EVALUATION OF THE INNOVATION POTENTIAL OF OECD COUNTRIES: A CLUSTER ANALYSIS AND STRATEGIC RECOMMENDATIONS

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ABSTRACT

This study examines the role of innovation in promoting global progress, particularly in OECD countries. Innovations, crucial for productivity and competitiveness, are explored alongside their connection to knowledge production and integration. In contrast to prior studies employing Data Envelopment Analysis (DEA), this research utilizes the Fuzzy C-Means (FCM) method to analyze the innovation potential in products and services across the member nations of the Organization for Economic Cooperation and Development (OECD). Objectives include evaluating innovation potential using the Global Innovation Index (GII), conducting cluster analysis, and developing strategic recommendations for countries emerging as potential innovation leaders. By addressing gaps in existing literature, this research aims to provide insights into innovation dynamics and inform policy decisions, contributing to economic and social advancement.

KEYWORDS: Fuzzy C-Means (FCM), Global Innovation Index (GII), Innovation Potential, Organization for Economic Cooperation and Development (OECD).

1. INTRODUCTION

Since the Industrial Revolution, innovations have played a fundamental role in driving global well-being, facilitating significant scientific and technological progress. They are widely recognized as crucial drivers of productivity, competitiveness, and employment across various sectors, from individuals to organizations, regions, and nations. Abrunhosa (2003) emphasized the intimate connection between innovations and knowledge, highlighting the importance of knowledge production, transmission, absorption, and integration in shaping innovation processes and, consequently, corporate and national trajectories.

In recent times, an increasing number of nations have focused on fostering environments conducive to innovation, aiming to gain competitive advantages in a rapidly evolving and complex economic scenario. This acknowledgment highlights

innovation as a crucial driver of economic growth, global competitiveness, and sustainable development. In this context, the Organization for Economic Co-operation and Development (OECD) plays a key role in influencing the innovation strategies of its member nations. It offers guidance and suggestions aimed at augmenting their innovative capabilities and technological progress (OECD, 2024).

In accordance with the guidelines set forth in the Oslo Manual, innovation covers the creation of novel products or processes, enhancements in marketing approaches, improvements in organizational structures, and strategies for external relations (OECD and Eurostat, 2005). This multifaceted concept includes efforts in the fields of science, technology, organization, finance, and commerce, all of which are crucial for fostering economic growth, competitiveness, and social advancement. It is worth noting that Işık and Kılınç (2011) highlighted the significant contribution of innovation to economic growth, especially in developed nations, where it accounts for over 50% of growth over the last quarter-century.

While many studies have investigated the performance and efficiency of innovation systems in OECD countries using Data Envelopment Analysis (DEA) (Chen et al., 2011; Murat, 2020), the present study aims to utilize the Fuzzy C-Means (FCM) method to analyze the innovation potential in products and services of OECD countries, along with providing a set of recommendations for the analyzed country clusters. Despite the widespread recognition of the importance of innovation, there is still a lack of comprehensive analysis identifying and evaluating the specific innovation potential of each country, especially concerning regional differences. As noted by Chen et al. (2011), although many OECD countries demonstrate a strong commitment to innovation, innovation capacity varies significantly among countries.

Due to the significant importance of innovation, evaluating innovation performance plays a crucial role in gauging national growth and well-being. Various organizations, such as the World Economic Forum (WEF) and the International Institute for Management Development (IMD), alongside academic and research institutions, create comprehensive indices to evaluate scientific, technological, and innovation capabilities. These indices, exemplified by the Global Innovation Index (GII), provide invaluable insights into a nation's innovation potential, guiding the formulation of policies and allocation of resources to promote sustained growth in productivity and competitiveness (Hollanders et al., 2019).

In this study, we seek to bridge the existing gap in the literature by conducting a detailed analysis and providing recommendations. Our main goal is to assess the potential for innovation in products and services among OECD countries. To accomplish this, we will outline the following specific objectives:

- Utilize the Global Innovation Index (GII) indicator for 2023 to assess the potential for innovation in products and services of OECD countries.
- Conduct a cluster analysis using the Fuzzy C-Means (FCM) method to group OECD countries based on their innovation potential patterns.
- Develop strategic recommendations for each country cluster, considering their specific characteristics and strengths in terms of innovation.
- Identify countries emerging from the analysis as potential leaders in innovation in products and services, as well as countries average and below average in terms of innovation potential.
- Formulate a comprehensive strategy, comprising a set of specific recommendations, for OECD countries to implement in the future to enhance their innovation potential in products and services.

Upon completion of this study, it is expected not only to gain a deeper understanding of the current state of innovation in OECD countries but also to provide valuable insights to guide innovation policies and strategies in the future, thereby contributing to the economic and social advancement of these countries and the global community as a whole.

2. LITERATURE REVIEW

2.1. ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD)

The Organization for Economic Cooperation and Development (OECD) serves as an international entity committed to developing improved policies for societal welfare. The primary aim is to develop policies that promote prosperity, equality, opportunities, and the overall welfare of all individuals. Leveraging 60 years of accumulated experience and insights, the OECD endeavors to better prepare the global community for the challenges of the future (OECD, 2024).

According to the OECD (2024), the operational approach of this organization comprises various facets. In its role of informing and advising, the organization serves as one of the world's largest and most reliable sources of comparative

socio-economic data and analysis, facilitating informed decision-making. Additionally, it seeks to engage and influence, promoting collaboration among policymakers and influencers for the exchange of ideas, shared experiences, and progress in various policy areas. Peers from different backgrounds gather to inspire one another. The OECD also plays a fundamental role in setting standards and providing policy support. It encourages nations and other stakeholders to develop international standards, promoting a shared commitment to uniform regulations and encouraging cooperation to achieve common objectives.

Among the countries that are part of this organization are: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom, and United States.

Initially established as the Organization for European Economic Co-operation (OEEC) post-World War II, the transformation into the OECD occurred in 1961, signifying a commitment to resilient, inclusive, and sustainable growth worldwide. Through evidence-based policy analysis and active collaboration with global policy networks, including the G7 and G20, the OECD has contributed significantly to advancing reforms and addressing global challenges in areas such as education, tax transparency, and artificial intelligence (OECD, 2024).

2.2. PRODUCT AND SERVICE INNOVATION

Product and service innovation encompasses the development of new or significantly improved products, services, or processes within an organization, leading to increased value for the company and its customers (Wagner, 2008; Huang, 2021; Godenhjelm & Johanson, 2016). In the context of service innovation, it is essential to note that the terms "service product innovations" and "product innovations" are often used interchangeably to describe a specific set of innovations in service companies (Oke, 2007). Service innovation can be categorized into radical innovations, including major innovations and new services for the markets being served, and additional innovations, such as service improvements and style changes (Lussak et al., 2020). Furthermore, the interaction between product and service innovation is crucial and should be part of the new service development framework

in manufacturing companies (Gebauer et al., 2008). It is also important to emphasize that service innovation is customer-oriented, aiming to provide customers with new products or services through a customer-centric service innovation process (Zhao & Ma, 2017).

Innovation in products and services has emerged as a key component in the contemporary business landscape, driving the growth and competitiveness of organizations. Various studies and research have explored emerging trends in this crucial sector, reflecting a constant quest for new approaches and practices.

A noteworthy aspect of recent trends in product and service innovation is the growing emphasis on customer-centric approaches. As highlighted by Pine and Gilmore (2008), personalization and the creation of unique experiences for consumers have become crucial elements in product and service differentiation. This perspective is reinforced by Vargo and Lusch (2008), who propose the concept of "service-dominant logic," emphasizing the importance of value co-creation with customers. In line with Von Hippel (2005), involving consumers in the development of new products and services not only results in solutions more aligned with their needs but also strengthens customer engagement and loyalty.

Furthermore, the literature points to the increasing importance of business model innovation as an integral part of service and product innovation to achieve global competitiveness (Calia, Guerrini & Moura, 2007). The reinvention of traditional models and the introduction of disruptive new models have been strategies adopted by visionary companies to stand out in competitive markets. As emphasized by Chesbrough (2010), different business models can yield different outcomes for the same technology introduced to the market.

Another significant trend is the integration of emerging technologies, such as artificial intelligence, the Internet of Things (IoT), and machine learning, in the design of new products and services. As noted by Kusiak (2018), the strategic integration of these technologies can result in smarter, connected products that align with the expectations of modern consumers. Thus, these technologies not only offer benefits in terms of operational efficiency but also promote innovation in creating more personalized and adaptable experiences, shaping market expectations, and driving business competitiveness.

The dynamic interplay between productivity, quality, and innovation in the service sector is also a relevant theme (Parasuraman, 2010). The service

productivity approach, incorporating perspectives from both the company and the customer, has proven crucial for understanding the impact of innovations on overall outcomes.

In conclusion, the new trends in product and service innovation reflect a constant evolution driven by the pursuit of customer-centric experiences, the integration of emerging technologies, and the reinvention of business models. These changes shape a dynamic and challenging landscape for organizations, underscoring the importance of remaining agile and adaptable to thrive in an ever-transforming business environment.

2.3. INNOVATION POTENTIAL OF COUNTRIES

Chen et al. (2011) conducted a comparative analysis of R&D efficiencies among nations using a 24-nation panel series spanning the period from 1998 to 2005. The study included both OECD members and non-OECD members and developed several R&D efficiency indices based on Data Envelopment Analysis (DEA). The input variables considered were total R&D manpower and expenditures, while the output variables included patents, scientific journal articles, royalty, and licensing fees.

The research outcomes indicated that nations showed comparable R&D efficiencies in patents and royalties, while their performances varied notably in journal publications. Additionally, the average R&D efficiency in OECD nations exceeded that of non-OECD nations by a considerable margin. Among the countries studied, Hungary, Israel, the UK, and the US were identified as having optimal R&D efficiency across multiple indices. Conversely, Romania, Russia, and Mexico consistently ranked lowest in each R&D efficiency index assessed (Chen et al., 2011).

Murat (2020) conducted research with the objective of assessing the innovation performance of OECD member nations utilizing Data Envelopment Analysis (DEA). The study utilized variables from the innovation input and output indices specified in the Global Innovation Index (GII) specifically designed for OECD countries. The results of the analysis indicated that Switzerland, the United Kingdom (UK), and the United States of America (USA) achieved the highest efficiency scores, while Colombia, Mexico, and Chile obtained the lowest efficiency scores among the OECD countries studied.

Belazreg and Mtar (2020) employed a panel vector autoregressive model to investigate the interactions among trade openness, innovation, financial development, and economic growth in 27 OECD countries from 2001 to 2016. The study focused on the four-way linkage between these variables. The empirical findings indicated a neutral relationship between economic growth and innovation, between innovation and financial development, and between innovation and trade. Similarly, a unidirectional relationship was found between economic growth and financial development, as well as between financial development and trade. Finally, a bidirectional relationship was observed between economic growth and trade.

Ulku's (2007) research utilizes data from 41 OECD and non-OECD (Organization for Economic Cooperation and Development) countries to examine the predictions of scale-free endogenous growth theories. These theories suggest that an increase in the proportion of researchers in the workforce leads to innovation and that innovation, in turn, increases per capita production. The findings reveal that an increase in the proportion of researchers in the workforce only enhances innovation in OECD countries with large markets. Moreover, innovation boosts GDP per worker in all non-OECD countries except low-income ones, while it increases only in high-income OECD countries. These conclusions imply that while large-market OECD countries lead in innovation globally, non-OECD countries benefit more from it in promoting their growth.

3. METHODOLOGY

No current study, analysis encompassed the participation of 38 OECD member states, namely: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom, and United States.

The data from the OECD GII 2023 report was used for the analysis, and the Fuzzy C-Means method was applied. The Global Innovation Index (GII) is a ranking that assesses the performance of countries in terms of innovation across various sectors and comprises 7 primary indices, namely: Institutions, Human Capital and Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge and Technology Outputs, and Creative Outputs. These indices are accompanied by

21 sub-indices. Specific details regarding these indices are delineated in Table 1, with comprehensive insights into the overarching GII framework and its sub-indices provided subsequently (WIPO, 2023).

Table 1. Index of Global Innovation

Input/Output	Index of Global Innovation	Sub-indices
Innovation Input Sub-Index	**Business Sophistication (BS)**	Knowledge workers
		Innovation linkages
		Knowledge absorption
	Human Capital and Research (HCR)	Education
		Tertiary education
		Research and development (R&D)
	Infrastructure (INF)	Information and communication technologies (ICTs)
		General infrastructure
		Ecological sustainability
	Institutions (INS)	Institutional environment
		Regulatory environment
		Business environment
	Market Sophistication (MS)	Credit
		Investment
		Trade, diversification, and market scale
Innovation Output Sub-Index	**Creative Outputs (CO)**	Intangible assets
		Creative goods and services
		Online creativity
	Knowledge and Technology Outputs	Knowledge creation
		Knowledge impact
		Knowledge diffusion

Source: Global Innovation Index Database, WIPO, 2023

According to WIPO (2023), the GII 2023 highlighted the innovative performance of 132 countries and the top 100 science and technology clusters worldwide. The report pointed out two innovation trends: one focused on digital innovation with artificial intelligence, supercomputing, and automation, and the other on advanced scientific innovation with biotechnology and nanotechnology. The 7 primary indices are better described below:

Business sophistication: assesses the sophistication and level of development of businesses in a country, including the presence of knowledge workers in knowledge-intensive jobs, formal training offerings by companies, R&D investment by companies, collaboration in R&D between universities and industries, industrial cluster development, foreign company R&D funding, joint venture/strategic alliance agreements, and knowledge protection and absorption through intellectual property payments and high-tech imports.

Human Capital and research: assesses the quality and investment in education, including government spending, expected years of schooling, performance in standardized tests, student-teacher ratio, tertiary enrollment, science and engineering graduates, international student mobility, research and development (R&D), and R&D investment by global enterprises.

Infrastructure: assesses the quality and availability of infrastructure in a country, including access and use of information and communication technologies (ICTs), government online services, e-participation, electricity production, logistical performance, gross capital formation, and ecological sustainability.

Institutions: can be described as a comprehensive assessment of a country's institutional environment, encompassing operational stability for businesses, government effectiveness, regulatory quality, rule of law, and business environment in terms of policies and entrepreneurial culture.

Market sophistication: evaluates the sophistication and development of markets in a country, including available credit for startups and growing companies, domestic credit to the private sector, microfinance institution loans, market capitalization, venture capital investment, national industry diversification, domestic market scale, and trade tariffs applied.

Creative outputs: measures the production and value of intangible assets, including intangible asset intensity in top-value companies, trademark registrations, global brand values, industrial designs, cultural and creative services exports,

national film production, entertainment and media market, creative goods exports, top-level generic internet domains, country-code internet domains, and mobile app development activity. These indicators reflect the creativity and innovation present in the economy, as well as the impact of these assets and activities on trade and culture.

Knowledge and technology outputs: measures the production and impact of knowledge and technology in a country, including knowledge creation through patents, scientific papers, and H-index, knowledge impact on labor productivity, unicorn value (startups valued at over US$1 billion), software spending, high-tech production, intellectual property revenues, production and export complexity, high-tech exports, ICT service exports, ISO 9001 certifications, and other indicators related to knowledge and technology dissemination and impact.

In addition, comprehending the advanced data analysis techniques that support these evaluations is crucial when assessing the innovative performance of countries and technological clusters highlighted by the GII 2023. Fuzzy clustering emerges as a robust approach for unsupervised data analysis and model creation in this context.

Fuzzy clustering stands out as a technique in the realm of unsupervised data analysis and model creation. Unlike traditional hard clustering methods, it offers a more nuanced approach by allowing objects at class boundaries to exhibit partial membership, denoted by membership degrees ranging from 0 to 1. One of the most commonly employed algorithms in this domain is Fuzzy C-Means (FCM), which utilizes fuzzy partitioning to assign data points to multiple clusters with varying membership grades (Suganya & Shanthi, 2012).

According to Suganya and Shanthi (2012), the FCM algorithm operates by evaluating the distance between each data point and cluster center, assigning higher membership to data points closer to the respective cluster center. It ensures that the sum of memberships for each data point remains equal to one, maintaining the integrity of the clustering process. After each iteration, the algorithm updates both the membership values and cluster centers based on predefined formulas, refining the clustering accuracy and representation of the data.

In conclusion, the utilization of fuzzy clustering techniques, particularly Fuzzy C-Means (FCM), has proven highly effective in handling complex datasets with overlapping boundaries and varying degrees of membership. By incorporating partial

membership degrees and iterative updates of cluster centers, FCM ensures a robust and accurate clustering process that adapts well to diverse data structures, making it a valuable tool for unsupervised data analysis and model creation across various domains.

4. RESULTS AND DISCUSSIONS

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5. CONCLUSION

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