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Human Capital and Innovation in Developed and Developing Countries: A Systematic Literature Review Using Methodi Ordinatio and HyperSoft Sets

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Abstract. This article aims to analyze the influence of human capital on innovation. To achieve this, the Methodi Ordinatio methodology was used. The search for scientific articles was done using the Scopus and Web of Science databases. Only documents published between 2013 and 2023 were selected. The systematic review of the literature shows that human capital is relevant in promoting innovation in any type of economy; however, the impact may vary depending on the economic and regional context being studied. The data obtained are analyzed with the help of the hybridization of the Methodi Ordinatio with the HyperSoft Sets theory. In this way, the search is more flexible, because it allows to automatically represent complex combinations of keywords to find patterns of knowledge from the scientific literature on the subject.

Keywords: Human capital, innovation, Methodi Ordinatio, Soft Set, HyperSoft Set.

1 Introduction

In today's business environment, the ability to innovate has become a relevant factor for the success of any organization. Likewise, innovation, which is defined as the incorporation of new products, services, and processes, also allows organizations to endure over time.

During the industrial era, land, buildings, and property were of greater importance to companies, as their fixed assets and natural resources were considered their main source of wealth. However, in recent years a knowledge-based economy known as the post-capitalist society has emerged. In this emerging society, the value of knowledge has surpassed that of traditional elements such as physical capital, land, or labor.

These changes in the economy are more common in developed countries because they have the tools necessary to move from an industrial economy to a knowledge-based one. Thus, human capital, which includes knowledge, skills, creativity, and health, has become one of the most valuable intangible assets in organizations.

This systematic literature review seeks to understand how human capital influences innovation, therefore the following research question is established: How does human capital influence innovation processes in different economic and regional contexts?

To answer this question, a systematic literature review is carried out that will address the relationship between human capital and innovation in various countries and sectors. The main characteristics, trends, limitations, and challenges in this field of study will also be identified. Therefore, the analysis of this relationship will provide valuable information for companies, governments, and academics interested in understanding the behavior of this phenomenon.

The methodology known as Methodi Ordinatio is based on an equation to rank papers according to their scientific relevance. Some bibliometric indicators are used for this purpose. We believe that this methodology can be reinforced by using the theory of Soft Set extensions defined by Professor F. Smarandache [1-4].

The HyperSoft Sets, SuperHyperSoft Sets, and Fuzzy_Extension SuperHyperSoft Sets extend Soft Sets to a parametric function with domain in more than one set of parameters, their power sets, and even associated fuzzy truth values or some of their extensions [1-6].

Specifically, we adapted some components of HyperSoft Sets to model the bibliometric study linked to the Methodi Ordinatio [7-16]. This connection reaffirms the usefulness of these tools that emerged in the field of Neutrosophy, which allows for the modeling of complex real-world situations, where multiple dimensions are not always structured. By studying the relationship between words, knowledge is obtained, especially the relationship that exists between human capital and innovation.

To achieve this objective, the article is divided into a section called Preliminaries where the basic notions of the Methodi Ordinatio methodology are presented, as well as Soft Sets, HyperSoft Sets, SuperHyperSoft Sets, and Fuzzy_Extension SuperHyperSoft Sets. The article continues with a section showing the results of the study, based on the theories and methodologies presented in the previous section. The last section is the Conclusion.

2 Preliminaries

This section contains the basic notions of the theories and concepts that we use in this study.

2.1 Methodi Ordinatio

This systematic literature review article uses the methodology called Methodi Ordinatio, which takes into account factors such as number of citations, year of publication of the articles, and impact factor (IF) to classify the documents according to the scores obtained by the equation. In addition, a descriptive-qualitative research approach is adopted. Thus, a systematic review is a synthesis of the available evidence on a particular topic, taking into consideration quantitative and qualitative aspects of the selected studies to summarize the existing information. On the other hand, descriptive-qualitative studies comprise an important methodological approach, especially when we wish to directly describe the phenomena to be studied.

The first figure summarizes the phases of this methodology, which are described below, in Figure 1.

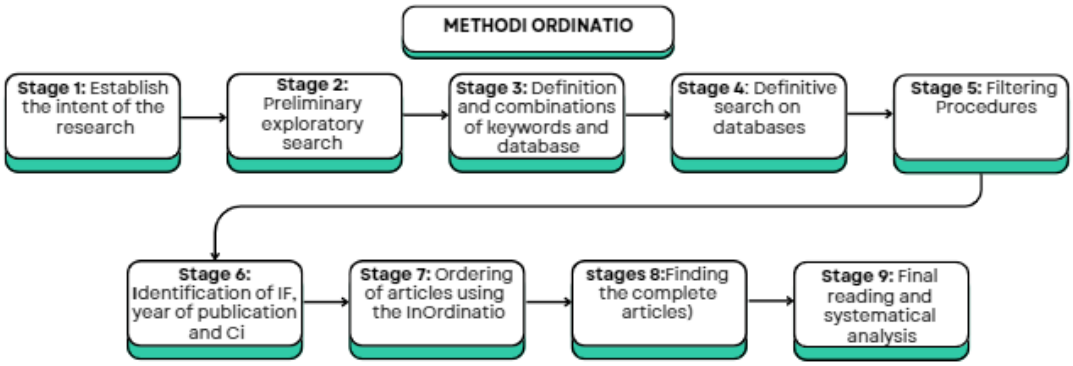

Figure 1: Phases of Methodi Ordinatio.

Phase 1. Establish the intention to investigate.

Phase 2. Preliminary exploratory research with keywords in databases.

Phase 3. Definition and combination of keywords and databases.

Phase 4. Final search of the databases: The final search is carried out in important databases such as Web of Science (WoS) and Scopus. For this step, descriptors and Boolean operators such as "AND", and "OR", among others, are included.

Phase 5. Information filtering procedure.

Phase 6. Identification of the impact factor, year, and number of citations.

Step 7. Classifying documents using the *InOrdinatio* equation: In this step, the *InOrdinatio* value is calculated for the found items, in Equation 1.

$$InOrdinatio = \left(\frac{IF}{1000}\right) + \propto * [10 - (ResearchYear - PublishYear)] + (\sum C_i) \qquad (1)$$

Where:

IF = Impact Factor (JCR, SJR).

$\propto$ = coefficient (1 to 10) Importance value of the year of the article.

Research Year = Year in which the research was conducted.

PublishYear = Year of publication of the article.

$\sum C_i$ =Total number of citations.

Phase 8. Search for complete documents, reading, and systematic analysis of the documents.

2.2 Soft Sets and their Extensions

This subsection is dedicated to explaining the basic notions of Soft Sets, HyperSoft Sets, SuperHyperSoft Sets, and Fuzzy_Extension SuperHyperSoft Sets.

Definition 1 ([1, 17]). Given U is the initial universe set and E is the set of parameters. A pair (F, E) is called a *Soft Set* (over U) if and only if F is a mapping of E into the set of all subsets of U.

That is to say, having a set E of parameters and fixing a parameter $\varepsilon \in E$, then $F(\varepsilon) \in \mathcal{P}(U)$, where $\mathcal{P}(U)$

denotes the power set of U and $F(\varepsilon)$ is considered the set of ε-elements of the Soft Set (F, E) or the set of ε-approximate elements of the Soft Set.

It is not difficult to realize that fuzzy sets are soft sets, this is a consequence of the α-levels definition of a membership function μ_A where we have the following:

$F(\alpha) = \{x \in U \mid \mu_A(x) \geq \alpha\}$, $\alpha \in [0, 1]$. Thus, if we know the family F, then we can reconstruct the function μ_A by using the following formula:

$$\mu_A(x) = \sup_{\substack{\alpha \in [0,1] \\ x \in F(\alpha)}} \alpha$$

Thus, a fuzzy set is a $(F, [0, 1])$ soft set.

Given a binary operation * for subsets of the set U, where (F, A) and (G, B) are soft sets over U. Then, the operation * for soft sets is defined as follows:

$(F, A) * (G, B) = (J, A \times B)$, where $J(\alpha, \beta) = F(\alpha) * G(\beta)$; $\alpha \in A$, $\beta \in B$, and $A \times B$ is the Cartesian product of the sets A and B.

Definition 2 ([5, 6, 17]). Let U be a universe set, $\mathcal{P}(U)$ the power set of U. Let $a_1, a_2, \ldots, a_n$, for $n \geq 1$, be n distinct attributes, whose corresponding attribute values are respectively the sets $A_1, A_2, \ldots, A_n$, with $A_i \cap A_j = \emptyset$, for $i \neq j$, and $i, j \in \{1, 2, \ldots, n\}$. Then the pair $(F, A_1 \times A_2 \times \ldots \times A_n)$, where: $F: A_1 \times A_2 \times \ldots \times A_n \to \mathcal{P}(U)$ is called a *HyperSoft Set* over U.

Definition 3 ([5, 6, 17]). Let U be a universe set, $\mathcal{P}(U)$ the power set of U. Let $a_1, a_2, \ldots, a_n$, for $n \geq 1$, be n distinct attributes, whose corresponding attribute values are respectively the sets $A_1, A_2, \ldots, A_n$, with $A_i \cap A_j = \emptyset$, for $i \neq j$, and $i, j \in \{1, 2, \ldots, n\}$. Then the pair $(F, \mathcal{P}(A_1) \times \mathcal{P}(A_2) \times \ldots \times \mathcal{P}(A_n))$, where:

$F: \mathcal{P}(A_1) \times \mathcal{P}(A_2) \times \ldots \times \mathcal{P}(A_n) \to \mathcal{P}(U)$ is called a *SuperHyperSoft Set* over U.

Definition 4 ([5, 6, 17]). Let U be a universe set, $\mathcal{P}(U)$ the power set of U. Let $a_1, a_2, \ldots, a_n$, for $n \geq 1$, be n distinct attributes, whose corresponding attribute values are respectively the sets $A_1, A_2, \ldots, A_n$, with $A_i \cap A_j = \emptyset$, for $i \neq j$, and $i, j \in \{1, 2, \ldots, n\}$. Then the pair $(F, \mathcal{P}(A_1) \times \mathcal{P}(A_2) \times \ldots \times \mathcal{P}(A_n))$, where:

$F: \mathcal{P}(A_1) \times \mathcal{P}(A_2) \times \ldots \times \mathcal{P}(A_n) \to \mathcal{P}\left(U\left(x(d^0)\right)\right)$ is called a *Fuzzy_Extension SuperHyperSoft Set* over U.

Where $x(d^0)$ is the fuzzy or any fuzzy extension degree of appurtenance of the element x to the set U. Fuzzy extension means Fuzzy Set or Intuitionistic Fuzzy Set, Pythagorean Fuzzy Set, Fermatean Fuzzy Set, Neutrosophic Fuzzy Set, Plithogenic Fuzzy Set, etc.

3 Results

The model used in the study contains combinations of elements with different linguistic meanings. An automatic search for words and combinations of words is required to find patterns that allow evaluating the relationship between the concepts studied, specifically "human capital" and " innovation" in both developed and developing countries.

Here the universe U is the set of papers published in the most important databases; these are the Web of Science (WoS) and Scopus. Of these articles, we are interested in the journal's impact factor and the number of citations of the article.

On the other hand, the set of parameters is given by the keywords to be searched. That is, in general, we are going to determine a set of parametric functions:

$F = \{F_1, F_2, \cdots, F_n\}$, $i = 1, 2, \ldots, n$ such that F_i: $A_{i1} \times \ldots \times A_{im_i} \to \mathcal{P}(U)$, where $m_i \in \mathbb{Z}_*^+$ or the set of positive integers. A_{i1} is a set of specific keywords, for example, $F_1(\text{"}Human\text{"}, \text{"}Capital\text{"}) \in \mathcal{P}(U)$ is the set of articles found that have as keywords the combination "Human Capital". Of these articles, we are interested in their relevance, which is measured by the *InOrdinatio* that appears in Equation 1. In this way, the Methodi Ordinatio is hybridized with Smarandache's theory of HyperSoft Sets.

Within each function, F_i: $A_{i1} \times \ldots \times A_{im_i} \to \mathcal{P}(U)$ the articles that have the words $w_{i1} \in A_{i1}, \ldots, w_{im_i} \in A_{im_i}$ for $F_i(w_{i1}, \ldots, w_{im_i}) = \{p_{i1}, \ldots, p_{il_i}\}$ as keywords are obtained.

On the other hand, among the parametric functions that appear in F, other relationships are defined between them, for example, the "OR", such that if $F_i(w_{i1}, \ldots, w_{im_i}) = \{p_{i1}, \ldots, p_{il_i}\}$ and $F_j(w_{j1}, \ldots, w_{jm_j}) = \{p_{j1}, \ldots, p_{jl_j}\}$ then, $F_i(w_{i1}, \ldots, w_{im_i})\ OR\ F_j(w_{j1}, \ldots, w_{jm_j}) = \{p_{i1}, \ldots, p_{il_i}, p_{j1}, \ldots, p_{jl_j}\}$, that is, the articles that have as keywords $w_{i1}\ AND \ldots AND\ w_{im_i}$ are included with those that have as keywords $w_{j1}\ AND \ldots AND\ w_{jm_j}$.

The results obtained after following each of the phases were as follows:

Phase 1. The main objective of this research is to analyze the impact of human capital on innovation processes in different economic and regional contexts.

Phase 2. In this stage, an initial search was carried out in databases such as Web of Science and Scopus, using the terms "innovation" and "human capital". This first sweep was done to find synonyms and keywords in titles and abstracts, contributing to the creation of the search equations; in total, 17,253 scientific articles were found.

Phase 3. We include specifications regarding the way to innovate using the following terms: "technological innovation", "organizational innovation", "product innovation", and "innovative performance". New words related to socioeconomic aspects of the countries studied in the articles were also included, such as: "advanced countries", "industrialized countries", "wealthy countries", and "developed countries", among others. The list of complete words can be seen in Table 1.

Database	**Keywords, HyperSoft Sets and Constraints**	**Results**
WoS	(ALL=(human capital)) AND ALL=("innovation" OR "technological innovation" OR "organizational innovation" OR "product innovation" OR "Innovative Performance") AND ALL=("advanced countries" OR "industrialized countries" OR "wealthy countries" OR "developed countries" OR "more developed countries" OR "prosperous countries" OR "advanced economies" OR "developing countries" OR "underdeveloped countries" OR "less developed countries" OR "emerging countries" OR "developing economies" OR "industrial nations" OR "industrial economies" OR "industrialized nations" OR "advanced nations" OR "developed nations" OR "industrial states" OR "industrial societies" OR "rich countries" OR "wealthier countries" OR "wealthy nations" OR "industrially advanced countries" OR "civil countries" OR "civilized nations" OR "civilized powers")	360
Scopus	TITLE-ABS (("human capital" AND ("innovation" OR "technological innovation" OR "organizational innovation" OR "product innovation") AND ("advanced countries" OR "industrialized countries" OR "wealthy countries" OR "developed countries " OR "more developed countries" OR "prosperous countries" OR "advanced economies" OR "developing countries" OR "underdeveloped countries" OR "less developed countries" OR "emerging countries" OR "developing economies" OR "industrial nations" OR "industrial economies" OR "industrialized nations" OR "advanced nations" OR "developed nations" OR "industrial states" OR "industrial societies" OR "rich countries" OR "wealthier countries" OR "wealthy nations" OR "industrially advanced countries" OR "civil countries" OR "civilized nations" OR "civilized powers")))	378
Total		738

Table 1. Final search equations.

Tools such as VOSviewer enable the implementation of a node cluster to locate and categorize the keywords represented graphically. A bibliometric analysis of the articles is carried out through VOSviewer. Words such as "impact", "growth", "productivity", "economic growth" and "education" have a larger circle, which indicates the importance of these terms for the research found. It also shows how these words are interrelated with others, forming clusters differentiated by colors. Figure 2 shows the nodes related to the terms "innovation" and "human capital".

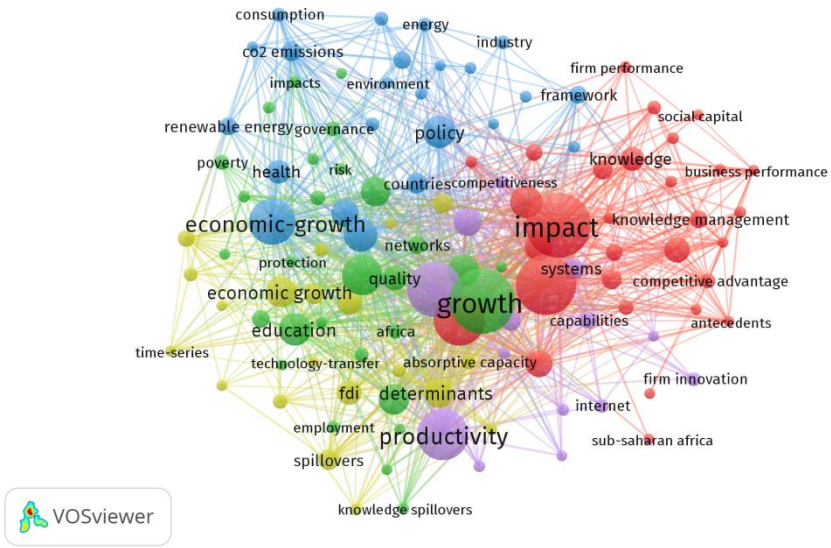

Figure 2. Bibliometric network of the terms innovation and human capital.

Phase 4. The final search was performed in major databases such as Web of Science (WoS) and Scopus. For this step, descriptors and Boolean operators were included, managing to find 360 articles on the WoS page and 378 on Scopus, for a total of 738 articles. The search equations used are shown in Table 1.

Phase 5. Using the Mendeley and Jabref tools, duplicate files were eliminated. The search was restricted to documents published between 2013 and 2023, excluding all types of documents other than articles, such as books or book chapters because these do not fit the Inordinatio equation by not having an impact factor. Documents not directly related to the research objective were also excluded, resulting in a portfolio of 27 documents.

Phase 6. Each document was assigned its corresponding impact factor calculated by Journal Citation Reports (JCR), as well as the number of citations, the year of publication, and the year of search for the articles. For journals without a JCR impact factor record, the SJR impact factor was chosen as a second option. Both indicators have demonstrated their capacity to measure the scientific influence of academic journals.

The number of citations and the year of publication were obtained through Google Scholar. We took into account that several authors recommend the use of this tool for its wide coverage and its high capacity to track citations; on the other hand, the search year was the same (2024) for all calculations because this bibliographic review was carried out on the same date.

Phase 7. The importance value of the year of publication of the articles ($\propto$) is assigned the lowest rating (equal to 1), because a filter had previously been applied to select only articles written during 10 years.

Phase 8. Finally, the Mendeley reference manager was used to collect the articles and perform the analysis of the documents obtained through the Methodi Ordinatio methodology.

Figure 3 represents a summary of the selection process carried out to build the final portfolio.

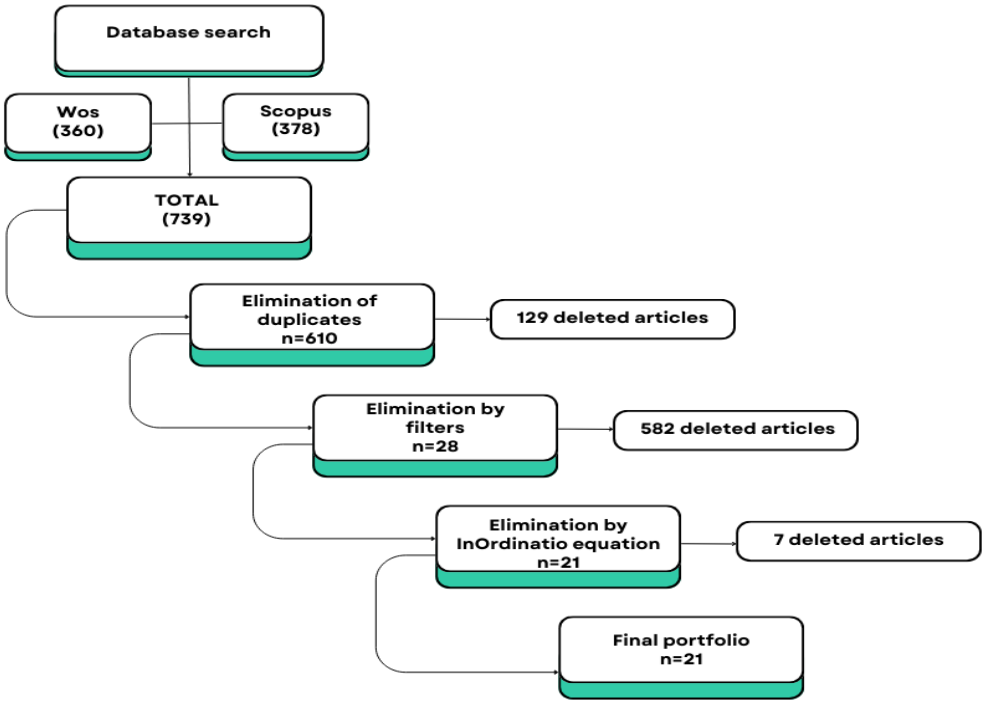

Figure 3. Summary of the bibliographic portfolio selection process

On the other hand, Figure 4 visually represents the countries with the highest number of publications related to the research topic, using a color scale ranging from light green for countries with fewer publications to dark green for countries with more publications. The United States and China are the countries with the most publications on the topic, followed by Canada, Australia, and Russia.

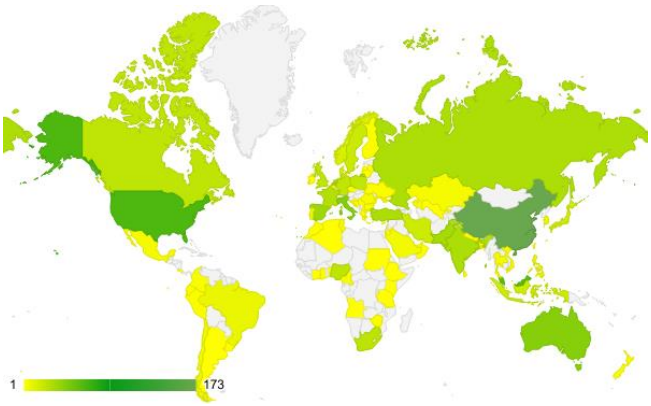

Figure 4. Countries with the highest number of publications.

Figure 5 shows the Sankey diagram of the selected articles, this is a graphical representation that shows the flow and relationships between different concepts or variables. In this case, the diagram focuses on the relationship between the terms "innovative", "capital", "innovation", and "human" with a series of subtopics and categories. Thus:

- **Innovative**: It is mainly connected with "knowledge" and "countries", suggesting that innovation is strongly influenced by knowledge and national context.
- **Capital**: Related to terms such as "relationship", "manufacture", and "competitive", indicating that capital has implications for competitiveness and relationships within the manufacturing process.
- **Innovation**: It is linked to "firms" and "development", suggesting that innovation is crucial both for firms and for development in general. In addition, it is connected to "technology" and "policy", showing the importance

of these factors in innovation processes.

- **Human**: It is associated with "impact", "institutions", and "process", indicating that human capital has a significant impact through institutions and processes within companies.

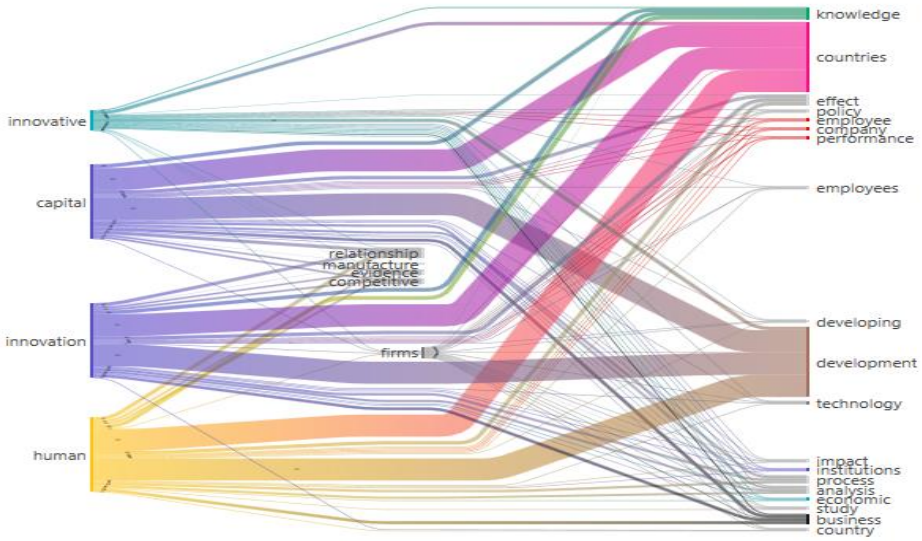

Figure 5. Sankey diagram of this study.

Finally, Figure 6 shows two trend lines that show the evolution of the number of publications in the Web of Science (WoS) and Scopus databases during the period between 2014 and 2022. These lines allow us to analyze the behavior of scientific production in the two sources of information over time, providing a longitudinal perspective on the development of research in the specific field addressed.

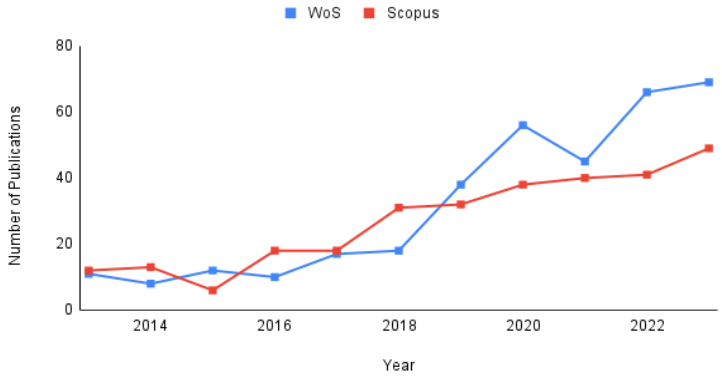

Figure 6. Evolution of the number of publications in the Web of Science (WoS) and Scopus databases.

Conclusion

Research consistently shows that human capital, characterized by education, skills, creativity, and health, is a critical factor for the generation and success of innovation. This finding is consistent with existing knowledge and expands the understanding of how human capital interacts with other factors, such as technological infrastructure and government policies.

In developed countries, there is a direct relationship between robust and well-developed human capital and the ability to generate relevant innovations. In contrast, in developing countries, human capital faces additional challenges, such as a lack of access to adequate educational and technological infrastructure, which limits its innovation potential.

The research also highlights the importance of public policies and cross-sector collaboration in promoting human capital for innovation. An important conclusion is the implication that governments and organizations must work together to develop and implement effective human capital strategies.

In terms of future research, this review suggests several directions. First, it would be valuable to conduct more

detailed studies in developing countries to better understand the specific challenges they face in terms of developing human capital for innovation. Furthermore, future research could further explore how rapidly evolving technology and changes in the labor market affect human capital needs in different industries.

It would also be beneficial to conduct longitudinal studies to better understand how investments in human capital influence innovation over time, providing a deeper understanding of the causal relationship between human capital and innovation.

This review provides a solid foundation for understanding the importance of human capital in innovation and highlights key areas for practice and future research. Although there are limitations that need to be addressed in future studies, the findings have important implications for those interested in fostering innovation through human capital development.

The findings of this systematic review have profound implications for human capital management strategies in organizations and governments. The research shows that investment in human capital development is crucial to fostering an enabling environment for innovation. Therefore, organizations should consider not only technical training but also the development of soft and creative skills that enhance the innovative capacity of their staff.

Collaboration between the educational and business sectors is also emerging as a key factor. Universities and other educational institutions must align their programs with the needs of the labor market, while companies can offer internship and training opportunities that complement formal education. This interaction could contribute to the creation of human capital that is better suited to the challenges of contemporary innovation.

This article once again shows the usefulness of using HyperSoft Sets to represent complex relationships between data automatically. In this research, these complex combinations led to obtaining useful knowledge about organizations, which is an example of text mining.

References

[1] Maji, P. K., Biswas, R., and Roy, A. R. (2003). Soft set theory. Computers & mathematics with applications, 45, 555-562.

[2] George, B., Jose, J., and Thumbakara, R. K. (2024). Co-normal products and modular products of soft graphs. Discrete Mathematics, Algorithms and Applications, 16, 2350012.

[3] Naveed, H., & Ali, S. (2024). Multi-Criteria Decision-Making Approach Based on Correlation Coefficient for Multi-Polar Interval-Valued Neutrosophic Soft Set. Neutrosophic Systems With Applications, 24, 18-33. https://doi.org/10.61356/j.nswa.2024.24417

[4] Sezgin, A., and Cagman, N. (2024). A New Soft Set Operation: Complementary Soft Binary Piecewise Difference (\) Operation. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 7, 58-94.

[5] Smarandache, F. (2022). Extensión de Soft Set a Hypersoft Set, y luego a Plithogenic Hypersoft Set. Neutrosophic Computing and Machine Learning, 25, 103–106. https://doi.org/10.5281/zenodo.7519268

[6] Smarandache, F. (2018). Extension of soft set to hypersoft set, and then to plithogenic hypersoft set. Neutrosophic sets and systems, 22, 168-170.

[8] Martin, N., & Smarandache, F. (2020). Introduction to Combined Plithogenic Hypersoft Sets. Neutrosophic Sets & Systems, 35.

[9] Naveed, H., & Ali, S. (2024). Multi-Criteria Decision-Making Approach Based on Correlation Coefficient for Multi-Polar Interval-Valued Neutrosophic Soft Set. Neutrosophic Systems With Applications, 24, 18-33. https://doi.org/10.61356/j.nswa.2024.24417

[10] . Smarandache, F. (2022). Aplicaciones prácticas de IndetermSoft Set e IndetermHyperSoft Set e Introducción a TreeSoft Set como una extensión del MultiSoft Set. Neutrosophic Computing and Machine Learning, 25, 1–8. https://doi.org/10.5281/zenodo.7517508

[11] Saqlain, M., Jafar, N., Moin, S., Saeed, M., and Broumi, S. (2020). Single and multi-valued neutrosophic hypersoft set and tangent similarity measure of single valued neutrosophic hypersoft sets. Neutrosophic Sets and Systems, 32, 317-329.

[12] Saeed, M., Rahman, A. U., Ahsan, M., and Smarandache, F. (2021). An inclusive study on fundamentals of hypersoft set. Theory and Application of Hypersoft Set, 1, 1-23.

[13] Debnath, S. (2021). Fuzzy hypersoft sets and its weightage operator for decision making. Journal of fuzzy extension and applications, 2, 163-170.

[14] Yolcu, A., Smarandache, F., and Öztürk, T. Y. (2021). Intuitionistic fuzzy hypersoft sets. Communications faculty of sciences University of Ankara Series A1 mathematics and Statistics, 70, 443-455.

[15] Yolcu, A., and Ozturk, T. Y. (2021). Fuzzy hypersoft sets and it'fs application to decision-making. Theory and application of hypersoft set, Pons Publishing House Brussels. pp. 50-64.

[16] Musa, S. Y., Mohammed, R. A., and Asaad, B. A. (2023). N-hypersoft sets: An innovative extension of hypersoft sets and their applications. Symmetry, 15, 1795.

[17] García Brito, O. E., Ribadeneira Vacacela, A. S., Sánchez Burneo, C. H., and Jimbo Galarza, M. C. (2024). English for specific purposes in the medical sciences to strengthen the professional profile of the higher education medicine student: a knowledge representation using superhypersoft sets. Neutrosophic Sets and Systems, 74, 84-91.

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