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How Intellectual Capital Predicts Innovation Output in EU Regions. Implications for Sustainable Development

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Abstract: Intellectual capital is an overarching concept that includes the intangible, human-related factors that are relevant to the innovation process, such as human capital and social capital. In the present study, intellectual capital was assessed by indicators measuring different aspects of human and social capital. Factor analysis demonstrated the existence of three underlying factors, with all variables of the model having important contributions to them. A linear regression analysis indicated that 8 out of the 12 variables of intellectual capital used have a statistically significant impact on the measure of innovation output. These findings were discussed and their implications for policy were considered. The paper provides research evidence on the importance of intellectual capital for innovation output and discusses potential ways to achieve smart, sustainable and inclusive growth in the context of the next generation of sustainable smart specialisation strategies.

Keywords: intellectual capital; smart specialisation strategies; human capital; social capital; regional innovation; sustainable development

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1. Introduction

Innovation, as a term, refers to meaningful change, in which a new element provides some clear advantage, such as a solution to a problem, better performance, better efficiency, or cost reduction [1–3]. Innovation is an extremely popular concept, and rightfully so, as it is the central issue determining prosperity and the main driver of progress and development throughout history [4]. For this reason, assessing and fostering innovation has become a key priority. However, it is important to briefly underline the difference of innovation as a concept and theory in the field of engineering, dealing with systemic conditions and production of novelty, and innovation in economics dealing with its contribution to wealth and growth [5,6].

Innovation is fostered by policies that are either centrally organised or rely on local decision-making and bottom-up actions. In the European Union (EU), innovation policies were first formulated in the 1980s and have culminated in the currently active and highly acclaimed Research and Innovation Strategy for Smart Specialisation (S3), which is based on the notion that countries or regions should identify a limited number of priority areas for knowledge-based investments, focusing on their strengths and comparative advantages to increase their innovation output [7,8]. Currently (2021) the EU is at the beginning of a new programming period for S3 stretching from 2021 to 2027 and new dimensions are considered to be included such as sustainability (leading to "S4"), societal challenges, data, and analytics [9–11].

When it comes to defining and measuring innovation in practice, approaches have evolved a lot since the first attempts in the 1950s. The emphasis has gradually shifted from companies to systems of innovation [2,12–14], and 21st-century approaches tend to focus on a knowledge-based networked economy and metrics such as knowledge, intangibles, networks, clusters, and systems dynamics [15,16]. This is reflected in several modern benchmarking metrics, available at different geographical levels and innovation systems, including the Global Innovation Index (GII), the European Innovation Scoreboard (EIS), the Regional Innovation Scoreboard (RIS), and various others.

1.1. Intellectual Capital in Innovation

The central premise of the present paper is that while innovation indices and innovation policies are highly successful in benchmarking and increasing the output of regional systems of innovation, they can sometimes overlook or oversimplify the "human-centric" aspects of innovation [16–18].

In order to offset this, the authors propose using the concept of "intellectual capital" both in innovation measurement and policymaking. Intellectual capital is a concept formulated in the 1990s [19], although it does not seem to have had or have a generally accepted definition [20] apart from representing the combined intangible assets of a company [21]. In regional policy, it is taken to represent the combined intangible, human-related aspects of regional innovation and development. It can include concepts such as human capital and social capital which, together, are often seen as one of the main determinants of competitiveness and economic growth [22].

Human capital refers to the value of human capacities [23]. It can be defined as a collection of knowledge, talent, skills, abilities and training possessed by individuals [24]. Human capital recognises that not all labour is equal, as the education, experience, and abilities—the skill set—of an employee can vary and has an economic value for employers and the economy as a whole [25].

Like any other kind of capital, human capital could be invested in. In this case, the investment can take place through education and training, and the resulting benefits are expected to lead to an improvement in the level and quality of production [23,26]. The creation of sustainable, inclusive growth requires a broad investment in human capital across society. Investment in small subsections of highly skilled labour cannot achieve this, and it is an unrealistic and outdated approach [25].

In practice, intangible aspects such as human capital are difficult to measure. The Global Innovation Index (GII) admits that "statistically capturing the human contribution to innovation is a daunting challenge" [27]. Firms assess their staff by examining the knowledge and skills of their individual employees, taking into account both formal education and on-the-job training [28]. The measurement of human contribution to innovation in a region or country is usually focused on roughly the same qualities, but the assessment of those qualities for a large and diverse population is a more complicated process, which requires specially developed scales and indices.

Such scales do exist, however, the Global Innovation Index considers human capital, along with research, as one of the pillars of its innovation input sub-index. The "Human Capital & Research" pillar is further divided into three sub-pillars. The first one includes a mixture of indicators capturing achievement at elementary and secondary education levels, the second assesses higher education by capturing enrolment rates, graduates in science and engineering, and the inbound mobility of tertiary students, while the third measures the level and quality of R&D activities through the number of researchers in the population, gross expenditures, and the quality of each country's top three universities according to the QS ("Quacquarelli Symonds") university rankings of the top 700 universities worldwide [27].

The European Innovation Scoreboard (EIS), measuring innovation in the European Union, follows a slightly different approach than the GII, but it still devotes a “dimension” of innovation enablers to human resources. This dimension consists of three indicators intending to measure the availability of a highly skilled and educated workforce. Those indicators are: (1) the number of new doctorate graduates in STEM (Science, Technology, Engineering, Mathematics), (2) the percentage of the population aged 25–34 that has completed tertiary education, and (3) the percentage of the population aged 25–64 having participated in lifelong learning [29,30]. So, in effect, it measures human capital.

The EIS is essentially the country-level version of the Regional Innovation Scoreboard (RIS) [29]. This regional focus is extremely important for several reasons [8]. Regions are—obviously—the focus of the EU’s Regional Policy (also known as Cohesion Policy) which is aimed towards the convergence of the member states and regions [31]. In addition, it is worth noting that most EU policies take place on the regional level [31]. The EIS reports have been published under the name “European Innovation Scoreboard” until 2009, as “Innovation Union Scoreboard” between 2010 and 2015, and again as “European Innovation Scoreboard” from 2016 onwards [30].

The Regional Innovation Scoreboard follows exactly the same formula as the European Innovation Scoreboard, so human resources are a dimension of innovation enablers consisting of the same three indicators. However, despite the crucial role that regions hold for EU policy, many of the indicators used by the EIS are not available at the regional level. This also includes the human resources dimension, as the number of new doctorate graduates is not available on the regional level, and human resources are therefore represented by only two indicators [29].

This still represents an improvement in regional data availability over previous versions of the RIS [32]. In addition, the 2021 version of the RIS also includes other human-related aspects of innovation that are listed under other dimensions. For instance, these include international scientific co-publications, scientific publications among the top-10% most cited publications worldwide, individuals who have above basic overall digital skills, and employed ICT (Information Communication Technologies) specialists [29].

Overall, the methodology used by the EIS and RIS has come under criticism for being flawed and potentially misleading [33]. The criticism mostly concerns the fact that the indicators referred to by these indices as “input” and “output” indicators are not directly connected to each other, but also that much more detailed information is needed in order to adequately capture innovation performance [33]. While these potential flaws do not negate the usefulness of the EIS and RIS as tools for assessing innovation and formulating policies, authors warn that these indices should not be implemented in an isolated manner, without being complemented with other quantitative and qualitative information regarding the system being assessed [34].

An index that specifically measures human capital is (predictably) the Global Human Capital Index [25], although it does so in the general context of meeting the future needs of the workforce and contributing to sustainable and inclusive economic growth, and not in direct connection to innovation. The Global Human Capital Index was developed by the World Economic Forum. It views human capital as consisting of four elements of equal importance: capacity, deployment, development, and know-how. Capacity measures attainment rates by stage of education, deployment measures participation in the workforce, development measures efforts to educate and train students as well as working-age population, and know-how measures growth or depreciation of employees’ skillsets through opportunities for higher value-added work [25]. These measures seem to follow the same approach used by the innovation indices in measuring and defining the human factor, although the Human Capital Index is more detailed and thorough, as it focuses specifically on the assessment of human capital.

Finally, regarding the metrics of human capital, it should be mentioned that the number of patents is an indicator that has been used since the early days of innovation benchmarking [4] and is still used in various studies [35]. However, the last decade has seen a concerted effort to move beyond patents data and replace them with other sources [36]. Overall, due to a variety of reasons connected to the peculiarities of patent laws and the conditions of the market, patents might more often be destructive rather than creative in terms of their economic impact [37], and they are probably a better proxy for how litigious businesses are, rather than how innovative they are [17].

Social capital is another intangible asset [38] that was developed to complement human capital by reflecting the added dimensions of collaboration, trust, relationships, and contact networks between people [39]. Social capital provides a value-added contribution to other types of capital or functions as a multiplier of their own effect [40]. According to the social network theories of innovation, social capital functions as a moderator in the relationship between expenditure on innovation and innovation output [41].

Like human capital, investment in social capital can be vital to the success of employers, organisations as well as entire economies [39]. Social capital is particularly relevant for innovation as it is part of the mediating mechanism that transforms innovation into economic growth [40]. Social capital influences innovative activity, with different dimensions of social capital having different effects on innovation [42]. This provides a powerful reason to foster strong social relationships within the modern networked economy [43].

Like human capital, social capital is also difficult to measure. There is no clear consensus on how to measure social capital and various metrics have been proposed [44]. Some research approaches have been tried [45], however, these tend to belong to either one of two general approaches. The first stems from the work of political scientists and sociologists and uses what are sometimes called “proximal” indicators such as the degree of civic engagement of individuals, which can indicate their involvement in social networks, or the degree of trust they place on institutions and other people [46].

The alternative approach stems from the work of economists [47] and uses a methodology that considers social capital like any other kind of capital, as “a durable asset, the result of a costly investment, which depreciates and is valuable because it offers services or benefits of some kind” [48]. This approach uses what are sometimes called “distal” indicators since they are not directly related to the key theoretical components of social capital. Such indicators include life expectancy, unemployment, GDP (Gross Domestic Product) growth, income inequality, the prevalence of secondary education, or enrolment rate in tertiary education [49].

The reasoning behind this is that communities with high income, high life expectancy, good education, low unemployment, and a fair distribution of income are expected to have high social capital and positive evolution [41]. Such “distal” indicators tend to be easier to obtain and more reliable than “proximal” ones. They also show a clear process of investment from which capital stock is derived, therefore providing a better match to the definition of social capital as a type of capital [48].

Other concepts can also be added under the overall label of intellectual capital, as representing intangible, human-related aspects of innovation. One such example is psychological capital, a term drawn from the approach known as positive psychology [39]. Psychological capital complements human and social capital by demonstrating, that, in the same way that human beings do not work in isolation from their external surroundings, they also do not work in isolation from their internal characteristics, capacities and identities [39].

On an individual level, psychological capital is assessed via factors such as intelligence, motivation, and personality [50,51]. On a wider scale, as in the case of large enterprises, regions and nations, culture can be used as a proxy for personality [52], a fact which has been backed by research showing that culture can reflect personality on a mass level [53]. Psychological capital, however, is also difficult to benchmark. Its measurement depends solely on the use of proxy indicators, usually based on self-reports, which can create a number of complications for research [54].

1.2. Research Aims and Hypotheses

The objective of this paper is to identify how intellectual capital predicts innovation output on the regional level and consider the implications of this for achieving sustainable development in EU regions. In order to build on the authors' previous work [16,54], a new, updated and streamlined model is proposed for measuring the concepts of human capital and social capital. This model was tested by the use of exploratory factor analysis in order to examine whether the indicators chosen according to the definitions and literature on human and social capital do indeed represent specific factors.

Since the indicators selected were based on relevant literature (see the materials and methods section, below) it was assumed that all variables will have an important contribution towards measuring the underlying factors revealed by the factor analysis.

Furthermore, after the factor analysis and the potential removal of any variables which did not contribute much to measuring the underlying factors, the model will be used to determine whether intellectual capital can predict innovation output in EU regions, by the use of a linear regression analysis.

Therefore, in this case, it was assumed that the variables of human capital and social capital have a significant impact on regional innovation performance in the EU, explaining a major part of the variation in innovation performance across different European regions.

2. Materials and Methods

2.1. Sample

The research is based on data from regions of the European Union. Most of the literature agrees that the main focus in the study of innovation is on the regional scale, making regional innovation systems the most important units for examining innovation performance and designing and applying innovation policies [8]. In addition, the EU Cohesion Policy, aiming towards the economic convergence of member states, is taking place on the regional level [31].

More specifically, the EU NUTS 2 (Nomenclature of Units for Territorial Statistics) level standards were used for selecting the sample regions (with NUTS 1 also used in a few cases of countries where NUTS 2-level data were not available), as the Regional Innovation Scoreboard [29] also uses those particular scales. Data were collected for all regions belonging to the European Union (27 countries), excluding some small islands or enclaves located outside Europe (e.g., the Azores, Madeira, Ceuta, and Melilla). In total, the complete dataset consisted of 207 regions.

2.2. Measures and Indicators

The indicators used in the research were selected according to the reasoning outlined in the literature review conducted in the introduction, above. They were selected in order to represent various different aspects of human capital and social capital as close as possible. In order to increase reliability and validity, the indicators chosen were based on demographic data instead of self-reports. The selection was restricted by data availability on a regional scale, which, as explained above, is an important issue. In every case, data for the most recent available year were selected for the research. The source database and year for each selected indicator are noted below. The most recent set of data available was selected in each case, with research data ranging from 2017 to 2020.

Human capital was measured by a total of eight indicators. These include six indicators used in the 2021 version of the RIS that reflect aspects of human education qualifications and skills. Five of these are under the "framework conditions" category, and one under the "investments" category [29]. Two more indicators were taken from the Eurostat database, chosen to reflect qualifications of the labour force that are relevant to innovation according to the literature. Note that RIS indicators that were not calculated by the RIS itself were taken directly from the original source, Eurostat, for the purposes of the research (and therefore non-normalised scores were used). Human capital indicators are presented in Table 1.

Table 1. Indicators used to measure human capital.

Indicator	Source	Year
Percentage of the population 25–34 having completed tertiary education	Eurostat	2020
Participation rate (%) in lifelong learning in the last 4 weeks (people from 25 to 64 years)	Eurostat	2020
Number of international scientific co-publications per million population	RIS (from Scopus and Eurostat)	2020
Number of scientific publications among the top-10% most cited publications worldwide per total number of scientific publications	RIS (from Scopus)	2018
Number of individuals who have above basic overall digital skills per total number of individuals aged 16 to 74	RIS (own estimates based on Eurostat data)	2019
ICT specialists as a percentage of total employment	RIS (own estimates based on Eurostat data)	2019
R&D personnel and researchers (headcount, in all sectors) as a percentage of the labour force	Eurostat	2017
Scientists and engineers (ISCO-08 groups 21, 22 and 25) as a percentage of the population in the labour force	Eurostat	2020

Social capital was measured by four indicators. These were chosen from the Eurostat database following the reasoning of the "econometrics approach" to social capital [41], conditional on data availability on a regional scale. Social capital indicators are presented in Table 2. Due to the difficulties and limitations to its measurement, mentioned in the section above, psychological capital was kept out of the intellectual capital model this paper attempts to define in order to streamline the model and maintain higher standards of validity and reliability.

Table 2. Indicators used to measure social capital.

Indicator	Source	Year
Working-age population (25–64) percentage with at least secondary education	Eurostat	2020
Unemployment rate percentage 20–64 years	Eurostat	2020
Average life expectancy	Eurostat	2019
Percentage of people at risk for poverty or social exclusion	Eurostat	2019

Innovation output is also taken into account, to be used as the dependent variable of the linear regression analysis. In order to provide a reliable measure of the output of innovation in practice, the "impacts" category of RIS was used for this purpose. According to the EIS methodology, this category is used to capture the effects of enterprises' innovation activities [30]. This is in agreement with the literature, which states that innovation output should be measured by the end-user utility of innovations in the market [17] and that commercialisation of innovation is a key aspect, with the degree to which enterprises develop novelty in terms of processes, management and marketing being highly representative of innovation output [55,56].

Three of the four available indicators that the RIS uses to measure innovation impact were used to calculate an "innovation output" score. Out of these three, two focus on employment impact in companies, while one focuses on sales impacts in companies. In order to have a single "innovation output" indicator as a dependent variable that reflects all three relevant aspects of regional innovation output reflected in the RIS, the mean of the three aforementioned indicators was calculated for this purpose. Since all three indicators are assumed to carry the same weight, they are scored in the same way (with higher scores representing a positive effect) and all of them are measured in the same 0–1 scale following data normalisation [29] calculating their mean was a legitimate approach. This means that the composite "innovation output" indicator reflects employment impact by 2/3 and sales impact by 1/3. The three RIS "impacts" indicators used to calculate the mean score are presented in Table 3.

Table 3. Indicators used to calculate the "innovation output" indicator.

Indicator	Source	Year
Employment in knowledge-intensive industries as a percentage of total employment	RIS (from Eurostat)	2019
Employment in innovative SMEs	RIS (from the Community Innovation Survey)	2018
Sales of new-to-market and new-to-firm product innovations in SMEs as a percentage of turnover	RIS (from the Community Innovation Survey)	2018

2.3. Procedure

The main statistical procedure used to examine how human and social capital can predict innovation output was linear regression analysis.

Initially, a factor analysis was performed to examine whether the different indicators selected for measuring human and social capital are likely to represent a real underlying factor. The results (briefly presented in the following section) showed that all indicators had high enough communalities so that no indicator had to be removed from the model prior to running the regression analysis. This is standard procedure since factor analysis is used to simplify data, as in the case of reducing the number of variables—if needed—in regression models [57].

There were 32 missing values in the dataset (due to data unavailability from the databases) out of 2898 values in total. This is 1.1% of the total, is well below the usually designated threshold of 2% so it was not considered an issue for running statistical tests.

The assumptions and conditions for the use of linear regression appear to be present. The data are quantitative and seem to be approximately linear. The residuals approximate a normal distribution, while there is no tendency in the error terms (see Figures 1 and 2).

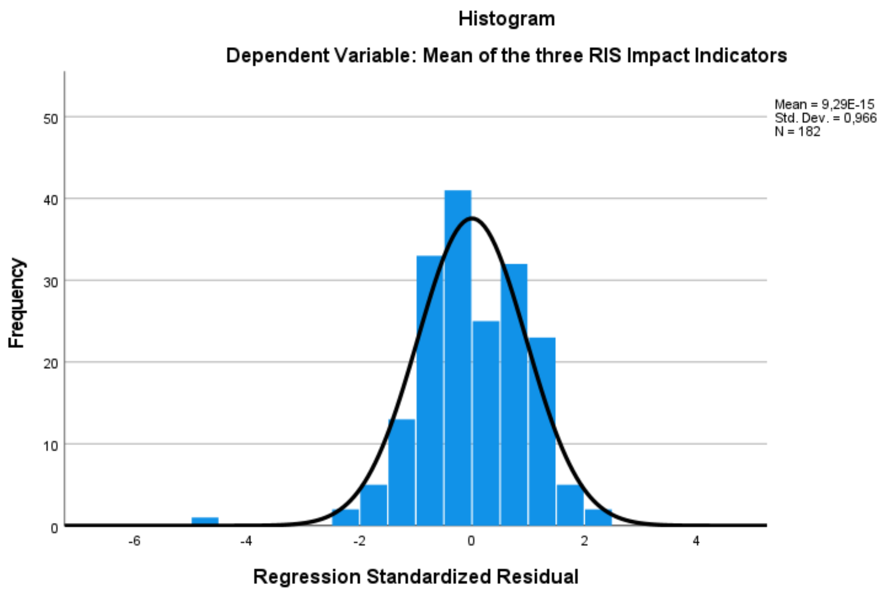

Figure 1. Histogram for the residuals of the regression analysis.

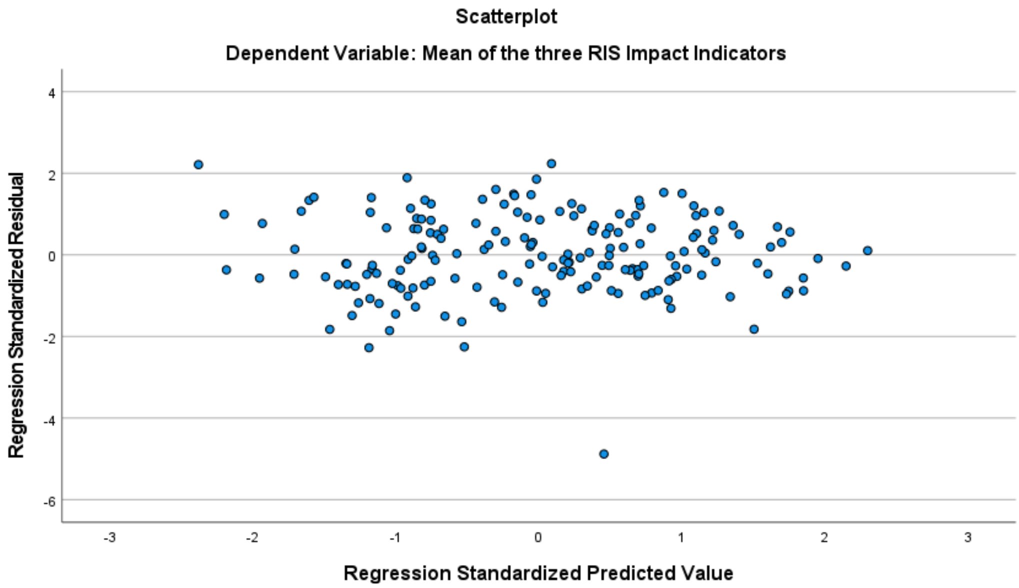

Figure 2. Scatterplot for the regression analysis.

Even more importantly, the use of regression analysis for this type of demographic data on the scale of regions and countries seems to be well established in the literature, both from official sources such as the European Commission [58], as well as from a multitude of scientific papers [53,59–62].

The linear regression analysis sought to establish the relationship between human capital and social capital on one hand, and innovation output on the other. The 8 indicators selected as the best available measures of human capital and the 4 indicators selected as the best available measures of social capital were the independent variables, while the innovation output score created by calculating the mean of the 4 RIS impact indicators (as described above) was the dependent variable. The regression analysis can demonstrate how the typical value of the regional innovation output changes when any indicator of human and social capital is varied while the other indicators are held fixed [63]. The results are presented and discussed below.

3. Results

The factor analysis performed on the 12 indicators measuring human and social capital revealed the existence of three main components. The rotated component matrix (see Table 4) demonstrates that these components coincide to a great extent with the existing theoretical model (explained in the introduction section above) since component 3 mainly includes the four indicators representing social capital. Human capital is broken down into two components, one of which is mostly associated with the numbers of university graduates, ICT specialists, scientists and engineers, and R&D personnel and researchers, while the other is mostly associated with scientific publications, digital skills, education and training, and life expectancy. The implications of this are briefly considered in the discussion section, below.

Moreover, the important finding for the present study is that all variables have relatively high communalities (0.659 and above, see Table 5). This means that, as assumed, they all have important contributions to measuring the underlying factors. Therefore, there is no need to remove any of the variables from the model.

Table 4. Rotated component matrix for the factor analysis.

	Component		
	1	2	3
Scientists and engineers in the labour force	0.835	-	−0.350
Percentage of the population 30–34 having completed tertiary education	0.833	-	-
ICT specialists	0.811	-	-
R&D personnel and researchers as a percentage of the active population	0.721	0.321	-
International scientific co-publications per million population	0.694	0.459	-
Scientific publications among the top-10% most cited publications worldwide	-	0.830	-
Life expectancy	-	0.796	0.342
Individuals who have above basic overall digital skills	-	0.793	-
Participation rate (percentage) in education and training in the last 4 weeks (25 to 64 years)	0.398	0.719	-
Unemployment rate	-	-	0.910
Working-age population with at least secondary education	-	-	−0.784
Percentage of people at risk for poverty or social exclusion	-	−0.349	0.744

Table 5. Communalities for the factor analysis.

	Initial	Extraction
Percentage of the population 30–34 having completed tertiary education	1.000	0.727
R&D personnel and researchers as a percentage of the active population	1.000	0.659
Participation rate (percentage) in lifelong learning in the last 4 weeks (25 to 64 years)	1.000	0.692
International scientific co-publications per million population	1.000	0.692
Scientific publications among the top-10% most cited publications worldwide	1.000	0.765
Individuals who have above basic overall digital skills	1.000	0.787
ICT specialists	1.000	0.771
Scientists and engineers in the labour force	1.000	0.863
Working-age population with at least secondary education	1.000	0.750
Unemployment rate	1.000	0.838
Life expectancy	1.000	0.795
Percentage of people at risk for poverty or social exclusion	1.000	0.711

Extraction method: principal component analysis.

The regression analysis tested the whole model, examining the impact of variables from human and social capital on the innovation output score. According to the Adjusted R Square (see Table 6), 66% of the variance in innovation output score can be explained by the independent variables, which is a very satisfactory percentage. The result of the analysis of variance (ANOVA, see Table 7) shows that the ratio of the variance explained by the regression to the unexplained variance is F (df12) = 30.228, and this has a significance of $p < 0.001$. Thus, the results of the regression are not due to chance.

Table 6. Model summary for the regression analysis.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin–Watson
1	0.826	0.682	0.660	0.10708	1.636

Table 7. ANOVA results for the regression analysis.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.159	12	0.347	30.228	<0.001
	Residual	1.938	169	0.011		
	Total	6.097	181			

Looking at the influence of the individual predictor variables that comprise the model, 8 out of the 12 variables used can significantly (significance < 0.05) predict innovation output (see Table 8). The exact impact of each significant variable is interpreted below:

- The percentage of the population aged 30–34 having completed tertiary education has a significant negative effect on innovation output, with $p < 0.001$ for t = −6.381. For every 0.009% increase in this variable, a 1 unit decrease in innovation output is predicted, holding all other variables constant.
- The percentage of R&D personnel and researchers in the active population has a significant positive effect on innovation output, with $p < 0.001$ for t = 4.148. For every 0.073% increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.
- The participation rate in education and training in the last 4 weeks for people between 25 and 64 years of age has a significant negative effect on innovation output, with $p < 0.019$ for t = –2.370. For every 0.005% increase in this variable, a 1 unit decrease in innovation output is predicted, holding all other variables constant.
- The number of international scientific co-publications per million population has a significant positive effect on innovation output, with $p < 0.003$ for t = 3.036. For every 0.180 increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.
- The number of scientific publications among the top-10% most cited publications worldwide has a significant positive effect on innovation output, with $p < 0.004$ for t = 2.925. For every 0.199 increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.
- The percentage of ICT specialists in the labour force has a significant positive effect on innovation output, with $p < 0.004$ for t = 2.955. For every 0.170% increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.
- The percentage of the working-age population with at least secondary education has a significant positive effect on innovation output, with $p < 0.001$ for t = 4.123. For every 0.005% increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.
- People's life expectancy has a significant negative effect on innovation output, with $p < 00.1$ for t = 4.350. For every 0.028-year increase in this variable, a 1 unit increase in innovation output is predicted, holding all other variables constant.

Overall, research results support a consistent model of innovation output based on measures of both human capital and social capital, and which consists of three underlying factors. One of these factors includes the selected measures of social capital, while the other two include different measures of human capital. Out of the latter two, one factor seems to be more strongly associated with components measuring the labour force specialisation while the other seems to be more strongly associated with components measuring the quality of people's skills and research networks.

This model is depicted in Table 9. Note that the variables that were found to be statistically significant predictors of innovation output in the regression analysis are in bold fonts. Dotted lines indicate instances where a component is also strongly associated with the adjoining factor as well.

Table 8. Regression coefficients.

Model		Unstandardised Coefficients		Standardised Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	–2.118	0.545	-	–3.885	<0.001
	Percentage of the population 30–34 having completed tertiary education	–0.009	0.001	–0.510	–6.381	<0.001
	R&D personnel and researchers as a percentage of the active population	0.073	0.018	0.293	4.148	<0.001
	Participation rate (percentage) in education and training in the last 4 weeks (25 to 64 years)	–0.005	0.002	–0.191	–2.370	0.019
	International scientific co-publications per million population	0.180	0.059	0.235	3.036	0.003
	Scientific publications among the top-10% most cited publications worldwide	0.199	0.068	0.232	2.925	0.004
	Individuals who have above basic overall digital skills	0.002	0.063	0.002	0.027	0.979
	ICT specialists	0.170	0.058	0.251	2.955	0.004
	Scientists and engineers in the labour force	0.006	0.007	0.092	0.812	0.418
	Working-age population with at least secondary education	0.005	0.001	0.295	4.123	<0.001
	Unemployment rate	0.001	0.003	0.039	0.484	0.629
	Life expectancy	0.028	0.006	0.419	4.350	<0.001
	Percentage of people at risk for poverty or social exclusion	0.000	0.002	0.007	0.088	0.930

Table 9. Human and social capital indicators which were found to be significant predictors of innovation output.

Intellectual Capital		
Human Capital		Social Capital
Labour Force Specialisation	Skills and Research Networks	
People with tertiary education (negative)	International scientific co-publications	Life expectancy
R&D personnel and researchers	Top-10% most cited publications	People with at least secondary education
ICT specialists	Participation in lifelong learning (negative)	People at risk of poverty and social exclusion
Scientists and engineers	Above basic digital skills	Unemployment rate

4. Discussion

The research results have confirmed both hypotheses described in Section 1.2 since all variables in the "intellectual capital" model had an important contribution towards measuring the underlying factors revealed by the factor analysis, and intellectual capital had a significant impact in predicting innovation output (namely, 66% of the variance).

However, some of the relationships revealed by the regression analysis are surprising. The model, based on the theory and literature analysed above, assumed that the different aspects of human and social capital would have a positive effect on innovation output. This holds true for six of the variables found to be significant predictors of innovation output, but not for the other two, which seem to have a negative impact on innovation performance.

These results are worth considering. The detrimental impact of the percentage of people with tertiary education on innovation output was also found in a previous, broader study conducted by the authors [54]. In addition, the present research indicates that participation in lifelong learning also has a similar detrimental effect. Therefore, a larger number of young graduates and adults who participate in learning can predict lower innovation output.

This is in contrast to the literature reviewed in the introduction, and various definitions of human capital, which consider education a central part of the concept [26,29]. However, it is not necessarily counter-intuitive. Learning and the acquisition of higher degrees are not necessarily associated with an improved ability to undertake productive work, and in fact, one study [64] outlined a negative causality between higher education and rates of economic growth. The same might very well apply between higher education and innovation.

There might be various explanations for this. The quality of the educational system and its institutions might play a greater part than the number of degrees that are awarded [65]. The type of degrees might be also a significant determinant, as the arts and humanities, or most social sciences might have very little impact on innovation output—especially when it is measured by the number of innovations applied on the market—while other fields, such as business, IT and engineering, probably have a much larger impact [64]. This is in line with the finding that the number of ICT specialists has a significant positive impact on innovation output.

Another explanation is that several problems in a country's educational system might complicate the relationship between education and innovation, preventing university graduates from having an impact on innovation output. This is illustrated very well by the case of Greece, which is consistently a low-ranked moderate innovator despite having one of the highest percentages of university graduates in the EU [30].

This discrepancy can be explained by various problems that Greece suffers from. Its education system is poor in terms of quality, especially in terms of technical education. The secondary school system is problematic and deficient as preparation for training in advanced manufacturing. Its thin industrial structure can absorb very few graduates, which makes technical education an unattractive career choice anyway [66]. Finally, Greek universities can often seem like "cathedrals in the desert", usually unconnected to the industrial structure of the country [66]. It can be assumed that similar weaknesses may apply to other countries, which cannot be identified by a framework that only measures the number of university graduates.

These explanations, however, do not address the question of why there is a negative relationship between the number of graduates and innovation output instead of no significant relationship at all, so additional possibilities must be considered. For example, the higher number of graduates requires larger class sizes, which are shown to have a negative impact on students [67] and may thus result in less competent graduates, who have a weaker impact on innovation output. Alternatively, it could be due to the fact that, as modern university curricula become more "technical" and more focused on professional skills, they neglect the development of cognitive and social skills, such as critical thinking [68]. Or, it could be connected with the fact that some of the organisations which hire highly educated people have high formalisation and centralisation, which are negatively correlated with empowerment and stifle the innovative behaviours of employees [69].

Another explanation is that the number of higher education graduates might become excessive for the economy after a certain point and actually harm innovation output. Indeed, it has been suggested that a huge increase in the number of university graduates can be harmful to the economy due to the mismatch between people's skills and the labour market. This is caused by the accumulation of large student debts (at least in countries that tend to have high tuition fees), university graduates taking over jobs that have traditionally been held by secondary education graduates, and, perhaps because of this, the fact that university graduates are increasingly finding themselves in roles which do not meet their career expectations [70]. If this is true then problems for the economy might also translate to problems for innovation output, especially in EU countries, which are among the countries with the highest percentage of the population with tertiary education worldwide [71].

The other findings are more straightforward and in line with the theory behind human and social capital and innovation, as well as with the literature reviewed in the introduction section. The significance of the percentage of R&D personnel and researchers for innovation output is quite expected according to the literature examined in the introduction [27], as the idea that research and development contribute to increased innovation and economic growth has been an axiom in the study of innovation for decades since the first attempt to understand the innovation process [4]. A region's exact capacity to transform R&D investment into innovation impact is contingent upon specific socio-economic characteristics, such as the levels of skills, the labour market situation, and the economic structure available. There can be little doubt, however, that the amount of R&D personnel in the workforce is a crucial prerequisite [72].

A similar reasoning applies to the positive impact of international scientific co-publications, and publications in the top-10% most cited ones, since, as already mentioned in the introduction, the RIS uses these indicators as proxies for the quality of scientific research and the efficiency of regional research systems [29]. This is in line with the entire concept of regional innovation systems [73] and can be taken as a reflection of the skills of local researchers, which are a key part of human capital [72]. The same holds true for the positive impact for ICT specialists since the positive impact of ICT skills on innovation and competitiveness is a central premise that is found in the literature and has been often confirmed by research results [74–76].

When it comes to social capital, the interpretation of the findings is slightly more complicated since, as explained above, it was measured by "distal" indicators. However, the finding that high life expectancy and a high prevalence of secondary education can predict high innovation output makes perfect sense according to the theory of social capital [40]. The idea that social capital can positively influence innovative activity, as seen in the introduction, is confirmed by the research results [42].

The proportion of the working-age population with at least secondary education reflects the marginal cost of investment in social capital, and its increase predicts an increase in innovation output. Life expectancy reflects the years of participation in the social network, and this also has a positive effect on innovation output [41,43]. Since regions with these features are expected to have a stronger network of positive relationships between people [40], therefore, they have high social capital and positive evolution [41].

Interestingly, the fact that unemployment rates and the percentage of people at risk for poverty were not found to be significant predictors of innovation output also makes sense, even though these are also measures of social capital according to the same theory [46]. This is because unemployment and poverty can cause people to abandon social capital components in order to prioritise finding a job and obtaining minimum necessities. Regions with high unemployment and poverty can be prone to crime, a large informal economy and widespread illegality, with all of these features counteracting the creation of social capital [45]. This explanation would make sense, especially for regions in southern and eastern Europe that have been hit by the economic crisis [77]. All these results are in line with the literature examined in the introduction section [41,49], that communities with low unemployment, good education, high life expectancy, and fair distribution of income have high social capital and, in turn, high innovation [40].

An additional issue to consider is what this model means for the benchmarking of innovation, as well as for policies aimed towards the overall goal of sustainable development, by the development of regional innovation output. With regard to the first question, the model seems to confirm that the RIS is a highly successful measure of human capital in regional innovation systems since out of the six human capital indicators found to be significant predictors of innovation output, five are included in the current version of the RIS [29] while one (R&D Personnel and Researchers) was included in previous versions of the index [30].

The significance of two key measures of social capital in predicting innovation output indicates that social capital indeed also plays a key role in encouraging regional innovation [45]. These measures may not be relevant for the RIS, which uses indicators that are directly associated with the innovation process instead of more "distal" ones.

However, their importance for innovation output, which has also been highlighted by the authors' previous work [54], means that studies seeking to understand regional innovation should take other factors of intellectual capital into account apart from human capital since education and skills do not reflect the entire human contribution to the innovation process. This could include the creation of dedicated indices to measure social capital, which is a quite challenging task.

With regard to addressing the second question and the significance of the model for innovation policies for sustainable development, a good starting point would be to examine this via Smart Specialisation Strategies (S3), since this is currently the main policy for enhancing regional innovation performance in the EU [7,11]. While considering lessons from the model for enhancing S3 is such an ambitious endeavour that it could very well require a dedicated paper, it is still possible to consider some potential implications here, based on the research findings.

The research findings support the view that S3 needs to have a strong "human-centric" basis. Enhancing the skills that are related to innovation as well as the degree of connectivity, trust and networking between people can be key to enhancing innovation within regional systems. Based on this, it is clear that S3 can benefit from cohesive and comprehensive user engagement within a quintuple helix approach that encompasses authorities, higher education institutions, enterprises, society and—very importantly—the environment as well [2,78–80].

That last point is extremely important since innovation goes hand-in-hand with sustainable growth, the one determining the other, and S3 are a key tool for implementing both concepts [81]. This is even more relevant in the context of the fight against climate change and the implementation of the European Green Deal. To deal with these challenges, policies should reinforce the pre-existing alignment between S3 and sustainability into what has been also called "S4" [9].

This alignment can be reinforced through a focus on convergence, as poorer areas can particularly benefit from the use of new technologies to address pressing environmental problems [82]. This is not only a question of investing sufficient funds, although budget allocation has been linked to particular aspects of sustainable development [83]. More importantly, however, it is a question of investing in a change of mentality, and a greater inclusion of civil society into the smart specialisation process on both the macro and micro scales, from policy decisions to individual projects [82].

This is also reflected in the specific research findings. In terms of human capital, findings support the need to invest in the quality of the labour force, especially in terms of ICT specialisation, an orientation towards R&D and international scientific collaboration resulting in excellent research networks. This is more-or-less in accordance with current policies [80]. An additional conclusion is the need to give a strong focus on outcome-based education (OBE) with observable and measurable outcomes [84]. While the idea of "knowledge for its own sake" is a noble one, it is not always productive (and can actually be counter-productive) in the context of modern economies, especially in developing ones [85].

Instead, in order for knowledge to be translated into innovation output and sustainable regional growth [86], higher education institutions must be strongly connected to businesses, government and local communities according to the quintuple helix model [78,87]. This can lead to higher education and lifelong learning having a positive impact on innovation output instead of a negative one. It is also key for supporting the transformational effect universities can have on regional economies in terms of sustainable development [88].

This reasoning does not only apply to academic or research institutions but to enterprises as well since an open innovation business model has been shown to open the way for new technological innovations [89]. In addition, various cases demonstrate that the concept of shared value, in which the company's growth is interlinked with the social and environmental wellbeing of the community in which it is based or operates [90], can also play a key role in the smart and sustainable regional development of the whole ecosystem of local stakeholders and citizens [18]. It should therefore be considered another key aspect in achieving this.

In terms of social capital, the findings highlight the importance of prosperous and healthy communities with strong civic engagement [91]. While, in practice, this is a very broad goal that is challenging to achieve [92], there are various practical ways to enhance social capital in practice. This can be achieved by enhancing social capital via ICT-based platforms and apps that encourage participatory democracy and/or e-governance [93,94]. In any case, innovativeness is interlinked with smart growth as well as sustainable growth, which includes inclusive growth [81].

Social innovation can be another crucial component for enhancing social capital since it provided solutions for a number of pressing social, economic and environmental issues being faced by communities [95]. Since social innovation tends to be locally generated and structured to meet the needs of the local environment [96], it can fit in very well with the S3 process, which is also designed to be adapted to local needs [11]. Social innovation should therefore be integrated into S3 along with the more "technical" aspects of innovation, as this can be beneficial for social capital and, in turn, for innovation output.

5. Conclusions

Research on social capital and innovation and its relation to sustainable development is an interesting issue and important from the point of view of results, which can help to create an economic policy supporting the right direction of development at the national and regional levels. However, there are some limitations during the research, which result both from the difficulties in defining human and social capital, as well as the construction of indicators measuring its level. In addition, there are problems with access to official public data, because some of them are collected only for the whole country, while there is no precise data at the regional level. This makes research at the regional level more challenging. In the case of the results presented in this paper, the conducted research confirmed both research hypotheses: all variables in the "intellectual capital" model had an important contribution towards measuring the underlying factors revealed by the factor analysis, and intellectual capital had a significant impact in predicting in innovation output.

Finally, specific attention should be devoted to what are probably the most puzzling findings of the research: that the percentage of young people with tertiary education and that the percentage of people participating in lifelong learning have a significant negative impact on innovation output. A potential explanation, provided above, is that regional innovation systems have an "ideal" limit of qualified people, after which an oversaturation of skill occurs, with harmful impacts on the market, the economy, and innovation.

Further research to investigate this paradox would be extremely welcome. For example, it would be worth examining whether the negative relationship found here is positive outside the EU, and especially in developing countries. One would expect this to be the case, as it can be safely assumed that at least a minimum number of higher education graduates and skilled people, in general, is necessary for innovation to occur. It may be that there is an "ideal percentage" of qualified people for each system, which depends on the state of development and needs of the economy. In this case, being below or above this percentage could become detrimental for the system in question.

In any case, perhaps a better measure of human capital with regard to innovation would be the percentage of graduates from a number of crucial education fields that are important for innovation and sustainable development. Alternatively, the percentage of doctoral graduates, since PhD-level research is supposed to be groundbreaking and highly innovative. Yet, obtaining this kind of information at the regional level will likely be very difficult judging by the problems of data availability on that level [29].

Overall, there are clearly many more questions to be explored about the effect on innovation of human-related factors that can be placed under the concept of "intellectual capital". The present research has demonstrated that several such factors, falling under the proven concepts of human capital and social capital, have a significant impact on innovation output. This, in turn, can provide important lessons both for the better measurement of regional innovation as well as for the policies exercised in the framework of smart and sustainable growth, the next generation of sustainable smart specialisation strategies and the EU Cohesion Policy.

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