indicators that were not available on the regional level, called "Group A indicators". Thus, the followings hold:

$$A_i = several\ indices\ of\ high\ interest,\ where\ i = 1, \ldots .n$$
$$A_{iN} = several\ indices\ of\ high\ interest\ available\ in\ national\ level$$
$$A_{iR} = several\ indices\ of\ high\ interest\ not\ available,\ but\ required,\ in\ regional\ level$$

The second step was to find indicators that are connected to the Group A indicators according to the literature, but available on both the national and regional levels. These were called "Group B indicators". Both of these steps were described above, in Section 2.1. Thus, the followings hold:

$$B_i = several\ indices\ of\ high\ interest,\ where\ i = 1, \ldots .n$$
$$B_{iN} = several\ indices\ of\ high\ interest\ available\ in\ national\ level$$
$$B_{iR} = several\ indices\ of\ high\ interest\ available\ in\ regional\ level$$

In the third step, time series of national-level data were created for Group A and Group B indicators:

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

In the fourth step, correlations were run between each of the Group A indicators (A_{iN}) and all Group B indicators (B_{iN}) to look for connections:

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

Four pairs of indicators that were found to be strongly correlated to each other (i.e., with an adjusted R squared greater than 0.8) were considered to be closely linked for the Group B indicators to be used to provide estimates for the Group A indicators on a regional level. In the fifth step, the four strong correlations identified in the fourth step were used to estimate regional-level data (which are unknown) for Group A (A_{iR}) indicators from regional-level data (which are available) for Group B indicators (B_{iR}) using regression analyses. It is assumed that these models are not influenced or slightly influenced by the geographical reference area. The regressions run then estimate the regional-level figures for the Group A indicators. The results of the regression models used on the four target indicators are provided in the "results" section below, and then further considered in the "discussion" section.

3. Results

Following the model fit methodology explained above, correlations were run between all Group A variables and all Group B variables. Out of the 696 correlations that were run, 4 were found to be particularly strong, with an adjusted R-squared of 0.8 or larger. These are summarised in Table 1 below. The four different Group A variables and four different Group B variables are those selected for the regionalisation process outlined above.

The four target indicators selected for regionalisation were all part of the "competence in information and communication technologies (ICT)" sub-system of the regional innovation system, as explained when discussing the sub-systems of the RIS, in the introduction above.

Table 1. Model 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 target indicators selected for regionalisation are listed below, together with the indicator strongly correlated with each one.

- "Employed ICT specialists" (A1I), available on the national level from the World Bank, was strongly correlated (adjusted R-squared of 0.901) with "Gross Domestic Expenditure on R&D (all sectors)" (B1P), available on both the national and regional levels from Eurostat. The resulting correlation relationship is as follows:

$$\text{A1I} = 0.239 \times \text{B1P} + 0.28;$$

- "Digitalisation" (A1W), available on the national level from European Innovation Scoreboard [6], was strongly correlated (adjusted R-squared of 0.895) with "Gross Domestic Expenditure on R&D in the government sector" (B1F), available on both the national and regional levels from Eurostat. The resulting correlation relationship is as follows:

$$\text{A1W} = 0.327 \times \text{B1F};$$

- "Enterprises with e-commerce as a percentage of total enterprises" (A1A), available on the national level from Eurostat, was strongly correlated (adjusted R-squared of 0.867) with "percentage of the population 25–64 years old with tertiary education" (B1K), available on both the national and regional levels from Eurostat. The resulting correlation relationship is as follows:

$$\text{A1A} = 0.032 \times \text{B1K};$$

- "Enterprises using cloud computing as a percentage of total enterprises" (A1F), available on the national level from Eurostat [53], was strongly correlated (adjusted R-squared of 0.994) with "R&D personnel and researchers in the tertiary education sector" (B1C), available on both the national and regional levels from Eurostat. The resulting correlation relationship is as follows:

$$\text{A1F} = 0.002 \times \text{B1C} + 33.24$$

4. Discussion

The "discussion" section considers how the existing literature substantiates the connections between indicators revealed by the model fit methodology. It also includes a consideration of the results and their implication for further research, together with the prospects of the methodological approach being used on other indicators in order to improve the ability to assess regional innovation systems.

Each pair of indicators found to be strongly connected to each other by the research methodology are considered in turn in the sub-sections below, in order to examine whether and how this connection is backed up by the existing research literature.

4.1. How Results Compare to the Literature

4.1.1. ICT Expertise and Public R&D

The presence of ICT experts and the existence of ICT expertise in enterprises is connected to R&D expenses in the public sector. There is a directly proportional connection,, which is universally accepted and also backed by the literature [54]. There is a complex interrelationship between R&D investments and ICT diffusion, but the two variables are closely connected [55]. According to Nair et al. [55], there is causality between ICT expertise and public R&D investment in the case of every OECD country, although the exact nature of the causality (i.e., unilateral or bilateral) depends on the case studied [55]. According to Hong [56], there is bidirectional causality between public and private sector investment, as one encourages the other. In addition, R&D investments in ICT are linked to economic growth, driving growth, as growth drives further ICT R&D investments, in a virtuous cycle [56].

Investment in R&D is generally seen as a crucial basis for innovation, and this is particularly true for ICT, as it is a high-technology sector [57]. Unsurprisingly, both public and private R&D expenditure is positively correlated with increased ICT productivity and value-added [57]. R&D and ICT are both strongly associated with innovation and productivity [58] and considered its main inputs [59]. Both can be used to explain why Europe underperforms in innovation compared to the USA [58]. R&D tends to be highly concentrated in the ICT sector, especially in the case of countries with a high level of technology [60]. R&D investment together with ICT infrastructures and diffusion are the main drivers of economic growth in OECD countries [55]. The total number of ICT specialists increases the impact of R&D, as well as innovation [61]. Overall, there is every indication regarding a possible complementarity between R&D and ICT [58], so the former indicator was used to estimate the regional value of the latter.

4.1.2. Digitalisation and Public R&D

There is direct proportionality between increased R&D allocations and increased digitalisation [54]. R&D and digitalisation have a two-way dynamic, with one supporting the other [62]. The digitalisation of the economy is arguably the key factor behind the fourth industrial revolution, and R&D, in turn, has a key role in bringing it about [63]. The level of R&D has a major beneficial impact on innovation, digitisation, and the entire spectrum of the digital transition [64]. Due to a financial risk that is often inherent in innovative ideas and high-tech sectors, together with the high cost of such investments, banks can be reluctant to provide finance. In this case, the role of public sector R&D expenditure is even more critical [63,65].

On the other hand, the impact of digitalisation has started to transform the nature of R&D and improve its practice [66], bringing increased consumer–customer intimacy, greater speed to market, broader use of open innovation, and more accurate forecasting [62]. Digitalisation has a major potential to revolutionise the form and efficiency of R&D in the future [67]. This tendency for the digitalisation of R&D [62] is evident in enterprises, where digitalisation in production, logistics, value chains, and the use of big data analytics can be an important element, especially in enterprises where R&D processes are open and not intramural [68].

This effect is not exclusive to enterprises, however, and can also be observed even more clearly in the public sector and on a national level as a whole [54]. This is evident when there are significant central initiatives towards digitalisation, such as the EU's "compass for the digital dimension", and especially via R&D innovations that are specific to the public sector, such as e-governance [61].

4.1.3. Web Sales and Tertiary Education

Although the COVID-19 pandemic has boosted web sales, they already had a steady tendency to increase over time regardless [69]. Web sales are among the several indicators that can be connected to the prevalence of tertiary education. First of all, Internet use, human capital, digitalisation, and innovation are closely linked in the literature, with complicated and mutually reinforcing relationships between them [61]. While the phenomenon of digitalisation has many aspects, increased e-commerce is often considered to be at its core [70]. However, digitalisation is also a key component in making the attainment of education more convenient and more accessible [71], as universities and other higher education institutions have used the Internet to transcend their physical and institutional borders [72].

In turn, tertiary education, especially in ICT or marketing, is a prerequisite for increasing the prevalence of online sales [70]. This is even more evident in smaller firms, as increased education and capacity can help even micro-companies (with 10 or fewer employees) to implement web sales and become successful in them, broadening the companies' horizon [73]. In addition, increased education can have an impact on consumer decision-making, increasing web sales [74] when factors such as security, information quality, and information quantity are present [75]. Education can be important in other, more indirect ways too. ICT development in various sectors, including e-commerce, can lead to increased productivity and employment, provided that there is an adequate prevalence of tertiary education to utilise this potential [76].

4.1.4. Cloud Computing and R&D Personnel in the Tertiary Education Sector

There is a quantifiable correlation between R&D personnel and the increase in computer and Internet use at companies' level, and this includes cloud computing [54]. The main advantage of cloud computing is the reduction in IT cost and especially initial IT investments, as organisations are able to rent resources and make payments only for services, instead of facing the expense of setting up an IT infrastructure [77]. This can be particularly useful in cases where setting up IT infrastructure is particularly difficult or beyond the means of the organisation in question, such as in small companies or in developing countries [77].

Cloud computing offers on-demand Internet-based computing services, and, as such, has been a valuable tool for universities and other tertiary education institutions for over a decade now [78]. Cloud computing is extremely useful in a tertiary education setting because it can be easily utilised by students and expand the capacity to provide courses in online, remote, and time-unconstrained conditions [79]. Overall, the adoption of cloud computing technologies by companies seems to be reinforced by sustained investments in R&D as well as the availability of the computing technology [80]. Whether in companies, universities, or other organisations, the availability of R&D and technology are key enablers in expanding the usage of cloud computing, via providing prerequisites such as personnel skills, security, and efficiency [81].

4.2. Limitations of the Study

There are several limitations to consider in this review. One notable limitation of our research is the assumption that there is no spatial variability in the computation of the indicators. Our next course of action involves careful utilising of spatial variability, which can be evaluated by spatial descriptive statistics.

One additional limitation of the study is the decision to implement regionalisation of the indicators specifically in Greece. The rationale for this decision is elucidated in the preceding article. Nevertheless, employing the technique over a diverse range of regions, while also incorporating the aforementioned spatial variability concerns, could yield a more comprehensive examination of the indicators' regionalisation process.

Adding to the above it could be mentioned that the use of panel estimation for regional data, which allows researchers to capture and analyse the dynamic interplay of variables across different regions and time periods, could be another method to use. It provides a powerful framework for understanding regional trends, assessing policy impacts, and uncovering underlying patterns that may not be apparent in cross-sectional or time-series analysis alone. Across our ongoing research, we will employ this approach to evaluate the two techniques across a broader selection of European regions.

4.3. Potential for Future Research and Applications

The present study is an attempt to create a methodology that can regionalise indicators identified only at national level. In the subsequent stage, the use of these indicators will be employed to construct a dynamic model that will allow the identification of the strong and weak points within the regional innovation system, enhancing those that generate multiplier benefits at the level of regional development. The utilisation of this model will prove to be a crucial instrument for policymakers, as it will enable them to evaluate the effects of various policies pertaining to smart technology and innovation within the framework of a regional innovation system.

Additionally, the study conducted by Ranga and Etzkowitz [82] underscores the importance of enhancing policies that necessitate the utilisation of diverse regional datasets to concurrently identify and prioritise regional objectives. Efficient smart specialisation strategies (RIS3) should lead to intricate and effectively coordinated interactions among regional data sets, methodologies, and elements, with each component making distinct contributions to the overall strategic growth [83–85]. The development of the above-mentioned dynamic model, comprising many quantifiable indicators that can now be translated to the regional level, has the potential to serve as a crucial factor in enhancing the efficacy of RIS3 planning processes.

5. Conclusions

As the research results have shown, out of the 53 different indicators examined assessing regional innovation systems in terms of smart technologies, four different pairs were found to be significantly correlated. ICT expertise in enterprises is connected to R&D expenses in the public sector, public R&D allocations are connected to increased digitalisation, web sales are connected to the prevalence of tertiary education, and cloud computing is connected with R&D personnel in tertiary education. These connections, backed by the literature, allow for the estimation of those indicators that are not available on the regional level.

The emphasis placed by the literature on the regional level is strengthened when considering the intricacy of national systems and the degree of diversification within individual regional production systems. Furthermore, the scholarly literature frequently highlights the notion that a unique regional system can effectively serve as a counterbalance in an era marked by escalating globalisation. This phenomenon underscores the inclination towards cultural homogenisation and the convergence of methods and solutions [6].

Economies continue to exhibit a persistent inclination towards regional integration. Hence, it is imperative to comprehend globalisation, the prevailing narrative of our era, in conjunction with a lesser-known phenomenon commonly referred to as "global regionalization" [17].

The ability to evaluate the performance of a regional innovation system is highly dependent on the availability of comparable and reliable data at the regional level. In addition to emphasising the importance of data, the Sustainable Development Goals (SDGs) encourage nations to enhance the accessibility of disaggregated data as a component of the objective to fortify data surveillance and accountability (SDG target 17.18) [85]. As data accessibility is considered an essential criterion for evaluating regional development, subnational data is urgently required in a variety of fields, including smart technologies, business innovation, employment impacts, and so forth.

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Data Availability Statement: The names of the indicators used, the databases from which they were taken, and the web link to the data base pages are included in Appendix A.

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Appendix A List of Indicators

Table A1. Listing of Group A indicators.

Indicator	Unit of Measure	Source (accessed on 27 September 2023)
E-commerce sales of enterprises	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/ISOC_EC_ESELS__custom_7512329/default/table?lang=en
Share of enterprises' turnover on e-commerce	Percentage of turnover	https://ec.europa.eu/eurostat/databrowser/view/tin00110/default/table?lang=en
Websites and functionalities by size class of enterprise	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/isoc_ciweb/default/table?lang=en
Social media use by type, internet advertising and size class of enterprise	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/isoc_cismt/default/table?lang=en
Integration of internal processes by size class of enterprise	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_iip/default/table?lang=en
Cloud computing services by size class of enterprise	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/isoc_cicce_use/default/table?lang=en
E-commerce sales of enterprises by size class of enterprise	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/isoc_ec_esels/default/table?lang=en
Enterprises that employ ICT specialists by NACE Rev.2 activity—all activities, without financial sector	Percentage of enterprises	https://ec.europa.eu/eurostat/databrowser/view/ISOC_SKE_ITSPEN2__custom_7573283/default/table?lang=en
Employed ICT specialists	Percentage of total employment	https://tcdata360.worldbank.org/indicators/ict.emp?country=BRA&indicator=27&viz=bar_chart
Broadband internet coverage by technology—fixed broadband	Percentage of households	https://ec.europa.eu/eurostat/databrowser/view/ISOC_CBT__custom_7573379/default/table?lang=en
Broadband and connectivity—households—household internet connection type: broadband	Percentage of households	https://ec.europa.eu/eurostat/databrowser/view/isoc_r_broad_h/default/table?lang=en

Table A1. *Cont.*

Indicator	Unit of Measure	Source (accessed on 27 September 2023)
Individuals' level of digital skills (until 2019)—individuals who have basic or above basic overall digital skills	Percentage of individuals	https://ec.europa.eu/eurostat/databrowser/view/ISOC_SK_DSKL_I__custom_7573518/default/table?lang=en
Percentage of the ICT sector on GDP—ICT services	Percentage	https://ec.europa.eu/eurostat/databrowser/view/tin00074/default/table?lang=en
Employed ICT specialists	Percentage of total employment	https://ec.europa.eu/eurostat/databrowser/view/isoc_sks_itspt/default/table?lang=en
Global entrepreneurship index		https://knoema.com/atlas/topics/World-Rankings/World-Rankings/Global-entrepreneurship-index https://thegedi.org/global-entrepreneurship-and-development-index/
Venture capital availability	1–7 (best), index 1–7 (best)	https://tcdata360.worldbank.org/indicators/h8a7ea3d1?country=BRA&indicator=529&viz=line_chart&years=2007,2017
Gini index	Percentage	https://data.worldbank.org/indicator/SI.POV.GINI
Innovation index	Points	https://www.theglobaleconomy.com/rankings/gii_index/
Ranking of Greece among the EU member states in the European Innovation Scoreboard	Rank	https://metrics.ekt.gr/sites/metrics-ekt/files/ekdoseis-pdf/2022/EKT_Greece_EuropeanInnovationScoreboard_2014_2021.pdf (pp. 27–30)
SII Greece over time—Summary Innovation Index Greece—relative to EU in 2014	0–180	https://metrics.ekt.gr/sites/metrics-ekt/files/ekdoseis-pdf/2022/EKT_Greece_EuropeanInnovationScoreboard_2014_2021.pdf (pp. 27–30)
Human resources	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Attractive research systems	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Digitalisation	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Finance and support	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Firm investments	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Use of information technologies	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)

Table A1. *Cont.*

Indicator	Unit of Measure	Source (accessed on 27 September 2023)
Innovators	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Linkages	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Intellectual assets	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Employment impacts	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Sales impacts	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Environmental sustainability	0–180	https://ariadne.ekt.gr/ariadne/bitstream/20.500.12776/17113/4/EKT_Greece_EuropeanInnovationScoreboard_2015_2022.pdf (pp. 23–26)
Individuals with above basic overall digital skills	Numerator: number of individuals with above basic overall digital skills; denominator: total number of individuals aged 16 to 74	https://ec.europa.eu/docsroom/documents/48374

Table A2. Listing of Group B indicators.

Indicator	Unit of Measure	Source(accessed on 27 September 2023)
R&D personnel and researchers by sector of performance, sex and NUTS 2 regions—business enterprise sector	Full-time equivalent (FTE)	https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSREG/default/table?lang=en
R&D personnel and researchers by sector of performance, sex, and NUTS 2 regions—private non-profit sector	Full-time equivalent (FTE)	https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSREG/default/table?lang=en
R&D personnel and researchers by sector of performance, sex, and NUTS 2 regions—higher education sector	Full-time equivalent (FTE)	https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSREG/default/table?lang=en
R&D personnel and researchers by sector of performance, sex and NUTS 2 regions—government sector	Full-time equivalent (FTE)	https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSREG/default/table?lang=en

Table A2. *Cont.*

Indicator	Unit of Measure	Source(accessed on 27 September 2023)
R&D personnel and researchers by sector of performance, sex, and NUTS 2 regions—total	Full-time equivalent (FTE)	https://ec.europa.eu/eurostat/databrowser/view/RD_P_PERSREG/default/table?lang=en
GERD by sector of performance and NUTS 2 regions—government sector	Million euro	https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDREG/default/table?lang=en
GERD by sector of performance and NUTS 2 regions—higher education sector	Million euro	https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDREG/default/table?lang=en
GERD by sector of performance and NUTS 2 regions—business enterprise sector	Million euro	https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDREG/default/table?lang=en
GERD by sector of performance and NUTS 2 regions—private non-profit sector	Million euro	https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDREG/default/table?lang=en
GERD by sector of performance and NUTS 2 regions—total	Million euro	https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDREG/default/table?lang=en
Tertiary educational attainment, age group 25–64 by sex and NUTS 2 regions	Percentage	https://ec.europa.eu/eurostat/databrowser/view/tgs00109/default/table?lang=en
Population involved in lifelong learning	Percentage—numerator: number of persons in private households aged between 25 and 64 years who have participated in the four weeks preceding the interview, in any education or training, whether or not relevant to the respondent's current or possible future job; denominator: total population aged between 25 and 64 years	https://ec.europa.eu/docsroom/documents/48374
International scientific co-publications per million population	Numerator: number of scientific publications with at least one co-author based abroad; denominator: total population	https://ec.europa.eu/docsroom/documents/48374
Scientific publications among the top 10% most cited publications worldwide	Percentage—numerator: number of scientific publications among the top 10% most cited publications worldwide; denominator: total number of scientific publications	https://ec.europa.eu/docsroom/documents/48374
Individuals who have above basic overall digital skills	Percentage	https://ec.europa.eu/docsroom/documents/48374
R&D expenditures in the public sector as percentage of GDP	Numerator: all R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD); denominator: regional gross domestic product	https://ec.europa.eu/docsroom/documents/48374

Table A2. *Cont.*

Indicator	Unit of Measure	Source(accessed on 27 September 2023)
R&D expenditures in the business sector as percentage of GDP	Numerator: all R&D expenditures in the business sector (BERD); denominator: regional gross domestic product	https://ec.europa.eu/docsroom/documents/48374
ICT specialists (as a percentage of total employment)	Numerator: number of employed ICT specialists; denominator: total employment	https://ec.europa.eu/docsroom/documents/48374
Public–private co-publications per million population	Numerator: number of public–private co-authored research publications with both domestic and foreign collaborators. The definition of the "private sector" excludes the private medical and health sector; denominator: total population	https://ec.europa.eu/docsroom/documents/48374
PCT patent applications per billion regional GDP	"Numerator: Number of patents applied for at the European Patent Office (EPO), by year of filing.	https://ec.europa.eu/docsroom/documents/48374
Trademark applications per billion regional GDP	The regional distribution of the patent applications is assigned according to the	https://ec.europa.eu/docsroom/documents/48374
Design applications per billion regional GDP	address of the inventor; Denominator: Gross Domestic Product in Purchasing Power Standard"	https://ec.europa.eu/docsroom/documents/48374
Employment in knowledge-intensive activities (percentage of total employment)	Numerator: number of trademark applications applied for at EUIPO; denominator: gross domestic product in purchasing power standard	https://ec.europa.eu/docsroom/documents/48374
Air emissions by fine particulate matter (PM2.5) in the manufacturing sector	Numerator: number of designs applied for at EUIPO; denominator: gross domestic product in purchasing power standard	https://ec.europa.eu/docsroom/documents/48374
SMEs introducing business process innovations as percentage of SMEs	Numerator: Number of employed persons in knowledge-intensive activities in business	https://ec.europa.eu/docsroom/documents/48374

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