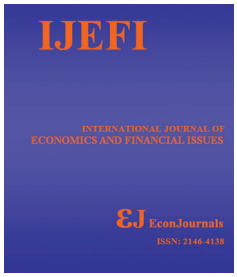

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Assessing EU Member States' Readiness for Innovation Parks: Financial and R&D Perspectives

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ABSTRACT

This article examines the readiness of EU member states to establish innovation parks by evaluating gross domestic expenditure on research and development (GERD) and the proportion of R&D personnel within the labor force. Utilizing k-means clustering, the research categorizes EU countries into three clusters based on GERD and R&D personnel metrics, allowing for a nuanced assessment of innovation potential. The analysis reveals significant disparities among EU member states, with Austria, Belgium, Denmark, Finland, Germany, and Sweden exhibiting the highest readiness for innovation parks, while others, such as Bulgaria and Romania, face substantial challenges due to limited R&D investment and workforce. This study focuses solely on GERD and R&D personnel, excluding other factors such as government policy or sectoral distinctions. Future research could integrate these elements for a more comprehensive analysis. Insights from this research can guide policymakers in tailoring interventions to enhance R&D funding and workforce development, particularly in underprepared regions. This study contributes to understanding EU innovation readiness by providing a comparative analysis based on financial and human capital, offering a novel clustering approach to assess innovation park potential across diverse EU contexts.

Keywords: Cluster Analysis, European Union, Innovation Parks, Innovation Ecosystems, Knowledge Economy
JEL Classifications: H52, O31, O32, O38, R58

1. INTRODUCTION

Innovation parks have emerged as vital components in fostering technological advancements and driving economic growth across nations. They serve as platforms where collaboration between research institutions, industries, and governments can spark innovation, leading to significant progress in areas like research and development (R&D). However, the success of innovation parks is heavily dependent on a country's financial capacity to invest in R&D and the availability of skilled personnel dedicated to research activities. These factors are crucial for the effective establishment and operation of innovation parks.

This study assesses the readiness of EU member states to develop and sustain innovation parks by analyzing two key indicators: Gross domestic expenditure on research and development (GERD) and the share of R&D personnel in the labor force. Through this examination, the study aims to classify EU countries based on their investment levels and workforce allocation, providing a comprehensive analysis of the disparities in R&D capacity across the region.

The relevance of this research lies in its ability to offer insights into the innovation potential of various EU member states. As the EU continues to prioritize innovation-driven economic strategies, understanding which countries are well-positioned to succeed in this area – and which are not – becomes increasingly important. By identifying the financial and human capital strengths and weaknesses of each country, this study provides a roadmap for future policy interventions, helping to close the innovation

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gap within the EU and fostering a more cohesive approach to technological development.

The primary aim of this study is to assess the readiness of EU member states to establish and operate innovation parks, with a particular focus on their financial investment in research and development (R&D) and their R&D workforce. Innovation parks are seen as key drivers of technological advancement and economic growth, making it crucial to evaluate how prepared EU countries are for their implementation. To achieve this, the study examines gross domestic expenditure on research and development (GERD) and the share of R&D personnel in the labor force as the two main indicators.

The objectives are twofold: firstly, to classify EU countries based on their financial and human capital investments in R&D using cluster analysis; and, secondly, to identify patterns that distinguish countries with high potential for innovation parks from those facing significant challenges. The analysis provides a comprehensive overview of the disparities in R&D readiness among EU member states and offers insights into the financial and human resource factors that contribute to the success or failure of innovation-driven initiatives. By clustering countries based on their R&D expenditures and personnel, the study aims to highlight areas for policy intervention and potential improvements in innovation capacity across the EU.

2. LITERATURE REVIEW

Innovation parks, including science and technology parks (STPs), play a vital role in driving economic growth, fostering collaboration among academia, industry, and government, and supporting regional development across Europe. For example, Squicciarini investigates the role of science parks (SPs) in Finland, focusing on tenant firms' innovative outputs and their relationship to co-location within SPs (Squicciarini, 2009). Using patent activity as a key indicator, Squicciarini demonstrates that knowledge spillovers within SPs significantly enhance innovation. However, the study is geographically limited to Finland, restricting its applicability to the broader EU context, where financial and regulatory environments differ widely. Moreover, the study focuses predominantly on patent activity, neglecting essential financial factors like funding mechanisms and government incentives, which are critical for supporting innovation parks and ensuring their sustainability across EU member states.

Nauwelaers, Kleibrink, and Stancova highlight the strategic importance of STPs in fostering regional development through smart specialization strategies (S3) (Nauwelaers et al., 2014). STPs serve as key stakeholders in regional innovation ecosystems, supporting new economic activities and enhancing regional connectivity. However, the study lacks a detailed analysis of how differences in R&D capabilities and financial support across EU regions affect the development and success of STPs. While STPs are presented as vital tools for regional development, the authors do not provide specific policy recommendations to overcome financial constraints or improve R&D infrastructure, both of which are necessary for assessing readiness across diverse EU member states.

Vásquez-Urriago, Barge-Gil, and Modrego Rico examine the impact of STPs on firms' innovation outcomes, with a particular focus on firm size and internal innovation efforts (Vásquez-Urriago et al, 2014). Their research shows that smaller firms with limited innovation efforts benefit significantly from STP locations, while larger firms also experience gains, though to a lesser extent. This firm-specific analysis, while valuable, is limited to Spain and does not consider regional differences across the EU. Moreover, the study emphasizes firm-level benefits without sufficiently addressing broader financial and R&D factors necessary for the successful establishment of STPs, such as regional economic policies, government support, and public-private partnerships.

Machado, Lazzarotti, and Bencke explore the role of technological parks (TPs) in fostering innovation through collaboration among various stakeholders—companies, universities, government, and civil society—using Triple, Quadruple, and Quintuple Helix models (Machado et al., 2018). The study underscores the importance of aligning TP strategies with these innovation models but lacks a detailed evaluation of the financial infrastructure and R&D capacity needed to support their growth. The analysis primarily focuses on the management dynamics within technological parks, overlooking critical factors like government policies, regulatory environments, and financial readiness, which are essential for the long-term sustainability of innovation parks across different EU member states.

Gorączkowska assesses the role of technological parks in Poland's Silesian and Pomeranian regions, revealing that these parks are more effective in boosting innovation in highly developed regions like Silesia (Gorączkowska, 2015). The study highlights the influence of regional development levels on the effectiveness of innovation parks, showing that innovation activities are more robust in advanced regions. However, the analysis does not sufficiently address the financial and policy frameworks that could support the establishment and sustainability of innovation parks across less developed EU regions. Financial readiness and R&D capacities remain underexplored, limiting the study's broader applicability for assessing EU-wide readiness for innovation parks.

Gursel emphasizes the importance of university collaboration in the success of STPs, particularly in fostering innovation, incubation, and startups (Gursel, 2014). While university-based STPs offer significant advantages, the study does not provide a comprehensive evaluation of broader R&D infrastructure, such as funding levels, quality of researchers, or the availability of cutting-edge laboratories, which are critical for determining readiness. Additionally, the study overlooks the roles of private industry and government agencies, which are crucial for financing and supporting innovation parks.

Luby, Chodák, and Lubyová compare innovation processes between the EU and the U.S., highlighting that Central and Eastern European countries lag behind innovation leaders like Germany and Finland (Luby et al., 2013). The study identifies several barriers to innovation in newer EU member states, including limited venture capital, an over-reliance on foreign direct investment (FDI), and weak technology transfer mechanisms.

While these insights are valuable, the authors do not provide specific strategies for overcoming these barriers in the context of innovation parks. The focus on technology transfer methods limits the broader relevance of the study to assessing EU-wide readiness for innovation parks, particularly from a financial and R&D perspective.

Gomes, Lopes, Ferreira, and Oliveira explore the role of STPs in enhancing regional innovation systems (RIS) in Portugal, using a quantitative methodology based on regional innovation inputs, outputs, and policy instruments (Gomes et al., 2022). The study highlights the positive impact of STPs on regional innovation performance but does not offer a comparative analysis of financial and R&D infrastructures across other EU member states. Furthermore, while the authors provide recommendations for policymakers to improve regional innovation, the study lacks specific strategies for addressing financial and R&D disparities that are crucial for the development of innovation parks across the EU.

Bellini, Teräs, and Ylinenpää explore the role of open innovation in Finland's Science and Technology Parks (STPs), particularly through initiatives like the Innovation Mill project (Bellini et al., 2012). While the study highlights the benefits of innovation parks in large cities due to their "knowledge hub" character, it lacks a comparative analysis of different EU member states. The reliance on qualitative examples and personal networks, without integrating quantitative data such as R&D investments, limits the ability to assess readiness across the EU. Additionally, there is no exploration of policy frameworks or government support mechanisms, making the study less applicable to understanding broader EU readiness for innovation parks.

Narula examines R&D strategies of multinational enterprises (MNEs) in new EU member states (NMS), focusing on the importance of enhancing specialized knowledge assets to foster R&D (Narula, 2009). However, the study does not specifically address innovation parks or their role in fostering innovation. While it provides valuable insights into the interaction between MNEs and local innovation systems, it lacks an analysis of the financial and policy frameworks necessary for establishing and managing innovation parks. The absence of stakeholder roles, such as government or academic institutions, limits its relevance to assessing EU-wide readiness for innovation parks.

Sokół discusses the challenges faced by technology parks in Poland, including an overemphasis on infrastructure and limited collaboration between R&D and businesses (Sokół, 2011). While the study highlights the risks of technology parks shifting toward industrial zones, it focuses solely on Poland and does not offer insights into other EU member states. The text lacks a discussion of government policies, financial incentives, or R&D investments, which are crucial for assessing the broader readiness of EU countries to develop and sustain innovation parks.

Ng, Appel-Meulenbroek, Cloodt, and Arentze examine the characteristics of SPs in Europe, focusing on their role in knowledge management and commercialization (Ng et al., 2017). The study provides valuable data on the resourcing of SPs, but its small sample size (82 parks) and uneven response rates across countries limit its generalizability. Moreover, the study lacks a detailed comparison of financial and R&D infrastructures across EU member states, which is essential for assessing readiness for innovation parks.

Taherzadeh discusses the role of technology in creating sustainable economic value, highlighting the importance of science and technology parks in fostering the commercialization of research (Taherzadeh, 2014). While the study underscores the significance of innovation parks in driving long-term economic growth, it provides little insight into the financial infrastructure required for their development. Key financial elements like funding strategies, investment needs, and government incentives are not adequately addressed, limiting the study's relevance for assessing readiness across EU member states.

Węglarz examines Poland's innovation performance relative to other EU countries, revealing gaps in human resources, research systems, and intellectual assets (Węglarz, 2018). The study highlights the need for targeted measures to improve Poland's innovation level but does not provide a comprehensive analysis of the financial and R&D infrastructure required to support the establishment of innovation parks. Understanding these structural factors is crucial for assessing the readiness of EU member states to support innovation parks.

Milius and Miliūtė assess the role of STPs in promoting technological progress in Lithuania, focusing on organizational challenges such as inadequate management and poor integration of engineering expertise (Milius & Miliūtė, 2005). While the study identifies critical barriers to the success of STPs, it lacks a detailed analysis of financial readiness and R&D capacity. These factors are essential for assessing the broader readiness of EU member states to establish and sustain innovation parks.

Ciliberti, Bröring, and Martino analyze the impact of cooperation and government financial support on innovation in the EU food industry (Ciliberti et al., 2015). The study finds that while collaboration with universities boosts product innovation, government financial support has not had a significant positive effect. However, the study focuses on the food industry and does not provide broader insights into the financial and R&D infrastructure required for innovation parks in other sectors.

Grafström, Söderholm, Gawel, Lehmann, and Strunz explore government support for renewable energy R&D across EU member states, revealing a divergence in support levels (Grafström et al.2023). While the study focuses on renewable energy, it provides valuable insights into government R&D funding mechanisms that could inform broader analyses of financial readiness for innovation parks. However, the specific focus on renewable energy limits its applicability to a broader assessment of innovation park readiness across various sectors.

The literature on science and technology parks in Europe offers valuable insights into their role in regional development and innovation. However, many studies focus on specific regions

or sectors, limiting their applicability to a broader EU context. Furthermore, there is a lack of comprehensive analysis of the financial and R&D infrastructure needed to support innovation parks. Addressing these gaps will be crucial for future research on the preparedness of EU member states for innovation parks, particularly from financial and R&D perspectives.

3. METHODOLOGY

The methodology for this study revolves around assessing the readiness of EU member states to establish and operate innovation parks, using two key indicators: gross domestic expenditure on research and development (GERD) and the share of R&D personnel in the labor force. The data used in this analysis was sourced from Eurostat. Specifically, two databases were employed: Gross domestic expenditure on R&D (GERD): "Purchasing power standard (PPS) per inhabitant at constant 2005 prices" and "Share of R&D personnel and researchers in the total active population and employment by sector of performance and sex: Percentage of population in the labour force in full-time equivalent (FTE)" (Eurostat, 2024a; 2024b).

These databases were selected due to their comprehensive coverage and consistency in reporting across EU member states, making them ideal for cross-country comparison over the 2013-2022 period. Their standardization ensures that the comparisons and clustering performed in the analysis are based on uniform metrics, enhancing the reliability of the results.

To analyze the readiness of these countries for innovation parks, k-means clustering was utilized as the primary statistical method. This method is well-suited for grouping entities based on shared characteristics and has been used in several studies for similar purposes, such as revealing gender equality patterns in ICT education (Tokar et al., 2023a) and examining disparities in tax systems across European countries (Reiff et al., 2016b). Additionally, cluster analysis has proven effective in analyzing economic development and gender equality in EU countries (Tokar et al., 2023b, Vinska and Vinska, 2021; Vinska et al., 2024) and for studying economic trajectories in post-communist nations (Reiff et al., 2016a). These precedents underscore the utility of clustering techniques for identifying underlying patterns in multidimensional datasets.

For this study, k-means clustering allowed the grouping of EU countries based on their GERD and share of R&D personnel. The clustering helped identify groups of countries exhibiting similar trends in R&D investments and workforce allocation, both essential factors for determining their capacity to develop and sustain innovation parks. The approach provided meaningful insights into how countries compare and contrast in terms of their innovation readiness.

Data normalization was necessary prior to clustering, to ensure comparability across the two indicators, GERD and R&D personnel. Normalization adjusts for the differences in the units of measurement between these variables (PPS and percentage of labor force). Without normalization, the results would be biased toward the variable with the larger scale.

The number of clusters (k) was determined using the elbow method. This method identifies the optimal number of clusters by plotting the ratio of variance explained for each potential number of clusters and selecting the "elbow" point, where adding more clusters does not substantially improve the explained variance. In this study, three clusters were chosen based on the elbow method, capturing 92.17% of the variance in the data.

After determining the number of clusters, the k-means clustering algorithm was applied. This algorithm begins by initializing k cluster centers randomly and assigning each country to the nearest center based on the Euclidean distance. The cluster centers are then recalculated as the average of all points within the cluster, and the process repeats until the sum of squared errors (SSE) within the clusters is minimized. The final clusters represent countries with similar patterns in their R&D investments and workforce structure. The free and open-source tools, including R (version 4.2.1) and Python, were used to perform this analysis ensuring that the study's methodology is reproducible by other researchers.

4. RESULTS

Table 1 presents an analysis of gross domestic expenditure on research and development (R&D) in EU member states between 2013 and 2022, expressed in purchasing power standard (PPS) per inhabitant at constant 2005 prices. The data reveals a steady increase in R&D expenditures in most EU member states over the period. This trend highlights the growing recognition of R&D's importance in advancing economic development, particularly as nations aim to stay competitive in the global economy. For instance, countries like Austria and Sweden consistently show high R&D investments, with average expenditures of 977.7 PPS and 1059.7 PPS per inhabitant, respectively. Sweden, in particular, demonstrates a strong upward trend, culminating in the highest 2022 expenditure of 1159.2 PPS, a significant rise from 976.2 PPS in 2013.

The data shows considerable disparities between EU member states in their R&D expenditure. Countries like Bulgaria, Romania, and Latvia exhibit the lowest levels of R&D spending, with Bulgaria averaging only 101.3 PPS per inhabitant, Romania at 58.8 PPS, and Latvia at 103.3 PPS. These figures contrast sharply with the higher spenders like Germany and Sweden, suggesting that wealthier nations with more advanced industrial bases can allocate more resources toward R&D. This disparity may further widen the innovation gap within the EU, potentially impacting long-term economic cohesion.

Some of the emerging economies in the EU, such as Croatia, Cyprus, and Poland, show notable growth in R&D spending. Croatia's expenditure grew from 102.6 PPS in 2013 to 257.1 PPS in 2022, while Poland saw its R&D expenditure rise from 136.1 PPS to 331.6 PPS over the same period. These upward trends highlight the increasing prioritization of R&D in countries striving to enhance their technological capacities and economic competitiveness within the EU.

The table also reveals instances of volatility in R&D spending. For example, Ireland experienced a sharp spike in 2022, reaching

Table 1: Evolution of research and development spending in EU member-states (PPS per inhabitant, 2013-2022, constant 2005 prices)

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Austria	912.1	952.1	942.4	969.2	964.0	993.2	1016.7	965.9	1022.3	1039.7	977.7
Belgium	659.9	679.0	706.3	738.5	790.2	859.2	964.7	975.8	1040.7	1052.3	846.7
Bulgaria	69.0	87.8	110.5	93.5	93.6	99.2	115.6	114.9	113.1	115.6	101.3
Croatia	102.6	99.6	110.4	118.7	123.8	145.2	172.4	182.9	209.1	257.1	152.2
Cyprus	97.3	101.9	99.1	115.3	126.3	149.4	179.7	201.8	210.3	203.8	148.5
Czechia	374.1	398.3	408.9	363.5	402.4	443.6	462.3	447.5	471.3	473.2	424.5
Denmark	831.4	825.3	880.6	911.2	882.3	906.8	910.0	895.3	886.8	935.8	886.5
Estonia	265.3	227.4	237.9	207.7	225.7	258.0	307.2	328.1	354.5	355.2	276.7
Finland	870.9	831.1	759.6	738.8	761.1	776.8	797.6	809.1	852.5	854.8	805.2
France	581.0	579.5	582.8	586.4	591.6	599.4	607.1	580.2	601.1	616.3	592.5
Germany	836.5	864.8	891.5	903.2	957.4	984.9	1012.1	961.8	993.6	1003.8	940.9
Greece	136.4	142.3	164.4	171.4	198.9	213.5	228.8	246.2	258.3	283.7	204.4
Hungary	201.2	204.6	212.2	191.7	224.0	271.0	278.0	287.4	318.8	284.1	247.3
Ireland	484.2	506.3	482.9	487.5	557.1	531.6	577.9	604.9	665.5	1444.4	634.2
Italy	291.8	299.9	302.5	313.5	320.1	336.5	347.7	327.2	337.9	343.6	322.1
Latvia	84.5	97.8	92.0	66.8	81.8	107.2	108.6	121.3	132.5	140.9	103.3
Lithuania	152.3	172.7	179.7	150.4	168.9	185.7	207.1	236.4	244.9	239.7	193.8
Luxembourg	731.7	723.7	743.6	771.5	745.8	700.5	713.0	642.3	645.2	651.4	706.9
Malta	166.6	164.2	181.7	142.8	153.7	165.4	167.2	169.8	192.3	190.9	169.5
Netherlands	695.3	708.1	709.1	722.1	746.8	745.5	771.7	779.5	807.1	826.7	751.2
Poland	136.1	152.1	167.7	166.6	187.8	231.1	264.9	272.0	307.6	331.6	221.8
Portugal	237.6	234.6	231.3	243.9	260.8	274.9	292.3	309.4	338.5	366.5	279.0
Romania	40.1	41.1	54.3	56.2	63.5	66.4	66.5	62.8	67.9	69.2	58.8
Slovakia	148.8	163.2	226.3	157.1	181.0	177.7	179.0	188.6	201.6	220.6	184.4
Slovenia	519.0	491.4	465.8	439.2	427.4	465.5	501.6	500.8	535.2	540.4	488.6
Spain	268.0	265.9	272.0	273.0	285.3	298.7	304.9	302.7	322.1	346.3	293.9
Sweden	976.2	943.8	1011.3	1029.1	1076.3	1068.0	1100.5	1100.7	1131.7	1159.2	1059.7

Source: Elaborated by the authors based on (Eurostat, 2024a)

1444.4 PPS, more than double its 2021 figure of 665.5 PPS. Such fluctuations could indicate external factors influencing budget allocations or sudden shifts in economic strategy, but these deviations from the average could also be temporary and may stabilize over time. Estonia also shows some volatility, with R&D expenditure fluctuating between 207.7 PPS and 355.2 PPS, suggesting inconsistent prioritization of R&D investment.

Austria, Germany, and Sweden stand out as consistent high spenders on R&D. These countries, known for their strong industrial bases and commitment to technological advancement, have maintained high levels of R&D expenditure, which likely contributes to their robust economic performance and innovation capacity. Germany, for example, maintains an average R&D expenditure of 940.9 PPS per inhabitant, indicative of its sustained commitment to research and development.

Table 2 provides data on the share of R&D personnel and researchers as a percentage of the total active population in the labor force (expressed in full-time equivalent, FTE) in EU member states from 2013 to 2022. Certain countries consistently maintain a high percentage of their labor force engaged in R&D activities. Denmark, Finland, and Luxembourg stand out as leading nations in this regard. Denmark exhibits the highest average of 2.14% across the years, indicating a sustained commitment to R&D and innovation. This is closely followed by Finland with 1.98% and Luxembourg with 1.91%. Such high levels of R&D personnel reflect a strong emphasis on fostering technological development and innovation-led economic growth.

Several countries show significant growth in the share of R&D personnel and researchers over time. For example, Belgium's R&D workforce share increased from 1.38% in 2013 to 2.41% in 2022, averaging 1.80% across the period. Similarly, Germany also experienced a steady increase from 1.47% to 1.86%, averaging 1.67%. This growth suggests that these countries are expanding their focus on R&D activities as a cornerstone for future economic competitiveness.

Emerging economies such as Bulgaria and Croatia show notable progress in increasing their R&D workforce. Bulgaria saw an increase from 0.53% in 2013 to 0.91% in 2022, while Croatia's share rose from 0.58% to 0.96% over the same period. Though these figures are lower compared to more developed economies, the upward trend signals an ongoing commitment to building R&D capacity in these countries. This is a promising development, as increased R&D personnel is likely to boost innovation and technology transfer in the long run.

Some countries exhibit volatility in their R&D workforce share. Ireland showed fluctuations over the years, with the percentage of R&D personnel peaking at 1.55% in 2022, after dropping to 1.35% in 2018. Similarly, Italy's R&D workforce increased steadily from 1.01% in 2013 to 1.43% in 2019, but plateaued at 1.38% in 2021 and 2022. Such fluctuations may indicate shifting national priorities or economic pressures affecting R&D investments.

Several EU countries still allocate a relatively small portion of their labor force to R&D activities. Romania consistently records one of the lowest percentages, remaining around 0.40% over the

Table 2: Personnel as a share of the labor force in EU member-states (2013–2022, percentage of active population in full-time equivalent)

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Austria	1.55	1.63	1.65	1.70	1.71	1.79	1.86	1.84	1.94	2.02	1.77
Belgium	1.38	1.48	1.57	1.59	1.67	1.77	1.85	1.92	2.33	2.41	1.80
Bulgaria	0.53	0.59	0.69	0.78	0.71	0.80	0.81	0.82	0.80	0.91	0.74
Croatia	0.58	0.54	0.57	0.64	0.65	0.73	0.82	0.88	0.93	0.96	0.73
Cyprus	0.29	0.30	0.30	0.33	0.37	0.43	0.49	0.51	0.50	0.48	0.40
Czechia	1.19	1.24	1.28	1.26	1.33	1.42	1.51	1.55	1.62	1.68	1.41
Denmark	2.09	2.10	2.15	2.21	2.10	2.07	2.12	2.12	2.11	2.36	2.14
Estonia	0.89	0.89	0.86	0.87	0.91	0.93	0.96	0.97	1.03	1.19	0.95
Finland	2.04	2.01	1.95	1.83	1.88	1.90	1.95	2.04	2.11	2.10	1.98
France	1.42	1.42	1.45	1.47	1.50	1.53	1.57	1.62	1.68	1.67	1.53
Germany	1.47	1.50	1.58	1.59	1.66	1.71	1.76	1.78	1.81	1.86	1.67
Greece	0.88	0.91	1.05	0.88	1.01	1.10	1.16	1.32	1.37	1.50	1.12
Hungary	0.86	0.82	0.80	0.77	0.86	1.16	1.20	1.26	1.29	1.32	1.03
Ireland	1.45	1.52	1.45	1.52	1.48	1.35	1.40	1.50	1.55	1.55	1.48
Italy	1.01	1.01	1.05	1.16	1.27	1.38	1.43	1.43	1.38	1.38	1.25
Latvia	0.55	0.60	0.58	0.54	0.57	0.62	0.64	0.71	0.79	0.76	0.64
Lithuania	0.77	0.82	0.74	0.76	0.82	0.85	0.92	1.00	1.05	1.09	0.88
Luxembourg	1.98	2.01	1.92	1.95	1.94	1.85	1.90	1.86	1.78	1.91	1.91
Malta	0.71	0.73	0.69	0.70	0.68	0.63	0.62	0.69	0.72	0.75	0.69
Netherlands	1.50	1.52	1.55	1.60	1.66	1.71	1.73	1.79	1.85	1.92	1.68
Poland	0.56	0.62	0.65	0.67	0.86	0.98	0.97	1.03	1.07	1.13	0.85
Portugal	0.96	0.96	0.99	1.03	1.12	1.18	1.24	1.36	1.41	1.48	1.17
Romania	0.41	0.39	0.39	0.40	0.40	0.40	0.39	0.41	0.42	0.43	0.40
Slovakia	0.62	0.63	0.63	0.63	0.68	0.73	0.76	0.82	0.83	0.86	0.72
Slovenia	1.55	1.51	1.45	1.48	1.47	1.56	1.69	1.67	1.74	1.72	1.58
Spain	0.88	0.88	0.88	0.91	0.96	1.00	1.01	1.03	1.08	1.13	0.98
Sweden	1.64	1.68	1.67	1.79	1.73	1.77	1.75	1.81	2.18	2.25	1.83

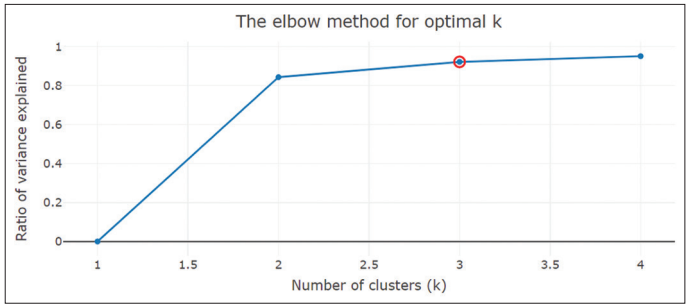
Source: Elaborated by the authors based on (Eurostat, 2024b)

entire period, while Cyprus averages only 0.40% as well. These figures highlight a significant gap in R&D personnel compared to countries like Denmark or Sweden. This disparity might impact these countries' ability to innovate and remain competitive in technology-driven sectors.

The data provided divides EU member states into three distinct clusters based on their gross domestic expenditure on research and development (GERD) and the share of R&D personnel within the labor force. This clustering model, which explains 92.17% of the variance, reveals crucial insights into the varying capacities of these countries to foster innovation, particularly in the context of establishing and operating innovative parks (Figure 1).

Cluster 1, which comprises 15 EU member states, includes countries such as Bulgaria, Croatia, Cyprus, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, and Spain (Table 3). This cluster is characterized by the lowest GERD (197.13) and the lowest share of R&D personnel (0.84% of the labor force). The countries in this cluster face substantial hurdles in terms of their innovation capacity. Low investment in research and development and the limited presence of skilled human capital make it difficult for these countries to create and sustain innovative parks. Without adequate funding and personnel dedicated to research, it becomes challenging to foster a thriving ecosystem that supports technological advancements and commercialization. As a result, countries in Cluster 1 are the least likely to see effective development and operation of innovative parks.

Figure 1: Optimal number of clusters for analysing financial and R&D perspectives for establishing innovative parks in EU member-states



Source: Elaborated by the authors

Cluster 2 includes six countries: Czechia, France, Ireland, Luxembourg, Netherlands, and Slovenia. The cluster center for Cluster 2 reflects a GERD of 599.65 and 1.60% of R&D personnel within the labor force. These countries fall into a middle category in terms of innovation capacity. While they are better positioned than Cluster 1 nations, they still have room to improve their research and development ecosystems. With moderate levels of both R&D expenditure and personnel, Cluster 2 countries are capable of establishing and maintaining innovative parks, though they may not reach the high potential of Cluster 3 nations. Nevertheless, with targeted policy interventions and increased investment in R&D, these countries could significantly enhance their innovation landscapes, allowing them to compete more effectively in the global market.

Cluster 3, which also includes six countries – Austria, Belgium, Denmark, Finland, Germany, and Sweden – stands out as the

Table 3: R&D personnel as a share of the labor force in EU member-states (2013–2022, percentage of active population in full-time equivalent)

Clusters	Cluster centres		EU member-states
	GERD	R&D personnel	
1	197.13	0.84	Bulgaria, Croatia, Cyprus, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Spain
2	599.65	1.60	Czechia, France, Ireland, Luxembourg, Netherlands, Slovenia
3	919.45	1.87	Austria, Belgium, Denmark, Finland, Germany, Sweden

Source: Elaborated by the authors

most promising group for fostering successful innovative parks. The cluster center shows the highest GERD at 919.45 and the highest share of R&D personnel at 1.87% of the labor force. These countries are well-positioned to lead in technological innovation, with both the financial resources and human capital necessary to support dynamic and effective innovative parks. Their strong investment in research and development, combined with a highly skilled workforce, creates an environment conducive to technological innovation, entrepreneurship, and collaboration between universities, industries, and research institutions. The strategic commitment of these countries to maintaining a robust innovation ecosystem allows them to stay at the forefront of technological advancements, making them ideal locations for the successful implementation of innovative parks.

5. DISCUSSION

The results of this study align with and, in some cases, build upon the findings of previous research on the role of innovation parks, science and technology parks (STPs), and R&D investment in fostering economic growth and innovation. By comparing the readiness of EU member states to establish and sustain innovation parks through an analysis of gross domestic expenditure on research and development (GERD) and the proportion of R&D personnel, this study confirms some established conclusions while offering new insights into the disparities among EU countries.

Squicciarini's research on Finland's science parks highlights the positive impact of co-location on firms' innovative outputs through knowledge spillovers (Squicciarini, 2009). This study supports Squicciarini's conclusions by showing that the countries in Cluster 3 (Austria, Belgium, Denmark, Finland, Germany, and Sweden) have the strongest potential for innovation park success due to their high levels of R&D investment and workforce. The results here echo the idea that well-developed ecosystems with significant GERD and R&D personnel support innovation outcomes. However, while Squicciarini focuses on patent activity as the key indicator of innovation, this study highlights that financial capacity and human capital are equally crucial in determining the overall readiness for innovation parks, extending Squicciarini's findings to a broader EU context.

Nauwelaers, Kleibrink, and Stancova discuss the strategic role of STPs in fostering regional development through smart specialization strategies (Nauwelaers et al., 2014). The current study confirms their assertion that STPs are key players in regional innovation ecosystems. The countries in Cluster 3, characterized by strong financial and human capital, demonstrate an environment conducive to such strategies. However, where this study departs from Nauwelaers et al. is in the emphasis on the need for significant R&D capabilities and financial infrastructure to make smart specialization strategies work effectively. The present research goes beyond simply identifying STPs as important stakeholders and shows that without robust GERD and skilled R&D personnel, these parks are unlikely to drive innovation or contribute to regional development. This discrepancy suggests that Nauwelaers et al. may underplay the importance of financial readiness in the success of innovation parks.

Vásquez-Urriago, Barge-Gil, and Modrego Rico focus on the firm-level benefits of STPs, particularly for smaller firms with limited internal innovation capacity (Vásquez-Urriago et al., 2014). This study's findings support their conclusion that innovation parks can provide significant benefits, especially to smaller firms. Countries in Cluster 3 are well-positioned to offer such benefits due to their advanced innovation ecosystems. However, this study expands the scope of Vásquez-Urriago et al.'s research by emphasizing that a country's overall financial and R&D readiness is essential for the success of STPs, not just at the firm level. The broader financial and R&D infrastructure must be in place to support both small and large firms, a point that Vásquez-Urriago et al. do not fully explore.

Similarly, Machado, Lazzarotti, and Bencke emphasize the importance of collaboration among various stakeholders in technological parks, using the Triple, Quadruple, and Quintuple Helix models (Machado et al., 2018). This study confirms their conclusion by showing that the countries in Cluster 3, with their strong R&D investment and high levels of R&D personnel, are well-suited to foster such collaborations. The financial and human capital readiness of these countries supports the dynamic interactions necessary for innovation. However, while Machado et al. focus on the collaboration models within parks, this study stresses the importance of the broader financial and R&D infrastructure that underpins these collaborations. Without the right financial and human capital, even the most collaborative models are unlikely to succeed. This adds a financial and structural dimension to their collaboration-focused approach.

Gorączkowska's research on innovation parks in Poland's Silesian and Pomeranian regions highlights that innovation parks are more effective in highly developed areas (Gorączkowska, 2015). This study concurs with her findings, particularly in its analysis of Cluster 3 countries, which are the most economically advanced in the EU and best positioned to support innovation parks. However, while Gorączkowska focuses on regional disparities, this study expands the discussion to include national-level differences across the EU. It shows that without adequate R&D investment and personnel, innovation parks are less likely to succeed in less developed countries and regions, reinforcing the need for a strong financial and human capital base.

Gursel underscores the importance of university collaboration in the success of STPs (Gursel, 2014). This study confirms Gursel's emphasis on the role of universities, particularly in Cluster 3 countries, where the high level of R&D personnel often correlates with strong academic institutions that foster innovation. However, Gursel's research does not address the broader financial and policy frameworks necessary for STPs to thrive. This study adds to Gursel's work by showing that financial and human capital readiness is just as critical as university collaboration in ensuring the success of innovation parks.

Finally, Luby, Chodák, and Lubyová's comparison of innovation processes between the EU and the U.S. finds that Central and Eastern European countries lag behind innovation leaders like Germany and Finland (Luby et al., 2013). This study agrees with their findings, especially as it pertains to countries in Cluster 1, such as Bulgaria, Romania, and Latvia, which have lower R&D investment and personnel and thus struggle to develop innovation parks. This study further confirms their conclusion by showing that the disparity in R&D investment is a key factor that widens the innovation gap between Eastern and Western Europe. However, unlike Luby et al., who emphasize technology transfer mechanisms, this study stresses the importance of financial readiness and R&D capacity as prerequisites for innovation park success.

While this study provides a comprehensive analysis of the readiness of EU member states to establish innovation parks, several limitations must be acknowledged. Firstly, it focuses exclusively on GERD and R&D personnel as key indicators, without incorporating other factors such as government policies, venture capital availability, or regional economic development strategies. Future research could integrate these factors to provide a more holistic understanding of innovation park readiness.

Secondly, the study does not differentiate between sectors or types of innovation parks, such as science parks, technology parks, or industry-specific parks. Different types of parks may require different levels of investment and R&D support, and future studies could explore these distinctions to provide more nuanced policy recommendations.

Lastly, the study does not include a detailed analysis of gender or sectoral disparities within the R&D workforce, which could offer additional insights into the effectiveness of R&D investments. Further research on these aspects could help to identify gaps in representation and utilization of human capital within innovation ecosystems.

6. CONCLUSION

The analysis of gross domestic expenditure on research and development (GERD) and the proportion of R&D personnel in EU member states from 2013 to 2022 provides valuable insights into the readiness of these countries to establish and operate innovative parks. The data reveals significant disparities in R&D investment and workforce allocation across the EU, with wealthier nations showing stronger commitments to R&D compared to emerging economies. This variation in R&D spending and personnel directly influences the potential for successful innovation-driven initiatives like innovative parks.

Countries in Cluster 3, which includes Austria, Belgium, Denmark, Finland, Germany, and Sweden, demonstrate the strongest potential for establishing effective innovative parks. These nations exhibit the highest levels of GERD, averaging 919.45 PPS per inhabitant, and have a larger share of R&D personnel in their labor force, with an average of 1.87%. The combination of high financial investment in research and a skilled workforce creates a conducive environment for innovation. These countries have well-developed ecosystems that foster collaboration between research institutions, universities, and industries, which are essential for the successful operation of innovative parks. Their continued commitment to maintaining robust R&D funding and personnel suggests that they will remain leaders in technological advancements and innovation in the EU.

In contrast, Cluster 1, comprising 15 countries such as Bulgaria, Croatia, Cyprus, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, and Spain, faces significant challenges in fostering innovation. With a low average GERD of 197.13 PPS per inhabitant and only 0.84% of the labor force engaged in R&D, these countries are at a disadvantage when it comes to developing and sustaining innovative parks. The lack of financial resources and limited human capital dedicated to R&D undermines their ability to create a thriving innovation ecosystem. Without targeted interventions to increase R&D funding and develop human capital, these countries are unlikely to see the same level of success in innovation-driven initiatives as their Cluster 3 counterparts.

Cluster 2, which includes Czechia, France, Ireland, Luxembourg, Netherlands, and Slovenia, occupies a middle ground in terms of innovation capacity. These countries have moderate levels of GERD, averaging 599.65 PPS per inhabitant, and an R&D workforce that constitutes 1.60% of their labor force. While they are better positioned than Cluster 1 countries, they still fall short of the innovation potential seen in Cluster 3. However, with increased R&D investment and strategic policy interventions, Cluster 2 countries could enhance their innovation ecosystems, making them competitive in the global innovation landscape.

Future research should explore the factors influencing the disparities in R&D investment and workforce allocation across the EU. Specifically, studies could examine the role of government policies, economic structures, and educational systems in shaping a country's capacity for innovation. Additionally, research could focus on identifying the barriers preventing countries in Cluster 1 from increasing their R&D investments and improving their innovation ecosystems. Another potential area of study could involve a deeper analysis of the collaboration between the public and private sectors in fostering innovation, particularly in countries with moderate to high R&D spending. Lastly, investigating the long-term impact of innovative parks on economic growth and technological advancement in countries from all three clusters would provide valuable insights into the effectiveness of such initiatives in the EU.

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