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Knowledge-Based Regional Economic Growth: The EU Perspective

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Abstract: The purpose of this paper is to address the research gaps by conducting an empirical analysis of the relationship between variables determining Knowledge-Based Economies (KBEs) and GDP growth within the regions of the European Union at the NUTS 2 level. Findings indicate that gross expenditure on research and development and employment in the knowledge-intensive sector are positively associated with gross domestic product per capita at the regional level. Additionally, this paper shows evidence that innovation does not tend to be concentrated in regions with higher student numbers, which were used as a proxy for the concentration of research and educational institutions.

Keywords: knowledge-based economy; entrepreneurship; regional development; economic growth.

JEL classification: F63; O47; P25; R11.

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1. INTRODUCTION

The global economy is undergoing a fundamental transformation towards a new phase of growth, in which knowledge is one of the most significant determinants. A country's regional development, entrepreneurial activities, innovativeness, and economic progress are all based on knowledge. Historically, nations and regions competed over material resources, but this has been displaced by a feud over non-material resources, such as knowledge of the most recent scientific findings (OECD, 1996). Nowadays, knowledge is widely recognised as the main driver of countries' economic growth (Dyker and Radosevic, 2000; Qian, 2018). At the same time, the future of countries and regions around the globe today is heavily predicated on human intelligence and scientific research, which provide novel solutions and "drive" a new form of the economic model. The above-mentioned factors explain the growing interest among researchers in Knowledge-Based Economies (KBEs) and their effect on economic growth.

One of the most prominent elements of a KBE is how knowledge has grown tremendously, evolving into a critical component of rising productivity and competitiveness, while also becoming a source of the socio-economic and financial well-being of nations (Drucker, 1998; Godin, 2006). Therefore, transitioning from an economy based on material consumption to a "new economy" based on knowledge has become the primary challenge for countries and regions in the twenty-first century.

Numerous studies have been conducted on the current state of society and economics, particularly concerning KBEs, regional development, and globalisation (Asian Development Bank, 2007; Zeibote *et al.*, 2019). Despite this, academics argue that many crucial issues, both fundamental and technical, related to KBEs and regional development remain unresolved.

Despite existing studies, a gap exists in the literature regarding the specific relationship between KBEs and GDP growth within the EU Nomenclature of Territorial Units for Statistics (or NUTS) 2 regions. While numerous studies explore the broader connection between KBEs and economic development, a deeper understanding of this relationship within the specific context of EU regions is lacking.

To address this gap, this paper conducts an empirical analysis of the relationship between KBE variables and GDP growth in EU NUTS 2 regions. The main research question is whether the development of a knowledge-based economy is associated with the value of regional gross domestic product (GDP) in the EU NUTS 2 regions.

Furthermore, this study seeks to demonstrate the importance of a KBE and its effect on long-term economic growth in the EU NUTS 2 regions. Moreover, the results of our contribution might also show that KBEs are essential for regional policies and that future policies surrounding KBEs could support GDP growth in the NUTS 2 regions.

This study aims to empirically analyse the relationships between KBEs and GDP growth in the EU regions at the NUTS 2 level. The rest of this paper is structured as follows: Section 2 provides the conceptual framework and reviews the literature related to the knowledge-based economy and regional development, while Section 3 presents the data and methodology. Section 4 provides the results and discussion, followed by Section 5 of the paper, which concludes with a summary of the findings.

2. LITERATURE REVIEW

2.1 The knowledge-based economy

The terms "knowledge economy" and "knowledge-based economy" have become increasingly synonymous in contemporary discourse. This widespread adoption has stimulated a vast and growing body of literature, reflecting the keen interest among researchers in refining and debating this key concept.

For decades, knowledge has been recognized as a key factor in scientific and innovative advancement and efficient manufacturing (OECD, 1996; Chen and Dahlman, 2005; Aparicio *et al.*, 2023). The value of knowledge has grown significantly over the twentieth century, and it has developed into one of the fundamental factors of production in different business fields (Collinge and Staines, 2009). Rapid scientific and technological advancements have further heightened the importance of knowledge, not only as a resource but also as a promoter of economic advancement and socio-political progress.

As stated before, economists have been acknowledging the role of knowledge in the economy for over a century. In his book The Theory of Economic Development, published in 1911, Joseph Schumpeter (1911) was the first to highlight the significance of knowledge in the economy. Fritz Machlup (1962), an Austrian-American economist, first presented the idea of the knowledge industry, also known as the knowledge-based economy, in his book The Production and Distribution of Knowledge in the United States in 1962. However, in 1969, Peter Drucker (1969) was one of the first who use the term "knowledge economy" in his book The Age of Discontinuity.

Leading organizations like the OECD define the knowledge-based economy as characterized by a growing reliance on knowledge, information, and high levels of ability (OECD and Eurostat, 2005). The World Bank defines knowledge economies according to four pillars: education and training, information infrastructure, economic incentives and institutional regime, and innovation systems (Chen and Dahlman, 2005). Eurostat echoes this definition, emphasizing the growing reliance on knowledge, information, and high skill levels in both commercial and public sectors (OECD and Eurostat, 2005).

Measuring a knowledge-based economy is challenging due to its reliance on intangible assets (OECD, 1999). However, the Global Knowledge Index (GKI) is an essential indicator for assessing knowledge all around the globe. The GKI, developed by Knowledge4All, has emerged as an alternative to the well-known Knowledge Economy Index, published in 2012 by the World Bank. The GKI provides access to a vast array of accurate data, which may assist governments and policymakers in better comprehending the interconnected developments and challenges so that they can respond more effectively to them.

For the GKI survey, seven sub-indices have been selected to measure progress in the cognitive and developmental processes (pre-university education, technical and vocational education, and training (TVET), higher education, research, development, and innovation (RDI), information and communications technology (ICT), economy and enabling environment) (United Natons Development Programme, 2021).

When an economy's information intensity changes, the sectors that make up the economy tend to alter their shape, with a rise in what is known as "knowledge-based" industries. To address this, the OECD (1999) has characterized the knowledge-based economy into the following three categories:

- High-tech manufacturing
- Service sector industries
- Business services.

Recent research has shown that a knowledge economy is one in which information is continuously developed and employed, as well as being at the center of the process by which economic growth is achieved (Powell and Snellman, 2004; Aparicio *et al.*, 2023). In addition, academics define it as a type of economy in which information is acquired, produced, disseminated, and applied effectively to stimulate economic growth (Kefela, 2010; Mensah and Enu-Kwesi, 2018).

In developing countries' economies, agriculture and manufacturing are often given significant attention, while in highly developed countries, service-related sectors make up a considerable part of the economy (Johnston, 1970; Windrum and Tomlinson, 1999). These include knowledge-based economic activities, including research, technical and professional assistance, advising, and others.

Furthermore, in classic economic theories, land, labour, capital, and the entrepreneur are the four major components of production. However, a knowledge-based economy is essential for expanding the potential applications of labour beyond the production of commodities on an assembly line and towards more versatility in designing, manufacturing, and executing business concepts.

According to empirical studies, it has also been seen that Research and Development (R&D) investments are essential for innovation and the increase of available knowledge (Cameron, 2000; Miroshnychenko *et al.*, 2020). The goal of scientific research is to generate new scientific information, as well as to rectify and integrate existing knowledge when it's immediately useful or relevant. For centuries, scientists have been experimenting with new ideas and theories. During the 20th century, R&D activities became the central focus of universities and enterprises in both the public and private sectors and measuring and indicating progress in R&D became more important in the 20th century (Nelson, 1982).

In today's knowledge-based economy, Intellectual Property (IP) is a basis for innovation, investment, and development (Cowan and Harison, 2001; Foray, 2002; Tekic *et al.*, 2014). Leading-edge, knowledge-based sectors are heavily reliant on the IP system. Furthermore, economists hold that the new economy will be more successful for nations and regions when IP regimes balance the interests of various parties. Over the last several decades, IP has emerged as a significant source of competitive advantage in today's knowledge-based economy (Sagiyeva *et al.*, 2018), and modern economies have seen a fundamental shift in how value is generated, which is one of the causes of this development.

An additional critical aspect of the KBE is that it's fundamentally a learning economy, where the learning process and increasing competence are essential to the economic performance of a university-educated workforce with access to lifelong learning opportunities (Sterlacchini, 2008). This fact has significantly influenced enrolment in vocational schools and universities in both developed and developing countries.

Overall, the KBE illustrates a transformation in economic structures and how enterprises and individuals' function across all industries. However, analysing the effect of KBEs on regional economic development is crucial. Having established the importance of knowledge-based economies, we next examine how they influence regional development.

2.2 Regional development

There are various interpretations of the term "regional development", which is generally defined as the concept and plan for the economic growth of regions in both developed and developing nations. With the help of regional development, countries in economically challenged areas may realise all their resources and residents' full potential, thereby improving their well-being in all aspects of life (OECD, 2022).

Comparisons between countries' regional development are frequent, yet it's difficult to draw meaningful comparisons between small, sparsely populated regions and the largest, most populous ones. Differences among regional economies exist when certain areas within a single nation expand at a faster rate, have higher levels of economic growth, and have a better economy than other regions. Unbalanced regional economic growth is the cause of a geographical pattern of interdependence between developed and developing regions. Thus, there are many variables impacted by regional development, some of which have a direct effect and others an indirect one. Key development variables include natural and human resources, the level of technical advancement, financial resources, knowledge, a legislative and institutional framework, values, ethics, and dedication.

To provide regional data for the European Community in the early 1970s, Eurostat established the Nomenclature of Territorial Units for Statistics (NUTS) classification. According to the NUTS classification, each Member State is divided into three separate regions from large to small locations. These levels cover NUTS 1, 2, and 3 (Eurostat, 2022).

Studies on the geographical location of the knowledge-based economy in EU member states have shown indications of growing differences between metropolitan centres and peripheries (Leydesdorff and Deakin, 2010; Kim *et al.*, 2022). Therefore, the knowledge base of various regional economies differs since each region has its own base of scientific, technological, and entrepreneurial knowledge. Several countries have planned to increase their direct investment in the generation of new knowledge as a way of promoting the growth of their domestic and regional economies.

There is increasing evidence that the promotion of regional economic development is an active process involving enterprises, different public or private development agencies, and research institutions. Therefore, knowledge-based regional development should emphasise the skills and potential of regional players like enterprises, urban centres, new tech hubs, research and education institutions, and more. These strong organisational cultures highlight the interdependence of public and private activities. To better understand the circumstances in which complex development processes occur, and to show the relevance and multi-level character of skills in regional development, we might turn to the network approach of knowledge-based regional development processes (Cooke *et al.*, 2007).

The importance of regional policy processes, meanwhile, cannot be denied. At the regional level, policymaking is understood as a group process of negotiation and compromise involving many different players from different policy levels, including non-state actors, non-governmental organisations, professions, and others (Cooke and Leydesdorff, 2006; Godin, 2008; Viale and Etzkowitz, 2010).

The literature study concludes that knowledge-based regional development involves several partakers and actions. It also necessitates a well-connected set of networks comprised of various players and interconnected skills widely dispersed throughout the networks responsible for developing and enforcing regional innovation strategies.

The literature review examined the KBE and its impact on regional development, particularly within the EU. It identified knowledge, information, innovation, human capital, and R&D as key drivers of growth. However, the review also highlighted the challenge of regional disparities in knowledge and economic development, with a widening gap between metropolitan centres and peripheries in the EU. The importance of a "network approach" and the multi-level nature of skills in regional development were emphasized. Additionally, the review pointed to the potential of universities, research institutions, and new tech hubs to foster knowledge-based growth. Finally, collaboration and knowledge exchange among regional actors were identified as crucial for successful development strategies. In essence, the review laid a foundation for further research on EU regional development in the context of the KBE.

3. DATA AND METHODS

Our research began with a comprehensive review of the recent literature on the topic, which included scholarly articles, reports, and government documents. As a result of this first step, we were able to identify crucial ideas, variables, and hypotheses related to the relationship between a knowledge-based economy and GDP growth in the EU-28 NUTS 2 regions. After laying this groundwork, we moved on to the empirical part of our investigation, where we analysed relevant studies and drew insightful conclusions from the data.

While ideally, we would leverage the most recent data possible, our study focused on the 2009-2012 timeframe due to a critical consideration: data consistency across the EU-28 NUTS 2 regions. This period, according to Eurostat (2022), offered the most reliable and consistent dataset for all regions, allowing for a robust analysis of the relationship between knowledge-based economies and GDP growth. Although this limits our study to a specific period, the advantage lies in the certainty and comparability of the data across all selected regions, which is essential for drawing accurate conclusions about this complex relationship.

Our study employs a dataset that contains a variable that serves as a proxy for the development of a knowledge-based economy. This variable provides panel data for NUTS 2 regions of the EU-28, allowing us to capture regional variations in economic indicators and their relationship to the knowledge economy. We conducted a comprehensive analysis of the available data, which included 225 regions at the outset. Due to breaks in the time series, we were forced to exclude data from a number of regions, including Ireland, Slovenia, and Lithuania.

To examine the relationship between a knowledge-based economy and GDP growth, we analyzed several key indicators, including gross domestic expenditure on R&D (GERD), R&D personnel and researchers, employment in knowledge-intensive jobs, patent applications, and student participation rates. These variables provided an extensive overview of the economic development determinants in the EU-28 NUTS 2 regions and their relationship to the knowledge-based economy.

The current paper attempts to investigate the linkages between features of the knowledge-based economy and economic growth. To do so, we test the following hypothesis (*H1*) versus the alternative (*H0*):

H1*: The value of a regional gross domestic product is associated with the development of a knowledge-based economy.*

H0*: The value of a regional gross domestic product is not associated with the development of a knowledge-based economy.*

This hypothesis is tested on a variation of proxies. As a proxy for regional GDP, GDP per capita adjusted for purchasing power parity is used as a dependent variable for modelling. For a knowledge-based economy, we test a number of independent variables as proxies. We test Fixed Effects (FE) and Random Effects (RE) models for appropriateness, using the Hausman test (Hausman, 1978) as a criterion to opt-in for specification. In general form, the econometric specification of the model is as follows:

$$lny_i^t = \beta_0 + \sum_{j=1}^{n} \beta_j lnx_{ij}^t + \gamma_i + \delta_i + \tau_i + \varepsilon_t \quad (1)$$

where y_i^t – regional gross domestic product (PPS per inhabitant); x_{ij}^t – independent variables; γ_i – entity (region) specific fixed or random effects; δ_i – country-specific fixed or random effects; τ_i – time-specific fixed or random effects; β_0, β_j – regression coefficients; ε_t – error term.

Table no. A1 (Annexes) provides descriptive statistics for the dataset, highlighting the study's key findings. This table provides an overview of the main trends and distribution of the selected variables, offering crucial insights into various aspects of the knowledge-based economy and GDP growth across various EU NUTS 2 regions. Notably, the total number of observations ranges from 600 to 896 due to incomplete data in certain years. Therefore, the time series in our analysis was restricted to four years, highlighting the difficulties associated with conducting empirical research using publicly available datasets. Due to various specifications (sets of independent variables), the number of observations utilized in estimating empirical models differs, and it is consistently stated for each model presented.

In conclusion, our study's limited time series, driven by data availability constraints, highlights the importance of careful data selection in empirical research. We utilized a panel data approach with Fixed Effects (FE) or Random Effects (RE) models. While these models provide a robust framework for analysing regional variations, it's crucial to acknowledge limitations. The chosen knowledge-based economy proxies may not fully capture all aspects of such an economy. Further research could explore alternative proxies or even composite indices to achieve a more comprehensive picture. By acknowledging these limitations and considering alternative approaches in future studies, researchers can ensure the validity of their findings and advance our comprehension of the intricate relationship between a knowledge-based economy and GDP growth in the EU-28 NUTS 2 regions.

4. RESULTS AND DISCUSSION

In this paper, we began with an estimate of FE and RE regression analysis for the selected variables throughout the selected period so that we could thus examine the impact of individual-specific factors on the panel data set's dependent variables. Table no. A2 (Annexes) shows the results of the regression analysis (FE and RE models). Here, independent and dependent variables are employed in levels, therefore the interpretation of the coefficients cannot be considered straightforward. In order to address this issue, we estimate fixed and random effects models in log-log form, in which the interpretation of coefficient estimates is in terms of elasticities, with the difference between the models being the number of selected variables. As a result of this study, we can observe that a number of different independent variables may have a significant influence on economic growth.

The RE and FE (within) models' estimates for the Gross Domestic Expenditure on Research and Development (GERD) as the independent variable demonstrate a positive and highly significant influence on GDP per capita (constant USD) at the level of the entire sample of regions for each year. The positive and statistically significant relationship between GERD and GDP per capita in our study reinforces the established notion within the KBE literature that R&D expenditure is crucial for knowledge creation and economic growth (Cameron, 2000; Miroshnychenko *et al.*, 2020). This finding highlights the importance of expenditure in R&D for the selected regions. Several studies have addressed the significance of GERD; however, their analyses were conducted at the country level rather than the NUTS 2 region level (Veugelers and Mrak, 2009; Ejermo *et al.*, 2011; Bąk *et al.*, 2022). It is reasonable to assume that such regional outcomes will have an impact on countries' overall outcomes.

R&D personnel are statistically significant for the FE (within) model only. According to the evidence presented in this chapter, the number of R&D personnel, the percentage of employment in education, and the ratio of the proportion of students over the proportion of the population have no significant influence on regional economic performance in the chosen areas. This partially contradicts studies highlighting the importance of human capital in knowledge economies (OECD, 1996; Hassani *et al.*, 2022). We consider that the governments of the regions' economies need to enhance investments in these sectors if they are to keep up with the advanced economies.

From Table no. A2, it can be seen that employment in high-tech manufacturing and knowledge-intensive and high-technology services has a negative, though significant, and at a very low level of correlation for each model. Medium-tech manufacturing sectors are highly statistically significant for the FE and FE (within) models. Employment in the wholesale retail and trade sector is statistically significant for the FE (within) model only, while finance and insurance coefficients is statistically significant only for the FE and FE (within) models. Employment in the human health and social work activities sector has a positive and highly significant influence on GDP per capita (constant USD) at the level of the entire sample of countries for each year. This aligns with the understanding of KBEs as learning economies where a skilled workforce is essential (Sterlacchini, 2008). Additionally, this finding demonstrates how important health, and social services are for the overall economic productivity of the EU (European Commission, 2014).

As a next step, we considered analysing the RE models (model RE (patents), model RE (students), model RE (patents, students)) in order to determine whether they may help us to get more information out of our data and distribute the variation in our model more effectively. These three models test the effect of number of patents and proportion of students in population on regional GDP per capita. Table 3 (Appendix 3) shows that various variables have a statistically significant effect on economic growth. Also, regional economic development seems increasingly dependent on GERD.

According to the model, we see that patents have a statistically significant relationship with GDP per capita. Among scholars, patents are recognized as an essential driver of economic development in a knowledge-based economy, and our findings match the results obtained by other experts (Tsakalerou, 2018).

Employment in high-technology manufacturing has a statistically significant coefficient; however, it is negative. In the long run, it is reasonable to expect that increased government spending and development of the manufacturing sector in regions will boost economic growth (Naudé and Szirmai, 2012; Behun *et al.*, 2018).

From the table, we see that employment in the professional, scientific and technical activities sector has a statistically significant relationship with economic growth. Recent economic growth has clearly been affected by several important factors, such as scientific progress and changes in technology.

It should be noted that, in this model, employment in the human health and social work activities sector has a significant effect on GDP per capita, and its increase of 1% is associated with a 0.3% increase in GDP per capita. This result backs up our earlier assumption, based on the results presented in Table no. A2, that the human health and social work activities in the employment sector is a key driver of regional economic growth. Furthermore, in this model, we can also see the correlation between the ratio of the proportion of students within the population and economic growth. According to this result, we might consider the importance of employment in knowledge-intensive sectors for the selected regions' economic development.

After testing several different models and variable selection procedures, we believe that the RE model (GERD and others) and the RE (GERD and significant) model provide the most accurate representations of our data (Table no. 1). Simultaneously, the results of the estimation of the fixed effects (FE) model are also reported. The results of the Hausman test showed that the fixed effects model should be preferable, however, we opted to report the random effects model as well, as this model shows a higher fit to the dataset. It should be noted that there is no significant difference in the magnitude and direction of effects reported by either model; both models contain the same set of independent variables, and their coefficients do not differ considerably. The results suggest that the choice of a model may not have a substantial impact on the results, but it is important to consider both models to ensure the robustness of the analysis. Table 4 demonstrates that GERD, like other models, significantly affects economic growth. Within the manufacturing category, employment in high-technology manufacturing and employment in medium-high-technology manufacturing have a negative and statistically significant relationship with economic growth.

In a knowledge-based economy, services play a crucial role. We can see that, in the model, the above-mentioned hypothesis is supported by the statistically significant coefficient, which reveals a strong relationship between employment in knowledge-intensive sectors and GDP per capita. A number of other researchers have come to the same conclusion, confirming the significance of services in a KBE (Boden and Miles, 2001; Miles, 2003).

According to this model, there is a correlation between R&D personnel and economic development; however, this correlation is not nearly as significant as the correlation between other variables. If the chosen regions were to invest more resources in this field, the influence on GDP per capita might increase.

The main conclusion from this model is that employment in the knowledge-intensive services sector is highly associated with GDP per capita for European regions within the NUTS 2 level (an increase of 1% is associated with a 0.4% increase in GDP per capita), while the proportion of students is negatively associated. This means that innovation isn't likely to be commercialised and provide economic benefits in the regions with a high concentration of students, but in other regions (most likely those with higher employment in knowledge-intensive services). These findings are similar to the outcomes of other scholars' investigations (Schwartz, 2006; Bąk *et al.*, 2022). It is essential to highlight that, generally, researchers focus on the significance of knowledge-intensive industries and their significant influence on economic growth at different country levels. However, in this paper, we conducted our study on EU NUTS 2 regions. Despite this fact, we assume that it is reasonable to estimate that the importance of knowledge-intensive service sectors and their significant effect in the various country regions might have a significant impact on the results of economic growth throughout the whole country, as shown in other scholars' studies. We believe that regional knowledge spillover and its influence on economic growth is insufficient, as shown by the differences in most knowledge economy performance-related indicators across the selected countries' regions.

Table no. 1 – Random effects models

	Model RE (GERD and others)	Model RE (GERD and significant)	Model FE (GERD and others)	Model FE (GERD and significant)
log(patents)				
log (GERD)	0.243***	0.191***	0.267***	0.182***
	-0.014	-0.015	-0.02	-0.02
log(rd_personnel)		0.058***		0.032
		-0.022		-0.02
log(high_tech_sectors)	0.082***		0.081***	
	-0.027		-0.027	
log(high_tech_man)	-0.051***		-0.045***	
	-0.015		-0.015	
log(med_tech_man)	-0.040**		-0.035	
	-0.02		-0.024	
log(wholesale_retail_trade)	-0.160***		-0.221***	
	-0.057		-0.058	
log(knowledge_intense_servi		0.415***		0.187*
ces)		-0.101		-0.104
log (knowledge_intense_high_tech_services)				
log(knowledge_intense_mark	0.147**		0.093***	
et_services)	-0.03		-0.03	
log(knowledge_intense_other				
_serviees)				
log(info_communication)				
log(finance_and_insurance)				
log (prof_scientifie_teeh_		0.183***		0.066**
activities)		-0.032		-0.029
log(education)				
log (human_health_social_	0.270**	0.158**	0.132***	-0.012
work)	-0.034	-0.049	-0.04	-0.049
log(proportion_students)		-0.102***		-0.033
		-0.033		-0.038
Constant	8.089***	6.721***		
	-0.217	-0.293		
Observations	528	524	528	524
R2	0.923	0.93	0.464	0.262
Adjusted R2	0.922	0.929	0.222	-0.071
F Statistic	784.931 ***	713.383**	44.905***	21.358***

Note: p<0.1*; p<0.05**; p<0.01***

Source: data was sourced from Eurostat (2022).

In addition, according to the results of our measurements using the selected indicators, we can assume that despite the attempts of national and regional governments to allocate resources proportionately, the economies of some regions will have a greater tendency than those of other regions to become knowledge based. Therefore, in order to increase regional economic growth, regional governments should aim at strengthening their scientific institutions, invest more in the R&D sector, and develop knowledge-intensive sectors.

5. CONCLUSION

This study aims to estimate and analyse the effects of the knowledge-based economy on the economic growth process in the EU-28 for the NUTS 2 regions. The empirical findings reveal that GERD robustly enhances growth performance. In addition, the percentage of employment in knowledge-intensive services has a positive and statistically significant effect on the economic performance of regions in EU member states.

Based on the findings of this study, the research indicates that the manufacturing sector of the knowledge-based economy has a significantly less impact on the growth of GDP per capita compared to the service sectors. One possible explanation is that not all countries prioritise investing in the knowledge-based manufacturing sector. In addition, the knowledge-based manufacturing sector has a less need to be located near major urban regions along with certain space requirements. The results of this empirical study allow us to form some preliminary conclusions about the relationship between KBEs and economic growth in the EU NUTS2 regions. It thus confirms our first hypothesis (H1), which states that the value of a regional gross domestic product is associated with the development of a knowledge-based economy.

The characteristics of human capital in research and development, the dissemination of technical achievements (in both knowledge-based intensive services and knowledge-based manufacturing sectors), and the availability of financial resources all have the capability to reduce the shortfalls in this field and enhance the overall growth performance in the EU.

Regional GDP per capita is positively related to investments in the above-mentioned sectors in the selected regions. NUTS 2 regions, on the other hand, need public and private sector supportive policies implemented as a priority to improve productivity and economic performance. Though we are hampered by a relatively limited length of time (which includes only a recent few years, 2009-2012) and, therefore, the limited size of the sample, we conclude that knowledge-intensive sectors are the primary drivers of regional economic growth at the NUTS 2 level. This provides a potentially valuable clue for a successful regional policy that aims to increase GDP per capita. Furthermore, we might consider this as a potentially crucial subject that should be examined in future studies.

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ANNEXES

Table no. A1 – Descriptive statistics of the dataset

Variable	Description	N	Min	Average	Std. dev.	Max
y_i^t	GDP per capita	860	25,970.8	13,417.1	3,213.1	88,646.2
x_1^t	Patent applications to EPO	786	19.2	27.0	0.1	202.0
x_2^t	R&D personnel	600	1.6	1.1	0.2	5.9
x_3^t	Gross Domestic Expenditure on Research & Development (GERD) by sector	762	975.7	1,792.5	1.8	18,393.1
x_4^t	Employment in high-technology sectors (high-technology manufacturing and knowledge-intensive high-technology services), in % of total.	852	3.4	1.8	0.5	10.1
x_5^t	Employment in the high-technology manufacturing sector, in % of total	621	1.3	0.9	0.2	5.8
x_6^t	Employment in medium high-technology manufacturing sector, in % of total	845	4.7	3.1	0.2	17.0
x_7^t	Employment in wholesale and retail trade; accommodation and food services activities; activities of households as employers, in % of total	894	19.7	4.6	9.9	41.0
x_8^t	Employment in total knowledge-intensive services sector, in % of total	896	37.3	8.4	14.2	59.9
x_9^t	Employment in knowledge-intensive high-technology services sector, in % of total	813	2.4	1.4	0.4	7.9
x_{10}^t	Employment in knowledge-intensive market services (expect financial intermediation and high-technology services) sector, in % of total	885	5.3	2.0	1.0	15.0
x_{11}^t	Employment in other knowledge-intensive sectors, in % of total	896	27.1	6.1	10.8	46.5
x_{12}^t	Employment in information and communication sector, in % of total	827	2.5	1.4	0.5	8.6
x_{13}^t	Employment in financial and insurance activities sector, in % of total	860	2.7	1.4	0.6	12.7
x_{14}^t	Employment in professional, scientific and technical activities sector, in % of total	881	4.4	1.9	0.8	12.9
x_{15}^t	Employment in education sector, in % of total	890	7.1	1.6	2.9	12.7
x_{16}^t	Employment in human health and social work activities sector, in % of total	896	10.5	4.4	3.2	25.5
x_{17}^t	Ratio of the proportion of students (ISCED 5-6) over the proportion of the population by NUTS 2 regions	736	0.9	0.5	0.1	4.1

Source: data was sourced from Eurostat (2022).

Table no. A2 – Random and fixed effects models

Dependent variable: log(gdp_per_capita) panel linear				
	Model FE	**Model RE**	**Model FE (within)**	**Model FE (reduced)**
log(patents)	-0.007	0.002	-0.010	
	(0.023)	(0.003)	(0.009)	
log (GERD)	0.038	0.230***	0.050***	0.530
	(0.029)	(0.020)	(0.017)	
log(rd_personnel)	0.121	0.006	0.099**	0.205
	(0.075)	(0.027)	(0.039)	
log(high_tech_sectors)	0.177	0.095	0.081	
	(0.191)	(0.069)	(0.102)	
log(high_tech_man)	-0.145*	-0.046*	-0.082**	
	(0.073)	(0.027)	(0.040)	
log(med_tech_man)	0.077*	-0.007	0.061**	
	(0.042)	(0.030)	(0.024)	
log(wholesale_retail_trade)	0.111	-0.037	0.262***	
	(0.160)	(0.081)	(0.089)	
log(knowledge_intense_services)	0.374	0.675	0.028	
	(1.446)	(0.588)	(0.777)	
log(knowledge_intense_high_tech_services)	-0.428*	-0.157**	-0.274**	
	(0.251)	(0.072)	(0.126)	
log(knowledge_intense_market_services)	-0.153	0.037	-0.024	
	(0.281)	(0.105)	(0.149)	
log(knowledge_intense_other_serviees)	-0.965	-0.511	-0.569	
	(1.131)	(0.453)	(0.610)	
log(info_communication)	0.176	0.122**	0.163	-0.536
	(0.255)	(0.060)	(0.125)	
log(finance_and_insurance)	0.370***	-0.022	0.308***	
	(0.128)	(0.055)	(0.071)	
log(prof_scientifie_teeh_activities)	0.681***	0.114*	0.606***	
	(0.225)	(0.066)	(0.113)	
log(education)	0.050	-0.038	-0.039	
	(0.158)	(0.072)	(0.090)	
log(human_health_social_work)	1.052**	0.339**	0.992***	
	(0.158)	(0.072)	(0.084)	
log(proportion_students)	-0.005	-0.043	-0.016	
	(0.056)	(0.041)	(0.030)	
Constant	7.517***	6.925***		7.180
	(1.429)	(0.742)		
Observations	110	331	331	4
R2	0.919	0.960	0.899	1.000
Adjusted R2	0.904	0.958	0.893	
F Statistic	61.511***	654.784***	162.576***	
	(df =17; 92)		(df =17; 310)	

Note: p<0.1*; p<0.05**; p<0.01***

Source: data was sourced from Eurostat (2022).

Table no. A3 – Random effects model

	Model RE (patents)	**Model RE (students)**	**Model RE (patents, students)**	**Model RE (reduced)**
log(patents)	0.205***		0.203***	
	-0.011		-0.013	
log (GERD)				0.235***
				-0.014
log(md_personnel)				
log(high_tech_sectors)				
log(high_tech_man)			-0.022*	
				-0.013
log(med_tech_man)				
log(wholesale_retail_trade)				
log(knowledge_intense_servi ces)				
log(knowledge_intense_high _tech_services)				
log(knowledge_intense_mark et_services)				
log(knowledge_intense_other _serviees)				
log(info_communication)			0.061	
				-0.02
log(finance_and_insurance)				
log(prof_scientifie_teeh_activ ities)		0.151**		
				-0.027
log(education)				
log(human_health_social_wo rk)		0.323***		
				-0.034
log(proportion_students)	0.295***	0.126***		
		-0.049	-0.043	
Constant	9.665***	9.994***	9.676***	7.557***
	-0.027	-0.034	-0.033	-0.099
Observations	753	712	618	519
R2	0.329	0.053	0.315	0.925
Adjusted R2	0.329	0.051	0.313	0.924
F Statistic	368.910***	36.506***	282.320***	763.738***

Note: p<0.1*; p<0.05**; p<0.01***

Source: data was sourced from Eurostat (2022).