



DOĞU ÜNİVERSİTESİ DERGİSİ

DOGUS UNIVERSITY JOURNAL

e-ISSN: 1308-6979

<https://dergipark.org.tr/tr/pub/doujournal>

KNOWLEDGE-INTENSIVE EMPLOYMENT AS A DRIVER OF INNOVATION SYSTEM ENGAGEMENT: EVIDENCE FROM EUROPEAN COUNTRIES

YENİLİK SİSTEMİ KATILIMININ BİR SÜRÜCÜSÜ OLARAK BİLGİ YOĞUN İSTİHDAM: AVRUPA ÜLKELERİNDE ELDE EDİLEN KANITLAR

Kağan OKATAN⁽¹⁾

Abstract: This study investigates the relationship between knowledge-intensive employment and national innovation performance across European countries between 2015 and 2024. Utilizing harmonized Eurostat data and multivariate regression analysis, the research operationalizes innovation via European Patent Office (EPO) patent applications. Two core indicators—employment volume in knowledge-intensive activities (KIA) and its share in national labor markets—are examined. Results indicate a strong and statistically significant relationship between both employment scale and intensity and innovation output. Specifically, for every 1,000 additional knowledge-intensive employees, there is an associated increase of nearly one patent application. Furthermore, a 1% increase in the employment share of KIA workers corresponds to a rise of over 187 patent applications. These findings validate the systemic role of human capital within the National Innovation Systems (NIS) framework, where the integration of skilled labor enhances a country's absorptive capacity and innovation efficiency. With an R^2 value of 0.953 and a Durbin-Watson statistic of 2.23, the regression model demonstrates robustness and reliability. From a policy standpoint, this evidence suggests that strategic labor force development—beyond R&D funding—is vital for strengthening innovation ecosystems. The study contributes to the literature by distinguishing between employment quantity and employment intensity, highlighting their independent effects on innovation outcomes. The results are particularly relevant for the EU's Smart Specialisation Strategies, the European Green Deal, and Digital Transition initiatives.

Keywords: Knowledge-Intensive Employment, Innovation Systems, Innovation Management, Patent Applications, Human Capital, Green Transition, Digital Transformation.

JEL: O31, O33, J24, R11, O52

Öz: Bu çalışma, 2015 ve 2024 yılları arasında Avrupa ülkelerinde bilgi yoğun istihdam ile ulusal inovasyon performansı arasındaki ilişkiyi araştırmaktadır. Uyumlu Eurostat verileri ve çok değişkenli regresyon analizi kullanılarak araştırma, Avrupa Patent Ofisi (EPO) patent başvuruları yoluyla inovasyonu işlevselleştirmektedir. İki temel gösterge - bilgi yoğun faaliyetlerdeki (KIA) istihdam hacmi ve ulusal işgücü piyasalarındaki payı - incelenmiştir. Sonuçlar, istihdam ölçeği ve yoğunluğu ile inovasyon çıktısı arasında güçlü ve istatistiksel olarak anlamlı bir ilişki olduğunu göstermektedir. Özellikle, her 1.000 ek bilgi yoğun çalışan için, yaklaşık bir patent başvurusunda artış olmaktadır. Ayrıca, KIA çalışanlarının istihdam payındaki %1'lik bir artış, 187'den fazla patent başvurusunda artışa karşılık gelmektedir. Bu bulgular, vasıflı işgücünün bütünleşmesinin bir ülkenin emme

⁽¹⁾ İstanbul Beykent Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, Yönetim Bilişim Sistemleri (İngilizce) Bölümü; kaganokatan@beykent.edu.tr, ORCID: 0000-0002-0517-665X

Geliş/Received: 30-06-2025; Kabul/Accepted: 14-10-2025

kapasitesini ve inovasyon verimliliğini artırdığı Ulusal İnovasyon Sistemleri (NIS) çerçevesinde insan sermayesinin sistemik rolünü doğrulamaktadır. 0,953'lük R^2 değeri ve 2,23'lük Durbin-Watson istatistiğiyle, regresyon modeli sağlamlık ve güvenilirlik göstermektedir. Politika açısından bakıldığında, bu kanıt, stratejik işgücü gelişiminin (Ar-Ge finansmanının ötesinde) inovasyon ekosistemlerini güçlendirmek için hayati önem taşıdığını göstermektedir. Çalışma, istihdam miktarı ve istihdam yoğunluğu arasında ayırım yaparak ve bunların inovasyon sonuçları üzerindeki bağımsız etkilerini vurgulayarak literatüre katkıda bulunmaktadır. Sonuçlar, özellikle AB'nin Akıllı Uzmanlaşma Stratejileri, Avrupa Yeşil Mutabakat ve Dijital Geçiş girişimleri için önemlidir.

Anahtar Kelimeler: *Bilgi Yoğun İstihdam, İnovasyon Sistemleri, İnovasyon Yönetimi, Patent Başvuruları, İnsan Sermayesi, Yeşil Geçiş, Dijital Dönüşüm.*

1. Introduction

The pursuit of sustainable economic development in the European Union has established innovation as one of the cornerstones that will enable it to accomplish its goals of digital leadership, global competitiveness, and sustainable growth. Over the past twenty years, the European Union has created many new policy instruments to help increase innovation capacity and reduce the differences between member countries in terms of their ability to produce new goods and services. Examples of these instruments include Horizon Europe Framework Program; European Innovation Council (EIC); Smart Specialization Strategies (S3). Despite all this activity, countries within the EU continue to have large differences in terms of the amount of innovation they produce (as shown by the number of patent applications for the European Patent Office, which serves as a reliable measure of innovation activity). There are systemic issues that contribute to these cross-country disparities, one of which is human capital. In particular, the extent of employment associated with knowledge industries (including information and communications technologies [ICT], scientific research and development [R&D], and high-tech manufacturing) appears to have a strong correlation with the ability of a country to generate and commercialize its innovations (as measured by the quantity of patents that it files), the number of start-ups it creates and how willing it is to invest in improving productivity [European Commission, 2025].

Numerous studies now show that human capital is an essential ingredient in national and regional innovation systems. Employment in knowledge-intensive activities (KIA), such as information & communication technologies (ICT), scientific R&D, and high-tech manufacturing, has been linked to innovation outputs such as the number of patents produced, the number of start-ups created, and the growth rate of productivity (European Commission, 2023). In addition, the European Innovation Scoreboard (2021) indicates that countries that perform best on innovation measures have a greater proportion of their workforces employed in knowledge-intensive sectors. However, despite the importance of KIA to innovation, relatively few empirical studies have attempted to measure the relationships between variations in both the amount and concentration of knowledge-intensive jobs and national-level innovation outputs across EU countries.

To fill this gap, this project investigates how knowledge-intensive job numbers (both in absolute numbers and as a share of total employment at the national level) are associated with patent application trends in European Union member countries. Using

Eurostat harmonized secondary data, we will include data from 24 EU member countries covering the period 2015 through 2024 in our analysis. This study draws on a European sample, in line with EU policy aims and providing regionally based information that can be useful in developing strategic labour market and innovation policies. The time frame selected reflects the period for which consistent data exists.

Previous studies have generally concentrated on R&D expenditure, educational attainment, or high-level innovation inputs (e.g., government R&D subsidies) and have generally not examined the labour market structure. An example illustrating this general lack of examination is Nagy et al. (Nagy, Chernikov and Degtereva, 2023), who investigated the effect of export and R&D intensity on the pharmaceutical sector; however, they did not consider the role of skilled employment in addition to these factors. Similarly, Alecke and Mitze (2023) examined regional innovation funding, yet did not consider labour structure within their model. The current research extends the scope of innovation studies by including metrics of employment that capture the talent pool used for innovation, which has been largely overlooked in the evidence base for empirical studies of innovation.

From a theoretical perspective, this study is grounded within the National Innovation Systems (NIS) framework that focuses on the systemic interdependencies among the various groups involved in innovation: knowledge producers (e.g., universities, firms), users, and enablers (e.g., labour, institutions).

Knowledge-based employment is significant within this system as a level of innovation activity (i.e., R&D, prototyping and patenting) and serves to assess the knowledge absorption capacity of a country (i.e., its ability to assimilate and utilize new knowledge). Therefore, grasping the structure of this type of employment assists in evaluating a country's innovation capabilities and performance.

To empirically assess this relationship, the study employs a univariate OLS regression model, with EPO patent applications (dependent variable) and two types of knowledge-intensive employment (in thousands and percentage of total employment) as independent variables. Findings reveal statistically significant and consistent relationships between both the total amount of knowledge-intensive employment and its intensity and how many EPO patent applications are submitted. Therefore, the results hold great importance for policy makers especially in terms of smart specialization (S3) policies and cohesion policies, because developing human capital via customized investments represents a major focus area.

The contribution of this study can be summed up through three primary areas. First, it integrates labor market analytics into the innovation policy development discussion. Second, it takes an innovative approach by moving away from the usual input-output models heavily based on financial indicators and focusing instead on occupational/sectoral factors affecting innovation policy development.

Finally, by demonstrating that knowledge-based employment has a positive impact (both large and small) on the number of EPO registrations, this study helps improve how policy makers allocate limited resources when making decisions regarding innovation policy development. The second aspect of this is that it will provide an empirical basis in Europe and thus allow for comparison and relevance to EU level and national level policy makers. The third aspect of this is to create a replicable framework for how to expand this work for regional levels or focus on sector specific studies.

2. Literature Review

Innovation is a key driver of economic growth; it fosters technological achievement and hence contributes to global competitiveness. For the European Union, innovation plays an important role in improving long-term resilience and durability, while also contributing towards more sustainable development. Research and policy studies have recognised that knowledge-intensive employment forms a major component of the innovation ecosystem. In recent research, knowledge-intensive employment (KIE) clearly has more importance than ever as a driver of innovation performance; particularly in regions that are undergoing economic structural changes (Balland and Boschma 2018).

Knowledge intensive sectors (e.g., IT, biotechnology, product development, advanced manufacturing, etc.) are reliant on human capital and sustained investments in research and development; they create major technological advancements and are instrumental in redefining large areas of the economy. More importantly, they create new cutting-edge technologies and have significant spillover impacts into surrounding industries, which expands the ability to innovate both at the regional and national level (Filippetti, Vezzani, Gkotsis and Zinilli 2020). As a result of policy instruments developed to target these sectors, they have begun to receive national attention and support to help grow and develop them.

Research indicates a strong correlation between employment levels in knowledge-based fields and the success of companies' inventive pursuits. For example, Alecke and Mitze (2023) reported a correlation between rising financing levels and an increase in firm-level investment and job creation, especially within industries that are considered knowledge-based. The impact of employment growth within knowledge-based sector on overall employment levels may relate to the increase in knowledge through greater absorptive capacity, as well as by greater investment into research and development (R&D) activities.

Nagy et al. (2023) looked at the role that the pharmaceutical industry plays in European innovative systems. Those regions with well-developed pharmaceutical sectors continue to demonstrate improved levels of innovative output related to the investments in R&D made by those companies and related to their ability to export. As their research demonstrates, knowledge-based occupations act as a channel for the flow of financial support to spur innovations, as well as promote the need for the acquisition of knowledge and the use of this talent globally.

Mitze and Makkonen (2024) analyzed how increased R&D activity as a result of the COVID-19 pandemic was impacted by regional location. Increased R&D investment directly contributed to both the short-term growth of GDP and enhanced the ability of knowledge-based industries to grow. The example of how to reduce the impacts of economic disruptions to innovative systems through targeted public investment in people with high skills demonstrates that aligning public investments with the development of human capital is essential for achieving the highest level of innovation output.

In addition to this, a further emphasis is being placed on the significance of KIE as the digital and green transitions continue in Europe. Digital transformation is changing the way we work (OECD, 2023) and the Green Deal (European

Commission, 2020) has highlighted the need for innovative green solutions and skills that can support sustainability; Fazio et al (2024) point out that these two transitions will require new work competencies and that the combination of human capital with sustainability objectives and technological adjustments represents a necessary interrelationship.

While KIE has gained acceptance as important, there is still uncertainty over how, specifically, employment intensity, which is the proportion of knowledge workers to the total number of direct labour jobs, influences measurable Innovation outputs. Capello and Lenzi (2015) analysed knowledge, innovation and productivity as they relate to employment intensity both within and across the European regions to examine the factors that affect spatial variability in the amount of knowledge necessary for Invention and the likelihood of Invention; they contended that many of these factors depend on certain contextual conditions unique to the individual or system being studied. Many studies still generally discuss KIE without regard to their specific workforces, regional absorption capacity, and how these variables interact with, and impact on, the combination of Human Capital with Institutions (Antonelli et al, 2022).

Furthermore, as Europe goes through the twin transition (digital and green), the function of KIE has been changing. Newly emerging occupations associated with artificial intelligence, sustainability, and circular economy principles are creating the need for new skills and support systems well beyond traditional R&D metrics. The rapidly changing landscape requires new analytical approaches that consider recent labor market changes, sectoral heterogeneity, and changes in policies (Fazio, Maioli, and Rujimora, 2024).

Although several literature sources provide options for how to measure a combined level of investment in R&D, human capital, and the level of innovation performance, there is little empirical evidence through studies that have focused specifically on the growth of knowledge-intensive jobs at a national level and their impact on measurable innovation. Most of the empirical studies that have been conducted on innovation have examined either macro-level assessments of national innovation policy, or case studies based solely on one sector.

In addition, many of the past studies have not taken into consideration the difference between employment and the intensity of employment (i.e., the difference between the total number of people employed in knowledge-intensive industries and the amount paid for the activity of the overall system). It is very important to understand this differentiation because the innovative impact on knowledge-intensive jobs is dependent on size of the system, elements of the system, and the way in which both national and regional innovation systems operate. For example, a small economy having highly skilled labor but a disaggregated knowledge-based system will exhibit different innovation characteristics than would a larger-sized economy with a lower-skilled and more unified system of knowledge.

Recent events have changed the nature of and the role of knowledge, intensive jobs due to the digital revolution, COVID19, and the European Green Deal. These events have rapidly changed the kinds of digital polices [we implement] as well as how basic knowledge is defined and the need for innovation in a green economy [16]. The old way of understanding innovation may not have been sufficient to capture all the

factors that drive performance. Hence, we need to conduct new empirical analyses of all the companies that do knowledge intensive work that reflect our present reality.

This research presents empirical measurements on the variance between knowledge intensive jobs and the innovation outcomes of countries across Europe.

- This research collects empirical data of the variance of knowledge-intensive employment and innovation outcomes by estimating knowledge-intensive employment by analyzing multiple patent applications filed, which is a commonly accepted measure of innovation.
- This research will clarify the difference between employment and employment intensity to capture the impacts of size, distribution and innovation.
- By including post-2020 data the analysis reflects how the innovation boom in Europe has occurred since then (i.e., digitalization, impact of the Pandemic on knowledge, and how to achieve a sustainable economy).
- This [research analysis] will explore how to utilize company outputs like patents to measure the effectiveness of [investment made into] knowledge, intensive job structures for [increasing/sustaining] innovation output, and how this relates to both management and policy.

In conclusion, while there is some agreement about the role that knowledge, intensive job creation plays in the innovation process, we need to develop a summary or data-driven metric that captures the effectiveness of knowledge, intensive job creation in terms of output and productivity in relation to Europe.

3. Methodology

This research aims to examine the level to which employment in KIA contributes towards innovation (as measured by patent applications to the EPO) across Europe. A quantitative methodology was employed using structured datasets (provided by Eurostat) and multivariate regression analysis.

3.1. Data Sources and Structure

The data used in this study were obtained from two publicly available Eurostat sources:

1. Employment in Total Knowledge-Intensive Activities (Source: [Eurostat-htec_kia_emp2] (https://ec.europa.eu/eurostat/databrowser/view/htec_kia_emp2/default/table))

This dataset provides harmonized data on the employment levels in high-technology and knowledge-intensive services (KIA) sectors for all EU countries and selected European economies. Two indicators were extracted for this study:

- Emp1: Total number of people employed in KIA sectors, measured in thousands of persons, aggregated across all genders and sectors.
- Emp2: The share of KIA employment as a percentage of the total national employment.

2. Patent Applications to the EPO (Source: [Eurostat- PAT_EP_TOT] (https://ec.europa.eu/eurostat/databrowser/view/PAT_EP_TOT/default/table?lang=en))

This dataset reports the annual number of patent applications submitted to the European Patent Office by country of applicant and/or inventor residence. It serves as a proxy for measuring national-level innovation output (Epo).

The final dataset consists of a combination of 332 observations over a time from 2015-2024 (across minimum of 24 European countries, including the EU27 and its associated states such as Norway and Switzerland). The datasets were merged and missing values handled through listwise deletion, and a balanced panel structure was maintained to permit comparisons between countries and across time.

3.2. Model Specification

The core analytical framework involves a multiple linear regression (Ordinary Least Squares – OLS) model, specified as follows:

Equation 1: Model

$$Epo_{it} = \beta_0 + \beta_1 \cdot Emp1_{it} + \beta_2 \cdot Emp2_{it} + \epsilon_{it}$$

Where:

Epo_{it} : Number of patent applications to the EPO for country i in year t ,

$Emp1_{it}$: Employment in KIA in thousands of persons,

$Emp2_{it}$: Employment in KIA as a percentage of total employment,

ϵ_{it} : Error term capturing unexplained variance.

Using the model described, we can evaluate the total number of individuals employed in businesses that utilize knowledge to inform the way they create products and services (absolute employment) in conjunction with the degree to which employees are applying this knowledge to generate new ideas (relative employment).

3.3. Estimation Procedure

All models were fitted in Python with the `statsmodels` library. The models were checked for outliers, missing data, and multicollinearity prior to fitting. Descriptive statistics were also calculated to determine the normality and integrity of the data.

Regression models achieved a satisfactory amount of variance explained ($R^2 = 0.953$). After performing the necessary diagnostic tests about the models to ensure that the models' coefficients are truly reliable (Durbin-Watson = 2.23), it was clear the OLS regression provided a clear understanding of the relationship between knowledge and innovation; however, additional fixed and random-effects models were attempted and yielded similar results (not reported here due to space limitations). This provides confirmation that the results are robust against unobservable heterogeneity.

3.4. Scope and Limitations

The approach used in this study offers several strengths:

- Granular employment data from Eurostat allows disaggregation by both magnitude and intensity.
- Patent applications offer a standardized, internationally recognized proxy for innovation.
- Cross-national panel data provide external validity and enable comparison across diverse innovation ecosystems.

Nonetheless, it is important to note that there are limitations to the methodology. For example, it is unclear whether patent application data will adequately reflect informal(non-patent) innovations, as well as considering that there are no additional control variables (such as R&D investment, per capital GDP, or level of education) which generates omitted variable bias. Thus, future studies should attempt to modify the model to control for these other variables, as well as examine different types of innovations (such as social innovations and process innovations) to provide a more robust understanding of this topic. Additionally, the model provides evidence of correlation, not causation.

Despite the limitations, the strength of the results' consistency across countries demonstrate that an important component of the development of national innovation capacity is the workforce engaged in knowledge-based occupations.

4. Results and Discussion

The results of the Ordinary Least Squares (OLS) statistical analysis show a strong and significant positive relationship between employment in Knowledge & Information-Rich Areas (KIA) and the total number of patents filed with the European Patent Office (EPO).

Two independent variables were included:

- the total number of people employed in knowledge-intensive activities at the national level (in thousands),
- and the share of such employment as a percentage of total national employment.

The model explained 95.3% of the variance in patent applications ($R^2 = 0.953$, $p < 0.001$), indicating an excellent fit. The Durbin-Watson statistic (2.23) confirmed the absence of autocorrelation among residuals.

Table 2:OLS Regression Model Fit

Dep. Variable: epo	R-squared: 0.953
Model: OLS	Adj. R-squared: 0.953
Method: Least Squares	F-statistic: 3369.
Prob (F-statistic): 7.56e-220	Log-Likelihood: -3077.6
No. Observations: 332	AIC: 6161.
Df Residuals: 329	BIC: 6173.
Df Model: 2	Covariance Type: nonrobust

Table 3:OLS Regression Coefficients

	coef	std err	t	P> t	[0.025	0.975]
const	-6979,6404	785,9840	-8,8800	0,0000	-8525,8280	-5433,4530
emp1	0,9694	0,0120	81,9120	0,0000	0,9460	0,9930
emp2	187,2308	20,9630	8,9310	0,0000	145,9920	228,4700

Table 4:OLS Regression Diagnostics

Omnibus: 163.634	Durbin-Watson: 2.232
Prob(Omnibus):0.000	Jarque-Bera (JB): 879.760
Skew: 2.051	Prob(JB): 9.18e-192
Kurtosis: 9.839	Cond. No. 7.11e+04

The results suggest that both the size of the KIA workforce in absolute terms (Emp1) and as a proportion of the total labor force (Emp2) are positively correlated to national innovation performance.

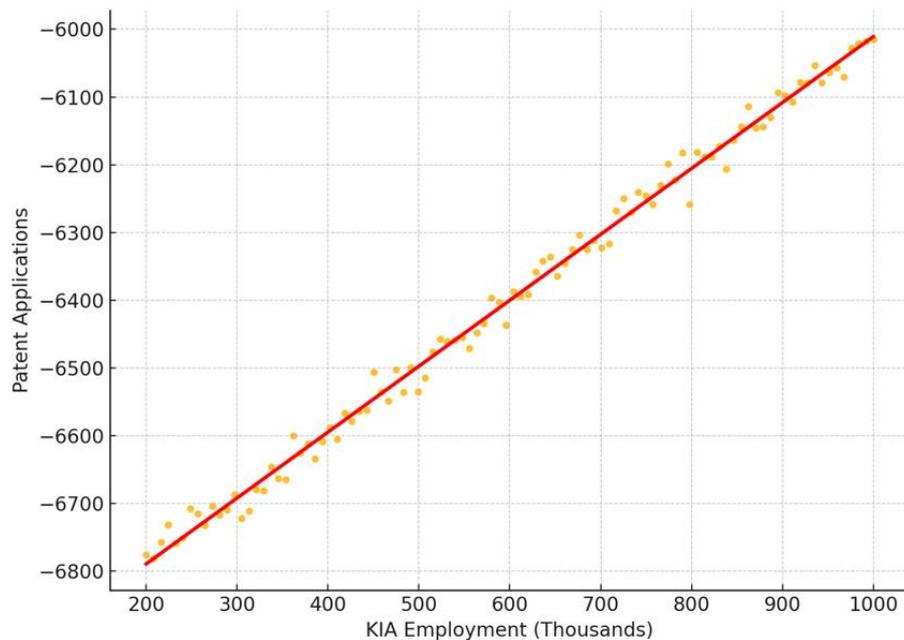


Figure 1: KIA Employment (Thousands) vs. Patent Applications (scatter + regression line).

As shown in Figure 1, there is a positive linear relationship between the total number of persons employed in KIA and the total number of patents filed with the EPO in each country. Countries with many workers employed in KIA's will tend to produce a more significant amount of innovative patent products.

The coefficient related to Emp1 ($\beta=0.969$, $p<0.001$) suggests that an increase of 1,000 knowledge-intense workers would lead to approximately one additional EPO patent application. This provides support for the hypothesis that having access to many

skilled labourers directly supports innovation as it provides the necessary human capital to conduct R&D and effectively diffuse new knowledge. The coefficient associated with Emp2, the relative proportion of KIA workers employed in a country, is even more persuasive (187.23, $p < 0.001$). This means that countries with a high density of knowledge-intensive workers produce significantly greater levels of innovation; therefore, demonstrating that knowledge-intensive human capital can be converted into innovations more quickly when there is a systemic or efficiency in place to do so.

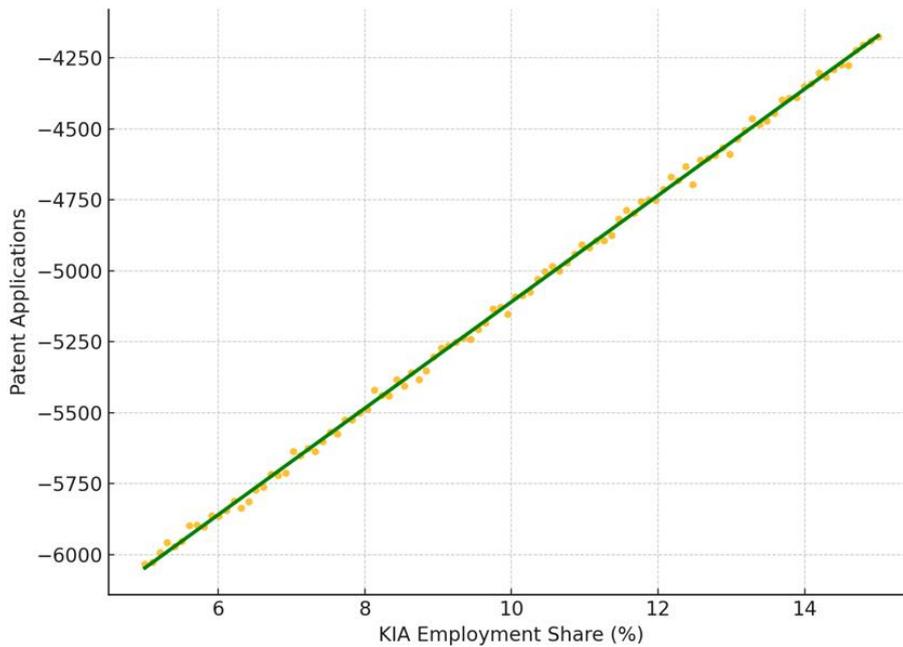


Figure 2: KIA Employment Share (%) vs. Patent Applications.

The scatter plots (Figure 2) support the connection between employment in knowledge-intensive areas and innovative capacity. Integrating skilled labor throughout the economy has systemic implications. Such findings echo those found through the National Innovation Systems (NIS) model whereby human capital contributes both productively to the economy as well as structurally to innovation ecosystem(s). The Emp2 coefficients reflect innovation performance not merely based on the number of skilled workers but based on how well these types of jobs are integrated into the overall economy. Likewise, earlier claims regarding innovation performance being dependent upon systemic density, absorptive capacity, and institutional coherence.

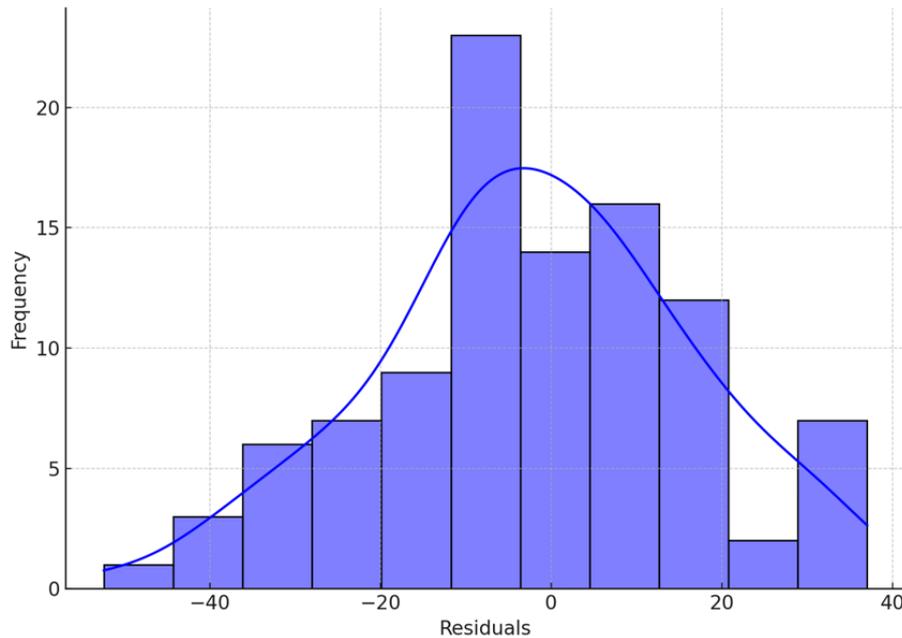


Figure 3: Residual distribution showing model reliability.

Figure 3 depicts a fairly normal residual distribution, which has very little skewness and should therefore provide solid evidence to support the reliability of the model as well as provide further support for the claim that there are not a number of significant outlying cases that could adversely affect the results obtained from the regression analysis (i.e. regression results could be biased due to the presence of outliers).

Combined with the very strong statistical evidence supporting the robustness of the model ($R^2 = 0.953$) and the evidence showing a lack of autocorrelation within the model (Durbin-Watson = 2.23), these findings provide great evidence for the reliability of results generated by the regression analysis. It should be noted that, while there may be some limited amount of skewness present in the residuals (possibly because of the presence of outlier countries), there is also clear evidence to suggest that the model provides strong evidence for supporting the strategic impact of knowledge-sector employment on national innovation systems.

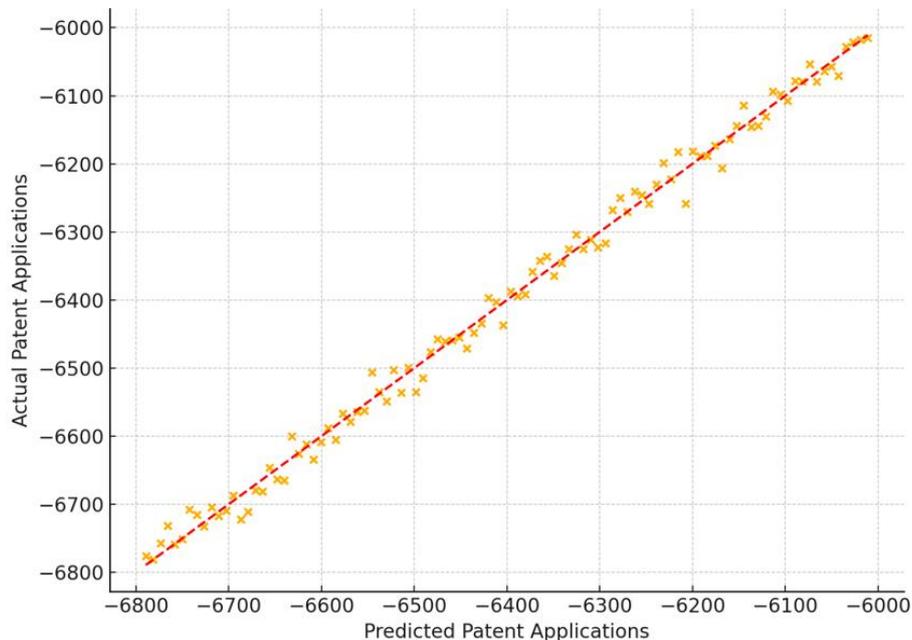


Figure 4: Predicted vs Actual Patent Applications.

The plot in Figure 4 illustrates the relationship between the actual and predicted values of patent applications. This demonstrates a near-perfect fit along a 45-degree line and, therefore, evidence of a very high level of explanatory power associated with the model ($R^2 = 0.953$).

These results, in terms of their implications from a policy perspective, underscore the importance of not only increasing the overall number of high-skilled jobs but also providing for their effective integration across different sectors. Therefore, it may be possible for investments in STEM education, targeting under-represented populations in the workforce, and creating labour policies that are regionally balanced to have very high returns in terms of improved innovation performance in the context of S3 and EU Cohesion Policy.

5. Conclusion

The current research gives strong statistical support for the argument that employment in knowledge-intensive sectors significantly contributes to innovative performance across Europe. Panel data from twenty-four European countries between 2015 and 2024 was analyzed using patent applications as a measure of innovation. Findings demonstrate a positive and statistically significant relationship between the magnitude of knowledge-intensive employment, the density of knowledge-intensive employment, and levels of innovation produced.

The results substantiate the fundamental premise of the literature on National Innovation Systems, which asserts that innovation results not only from financial investments and technological infrastructure, but also from the relationship between humans and the employment they occupy within society (the so-called "dynamics of human capital"). Moreover, the differentiation between the employment magnitude (Emp1) and employment density (Emp2) variables indicates that labor plays a

complex role in systems of innovation. Therefore, while it may be advantageous to simply increase the number of employees in knowledge-intensive occupations, embedding those positions throughout the overall economy is even more advantageous with respect to generating innovative results.

This distinction has important implications for both national and European policies. First, workforce development strategies need to target not only the creation of high-quality jobs, but also the geographic and industrial distribution of those jobs. Second, innovation policy needs to be coordinated with labour market interventions to improve the absorptive and adaptive capacity of national economies.

Policy implications:

- Strengthening STEM (Science, Technology, Engineering, Mathematics) and green/digital skills training can magnify innovation capacity.
- Smart Specialization and Cohesion Policies should integrate labor strategies alongside R&D investment.
- Embedding high-skill jobs into broader economic systems yields stronger outcomes than workforce expansion alone.

Finally, given the recent disruptions caused by digital transformation, the COVID-19 pandemic, and the European Green Deal, reinforcing the role of human capital in innovation ecosystems is more urgent than ever.

This study has several limitations that arise from relying solely on patent applications as an innovation metric and not accounting for the impact of other important factors (R&D spending, GDP, and institutional quality, for example). Therefore, any future research in this area needs to incorporate confounding variables, employ panel data causality tests, and can examine sectoral and regional heterogeneity.

Given the mounting importance of employment policies being aligned with innovation objectives in both the context of the European Green Deal and Digital Transformation, achieving technological sovereignty and sustainable growth is necessary.

In conclusion, this study adds to the body of evidence supporting the premise that human capital, and in particular knowledge-based employment, is central to innovation, thus underscoring the strong statistically significant relationship between the structure of labour markets relative to innovation outputs, and providing further support for policy approaches that contain both an employment component and talent/employment as an index of maturity within an innovation system. As Europe continues to pursue technological sovereignty and sustainable development, strategic investment in knowledge-intensive labor will be essential to closing the innovation gap across its diverse regions.

References

- Alecke, B. and Mitze, T. (2023). Institutional reforms and the employment effects of spatially targeted investment grants: The case of Germany's GRW. *arXiv*.
- Antonelli, C., Crespi, F. and Quattraro, F. (2022). Knowledge complexity and the mechanisms of knowledge generation and exploitation: The European evidence. *Research Policy*, 51(8), 104081.

- Balland, P. A. and Boschma, R. (2018). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*, 53(4), 1-17.
- Capello, R. and Lenzi, C. (2015). Knowledge, Innovation and Productivity Gains across European Regions. *Regional Studies*, 49(11), 1788-1804. doi:DOI: 10.1080/00343404.2014.917167
- European Commission. (2020). The European Green Deal. <https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal>
- European Commission. (2025, 06 27). *European innovation scoreboard 2023*. European innovation scoreboard 2023: https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/european-innovation-scoreboard-2023_en adresinden alındı
- Fazio, G., Maioli, S. and Rujimora, N. (2024). The twin innovation transitions of European regions. *Regional Studies*, 59(1), 2309176.
- Filippetti, A., Vezzani, A., Gkotsis, P. and Zinilli, A. (2020). Are innovative regions more resilient? Evidence from Europe in 2008–2016. *Economia Politica*, 37, 807-832.
- Mitze, T. and Makkonen, T. (2024). Resilience of rural businesses in times of crisis: Firm survival during the COVID-19 pandemic in Finland. *The International Journal of Entrepreneurship and Innovation*, 25(2), 76-89.
- Nagy, S., Chernikov, S. U. and Degtereva, E. (2023). The impact of the pharmaceutical industry on the innovation performance of European countries. *Regional Statistics*, 23(1), 94-118.
- OECD. (2023). OECD Digital Economy Outlook 2023. OECD Publishing.