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Potential of the Industry 4.0 services sector in Risaralda: Implications for competitiveness, internationalization, and health and well-being

Potencial del sector servicios de la Industria 4.0 en Risaralda: implicaciones para la competitividad, la internacionalización, la salud y el bienestar

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SUMMARY

Introduction: *Digital transformation has significantly boosted the dynamism of the services sector worldwide, highlighting its relevance as an engine of economic growth in emerging economies. In this context, Industry 4.0 represents a strategic opportunity to strengthen the global competitiveness of regions such as Risaralda, Colombia.*
Objective: *This study aimed to analyze the current state of the Industry 4.0 services sector in Risaralda and its potential as a strategy for international trade.*
Materials and methods: *The methodological approach developed was quantitative, descriptive in scope, and cross-sectional. Structured surveys were administered to 53 companies belonging to the Novitas Cluster, complemented by analysis of secondary sources. The collected data were organized and stored in databases using tools such as Excel and then analyzed using tabular and graphical techniques.*
Results: *The main findings show that the sector is predominantly composed of young companies, with a high level of adoption of Industry 4.0 technologies, such as cloud computing and big data, but with limited export capacity (only 19 % of exports).*
Conclusion: *The Industry 4.0 services sector in Risaralda has high growth and internationalization potential, but faces significant challenges in terms of human talent, innovation, and exports. Strengthening this sector may also contribute to improving access, quality, and efficiency of digital health-related services, supporting health systems and population well-being in line with Sustainable Development Goal 3 (Good Health and Well-Being).*

Keywords: *Digital transformation, industry 4.0, technological services, technological innovation, international competitiveness.*

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RESUMEN

Introducción: *La transformación digital ha impulsado significativamente el dinamismo del sector de servicios a nivel mundial, destacando su relevancia como motor del crecimiento económico en las economías emergentes. En este contexto, las industrias 4.0 representan una oportunidad estratégica para fortalecer la competitividad global de regiones como el departamento de Risaralda, Colombia.*
Objetivo: *Analizar el estado actual del sector de servicios de las industrias 4.0 en Risaralda y su potencial como estrategia para el comercio internacional.*
Materiales y métodos: *El enfoque metodológico desarrollado fue cuantitativo, de alcance descriptivo y de corte transversal. Se aplicaron encuestas estructuradas a 53 empresas pertenecientes al Clúster Novitas, complementadas con análisis de fuentes secundarias. Los datos recolectados fueron organizados y procesados en bases de datos utilizando herramientas como Excel, para luego ser analizados mediante técnicas de tabulación y representación gráfica.*
Resultados: *Los principales hallazgos muestran que el sector está compuesto mayoritariamente por empresas jóvenes, con una alta incorporación de tecnologías 4.0, como la computación en la nube y el Big Data, pero con una capacidad exportadora limitada (solo el 19 % realiza exportaciones).*
Conclusión: *El sector de servicios de las industrias 4.0 en Risaralda tiene un alto potencial de crecimiento e internacionalización, pero enfrenta desafíos significativos en materia de talento humano, innovación y exportación. El fortalecimiento de este sector también puede contribuir a mejorar el acceso, la calidad y la eficiencia de los servicios digitales vinculados a la salud, promoviendo el bienestar de la población y el cumplimiento del ODS 3: Salud y Bienestar.*

Palabras clave: *Transformación digital, industria 4.0, servicios tecnológicos, innovación tecnológica, competitividad internacional.*

INTRODUCTION

The tertiary sector, also known as the services sector, has shown sustained growth in recent decades, consolidating its position as one of the most dynamic areas of global trade. This progress has allowed developing countries to increase their share of global services trade, rising from 25 % to 33 % of total exports (1). This change has been driven by increasing digitalization and the use of advanced technologies, which have favored the transition of international trade from traditional goods to high-value-added services. However, this growth has not been uniform. Regions like Risaralda face significant structural challenges that hinder their competitive integration into international markets.

In Colombia, the services sector has been identified as a key driver of economic recovery. Activities such as Business Process Outsourcing (BPO), software development, and information technology have proven to generate employment, economic diversification, and attract foreign investment (MINCIT, 2021). However, these opportunities have not been fully capitalized on in regions like Risaralda, where barriers related to infrastructure, human talent training, and limited knowledge of export processes persist. These limitations directly affect the sector's competitiveness in an increasingly demanding global environment.

The services sector in Colombia, including activities such as software development and information technology, has demonstrated its capacity to boost labor productivity and innovation, especially when there is investment in research and development and innovative processes, both technological and non-technological, are implemented (2). In this sense, the economic recovery after the pandemic has been driven mainly by domestic demand and manufacturing. At the same time, services have shown a slower recovery, underscoring the need to strengthen this sector to return to previous levels of economic activity (3). Therefore, in the reactivation process, service companies have prioritized financial strategies and marketing and service innovation, although organizational and management challenges persist, affecting their capacity for innovation and competitiveness.

Prominent examples, such as that of Innovative Education, a Pereira-based company that exports virtual laboratory software to 19 countries, reflect the region's potential to position itself as a relevant player in Industry 4.0 (4). However, cases like this are exceptional in a context where a lack of awareness of the legal requirements for exporting services, coupled with unclear internationalization strategies, limits the sector's global reach. Despite the growing demand for

technological services in international markets, Risaralda has not yet consolidated an offering that fully capitalizes on this opportunity.

Technical capabilities, software infrastructure, and human resource competency are key determinants of the sustainable adoption of Industry 4.0 in export-oriented industries; market pressure and system flexibility also play a key role (5). The central problem is that, despite the dynamism and potential of the Industry 4.0 services sector in Risaralda, its export capacity is limited and its integration into international trade remains incipient. This situation reflects a disconnect between local capabilities and global market demands. Furthermore, low investment in innovation and a shortage of qualified human talent, especially in soft skills and languages such as English, exacerbate the sector's difficulties in competing internationally.

In this context, it is hypothesized that a lack of knowledge of export processes, limited investment in innovation, and limited human talent represent the main obstacles faced by companies in the Industry 4.0 service sector in Risaralda when trying to compete in international trade. Identifying and analyzing these internal factors will enable them to design effective strategies to boost their global competitiveness, as companies that invest in advanced technologies and digital transformation are better prepared to compete internationally and achieve better export performance, underscoring the importance of innovation and the development of qualified human talent (6).

In addition to its economic relevance, the development of Industry 4.0 services has become increasingly important for strengthening health systems and improving population well-being. Digital services such as health information systems, telemedicine platforms, data analytics, and decision-support tools contribute to more efficient, accessible, and patient-centered care. These contributions are directly aligned with Sustainable Development Goal 3 (SDG 3), which seeks to ensure healthy lives and promote well-being for all at all ages. In this sense, strengthening the Industry 4.0 services sector not only enhances regional competitiveness but also supports public health objectives through innovation, digital inclusion, and improved service delivery.

The purpose of this study was to analyze the current state of the Industry 4.0 services sector in Risaralda, identify the strengths and weaknesses that limit its global competitiveness, and propose strategies to promote its integration into international markets. To this end, questions such as: What are the main characteristics of companies in the sector? What is the current situation of Industry 4.0 services in Risaralda in relation to exports? Therefore, the proposed research evaluated the current state of Industry 4.0 services in Risaralda, a department whose economy has shifted from agriculture to trade and services. Seeking to identify the current conditions of the industry and what successful strategies some companies have used.

MATERIALS AND METHODS

This research was conducted using a quantitative, descriptive, cross-sectional design to characterize the Industry 4.0 services sector in Risaralda. The quantitative approach prioritizes objective measurement through standardized instruments and statistical analysis, which are essential for rigorously testing hypotheses and supporting conclusions based on numerical data (7). Based on the formulated hypothesis, we sought to identify the main internal obstacles related to limited knowledge of export processes, limited investment in innovation, and limited human talent, to propose strategies to strengthen their integration into international trade.

The study's main objective was to describe the current status of Industry 4.0 service companies in Risaralda, focusing on key aspects such as technological capabilities, innovation strategies, human talent competencies, and their relationship with international trade. It also assessed the barriers that hinder their global competitiveness.

The study population consisted of service-sector companies in Industry 4.0 in Risaralda, with special emphasis on those belonging to the Novitas Risaralda Cluster, which groups a significant percentage of the sector's representative companies in the region. The sample consisted of 53 companies selected using random sampling. This criterion was adopted because the sector

is concentrated in the Novitas Cluster, which serves as a strategic node for collecting relevant information on the department's industry behavior and characteristics.

A structured questionnaire was designed and administered, covering general company characteristics, implemented technologies, innovation strategies, human talent profile, and export practices. Additionally, an analysis of secondary sources, including institutional databases and prior studies on the sector, was conducted. The collected data was organized and processed in a database using Microsoft Excel. Descriptive statistical techniques were used to analyze qualitative and quantitative variables, including frequency and percentage distributions and graphical representations of the results. The data were grouped by the categories defined in the questionnaire and analyzed to test the proposed hypothesis and identify patterns and significant relationships among the variables.

The study was conducted in accordance with the ethical principles of scientific research. Informed consent was obtained from the participating companies to ensure the confidentiality of the information provided. Personal and business data were anonymized during the analysis to protect participants' privacy. Furthermore, transparency in the handling of information was ensured by validating the collected data and comparing it with reliable secondary sources. The interpretations and conclusions derived from the analysis respected the limits imposed by the data, avoiding unfounded extrapolations.

Finally, the methodology used enabled the identification of the comprehensive capabilities of the service sector of Industry 4.0 in Risaralda, providing valuable input for the formulation of strategies to strengthen its global competitiveness and its integration into international trade.

RESULTS

The characterization of the Industry 4.0 service sector in Risaralda provided a comprehensive view of the companies within it, their main characteristics, and the challenges they face. The results are structured around the main areas of analysis: location, seniority, services offered, technologies adopted, financial profile, human talent, and exports.

The research reveals that most companies in the sector are concentrated in Pereira, which is home to 91 % of the organizations studied. This centralization underscores Pereira's importance as a hub for Industry 4.0 development in Risaralda. Other cities such as Dosquebradas and Santa Rosa de Cabal account for 6 % and 4 % of the companies, respectively. Regarding company age, a predominance of young organizations is observed: 40 % are 1-5 years old, while 26 % are 6-10 years old. This data reflect the sector's dynamism and recent development, which represent both an opportunity for growth and a challenge for consolidation.

The analysis highlights that 61 % of companies offer customized software services, tailored to their clients' specific needs. Their main activities include digital transformation consulting (24 %), software and mobile application development (22 %), and services related to digital marketing, e-learning, big data, artificial intelligence, and cloud computing. These activities demonstrate a high degree of alignment with global technological demands, although their adoption is still limited by structural and financial factors (Figure 1).

In the context of Internet of Things 4.0 (IoT 4.0) thecnologies, companies have adopted key tools such as cloud computing, big data analytics, and the Industrial Internet of Things. These technologies are fundamental to digital transformation and represent a competitive advantage that must be strengthened to meet the challenges of international markets.

Regarding the sectors of focus, 19 % of the companies analyzed are classified as "Other service activities", reflecting the sector's diversity of services. The most representative sectors, with 16 % each, correspond to "Information and communication and support activities" and "Manufacturing industries." These sectors are closely related to the most commonly used used International Standard Industrial Classification of All Economic Activities (ISIC) codes, specifically 6201 (Computer systems development activities) and 6202 (Computer consulting and facilities management activities), under which 78 % of the companies are registered.

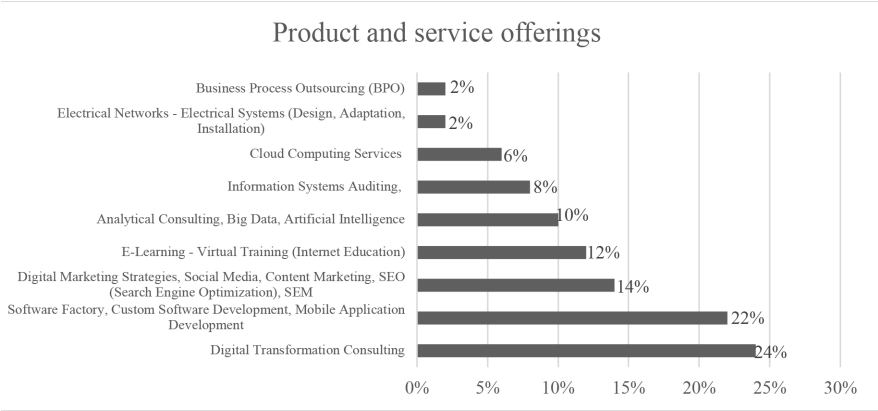

Figure 1. Main products and services offered.

In terms of product categories, 84 % of the services offered focus on integrating Industry 4.0 technologies and software design, highlighting the sector's technological specialization and its ability to deliver innovative solutions tailored to market needs. These results underscore the importance of software design as a central component in the value proposition of Industry 4.0 service companies in Risaralda.

The 4.0 technologies most used by the companies analyzed include cloud computing, big data analytics, and the industrial internet of things, demonstrating a focus on tools that enable process optimization and data-driven decision-making (Figure 2). Regarding development languages, 45 % of companies use Java or PHP as their primary languages, while 33 % use other languages, reflecting the diversity of the technologies adopted.

On the other hand, the most widely supported operating systems are Windows (33 %) and Android (28 %), reflecting an alignment with market preferences and the need to cater to both corporate environments and mobile users. This technological selection highlights companies' adaptability to customer demands and to global development and compatibility trends.

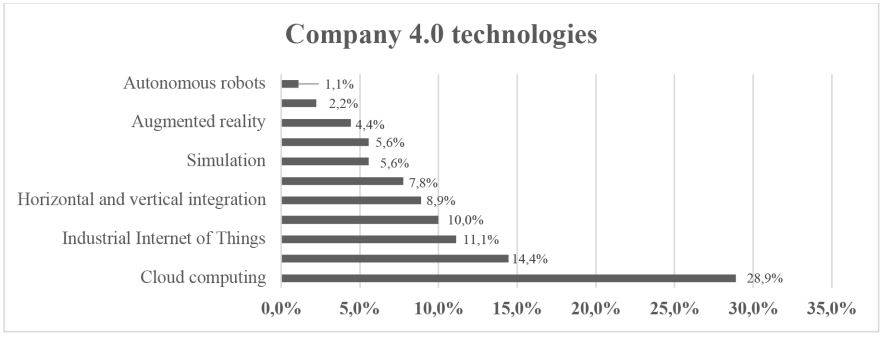

Figure 2. Company 4.0 Technologies.

Regarding their financial profile, most of the companies studied have financial assets between 501 and 5 000 times the current legal minimum wage (SMMLV), which is in line with their

status as small and medium-sized enterprises. However, many organizations' annual sales do not exceed 200,000,000 COP, reflecting modest income that limits their investment and expansion capacity. Additionally, a high percentage of business owners are unaware of the cost-to-sales ratio, suggesting there is a need to strengthen financial management skills within the sector; likewise, only 20 % of those surveyed import goods or services. Few companies (6 %) have import licenses.

Human resources are one of the sector's fundamental pillars, but they also constitute one of its greatest challenges. Most companies have small work teams, with between one and 10 collaborators. Of the total employees, 42 % have professional training, and 19 % hold a postgraduate degree, reflecting a considerable level of specialization. However, the most in-demand specific skills include certifications in programming, cloud computing, agile methodologies, and English proficiency. The lack of these skills represents a critical obstacle to the sector's internationalization, especially in markets where English is an essential requirement (Figures 3, 4 and 5).

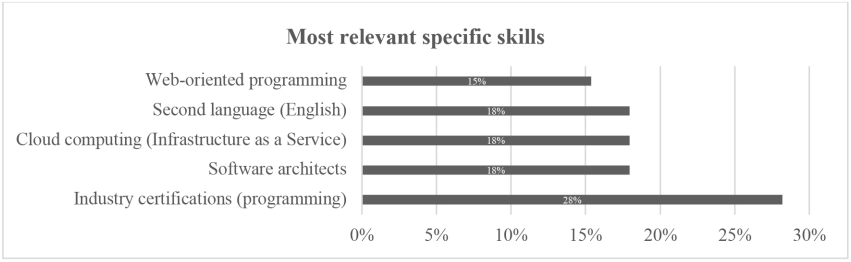

Figure 3. Most relevant specific competencies that the company has.

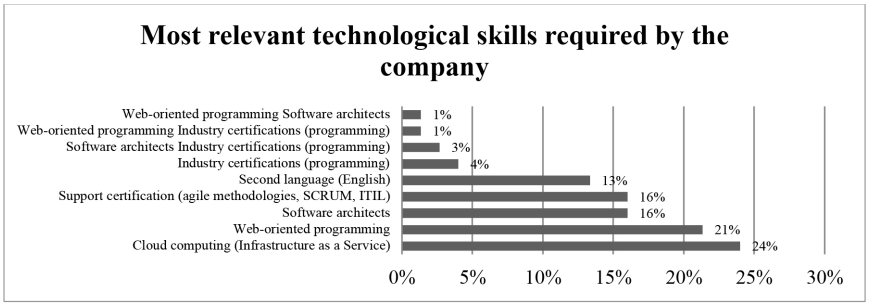

Figure 4. Most relevant technological competencies that the company has.

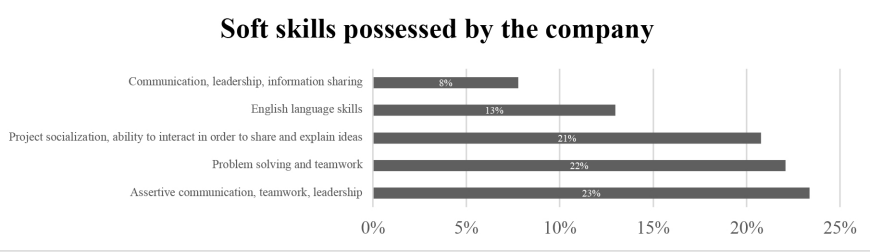

Figure 5. Soft skills that the company has.

In the area of innovation management, only 30 % of the companies surveyed reported carrying out specific activities, while 32 % conduct technological monitoring to stay up-to-date with industry trends. However, the creation of new knowledge appears to be limited, as only five companies (equivalent to 20 % of those who responded to this question) have registered intellectual property. This suggests that generating protected innovations is not yet a common practice in the industry.

The most notable innovation activities include the development of new products or services and the improvement of existing ones, with investment predominantly directed toward in-house software development. Innovation and technology development centers have been identified as the main sources of support, providing resources and guidance for these activities. According to data compiled from international patent databases such as the World Intellectual Property Organization (WIPO), IBM, Samsung, Qualcomm, Huawei, Intel, Microsoft, and Apple are among the top companies filing patents under ISIC codes 6201 and 6202 over the last five years. These applications reflect a high global demand for advanced technologies and innovative solutions.

Despite these efforts, most companies (81 %) lack business certifications, which can limit their ability to compete in more demanding markets. This situation reflects the need to strengthen both innovation management and the acquisition of certifications that support the quality and competitiveness of their processes and products.

Finally, regarding internationalization, only 19 % of companies export, with the United States as the primary destination. Other countries mentioned include Spain, Peru, Argentina, Chile, and Mexico. However, exports to Europe are scarce, and no sales to Asia or Africa are reported, reflecting limited geographic diversification. Furthermore, nearly 50 % of entrepreneurs expressed interest in exporting but reported lacking the necessary tools for their internationalization process. This outlook highlights the need to train entrepreneurs on the legal and operational requirements for exporting services, as well as to design strategic plans that promote internationalization.

From a health and well-being perspective, the high level of technology integration, including cloud computing, big data, and software development, identified in the companies analyzed, represents a significant opportunity for designing digital solutions for the health sector. These technologies are increasingly used in areas such as telehealth, health data management, digital education in health, and decision-support systems, thereby improving service efficiency and access. Therefore, the technological capabilities identified in the Industry 4.0 services sector in Risaralda may also support initiatives aligned with SDG 3, particularly in strengthening digital health ecosystems and promoting population well-being.

DISCUSSION

The results obtained in this research provide a detailed characterization of the service sector of Industry 4.0 in Risaralda and reveal significant similarities and differences relative to previous studies conducted in other regions and countries.

In terms of innovation, only 30 % of the companies surveyed in Risaralda reported carrying out management activities in this area, and only 32 % indicated implementing technological surveillance. This is consistent with other studies highlighting that, in emerging Latin American economies, innovation management remains limited in the technology sectors, primarily due to budgetary constraints and inadequate government incentives (8). However, this study emphasizes that companies that consistently invest in innovation have a greater capacity to adapt and succeed in international markets. The low investment in innovation and the limited practice of technological surveillance by most companies negatively impact their competitiveness. Although they develop and improve existing products/services, the lack of a systematic focus on innovation and surveillance limits the creation of specialized added value necessary to stand out in a dynamic global market.

Beyond economic competitiveness, the findings highlight the potential contribution of Industry 4.0 services to health and well-being outcomes. International evidence indicates that digital innovation in services plays a key

role in improving health system performance, particularly through telemedicine, health information systems, and data-driven decision-making, which enhance access, efficiency, and quality of care (13-15). The adoption of digital health technologies has been associated with better health service coverage, improved management of health data, and strengthened health system resilience, especially in middle-income countries (16,17). In regions such as Risaralda, where digital service companies demonstrate growing technological capacity, strengthening innovation management and human talent may enable the development of digital solutions that support public health goals, including preventive care, service continuity, and health system sustainability (18,19). This dual impact—economic and social—reinforces the strategic value of Industry 4.0 services in advancing Sustainable Development Goal 3 (Good Health and Well-Being) while fostering sustainable regional development (20).

On the other hand, the international demand for 4.0 services is evident through the high patenting activity by large technology companies in ISIC codes relevant to the cluster's companies (6201, 6202, etc.). This confirms the market opportunity but also underlines the need for Risaralda companies to develop and offer high-value services and stay at the forefront, as international competition demands a necessary level of innovation.

Likewise, the cluster's limited export capacity, with only 19 % of companies participating in export activities, and a widespread lack of awareness of the legal and regulatory requirements for exporting services, mean that the low use of emerging technologies constitutes a significant obstacle to its internationalization potential (9). This situation contrasts sharply with the sector's identification as a fundamental pillar of Colombia's economic recovery. Studies support this statement, pointing out that the application of emerging technologies enhances business competitiveness and enables economic growth through job creation, investment, and trade, which aligns with the possibilities of the international market (10). The absence of a structured export plan prevents cluster companies from effectively leveraging existing international demand and competing in foreign markets, ultimately hindering their growth and the national economy's expected impact.

A critical outcome is the need to strengthen human talent, particularly in mastering a second language (English), which is identified as the most in-demand technical and soft skill. The review of STEM skills in the Americas shows that "people who can speak English have greater ease in technological or digital literacy processes, since English is the vector of technological globalization" (11). This demonstrates that the shortage of qualified personnel in the short and long term not only limits technological adoption but also the construction of a solid value proposition capable of overcoming language barriers in international trade.

The small proportion of companies in the sector in Risaralda that are linked to the Novitas Cluster (ranging from 2.24 % to 28.57 % according to the International Standard Industrial Classification (ISIC)) represents a strategic opportunity to grow and strengthen the cluster by expanding its membership. Greater coordination and collaboration among ecosystem actors, such as that fostered through cluster initiatives, could help overcome common obstacles. For example, the lack of knowledge about export requirements and processes, a significant barrier to the internationalization of services, could be addressed. Furthermore, greater cohesion would facilitate continuous improvement in the quality of service delivery, a crucial aspect for competitiveness in global markets (10,12).

The results suggest that, while Risaralda has a strong base of 4.0 service companies, particularly evident in its digital transformation and software development consulting offerings, there are significant weaknesses in key areas, including internationalization, specialized human talent (particularly in languages), and innovation management. Addressing these areas is crucial for the sector to project itself effectively in international trade and contribute significantly to the regional and national economies.

CONCLUSIONS

This study characterized the Industry 4.0 service company cluster in Risaralda, identifying

that it is mostly composed of young companies with less than five years of operation. This young business model reflects the sector's dynamism but also poses significant challenges for its consolidation and growth.

Regarding the research question on the sector's main characteristics, the results indicate an ecosystem with significant potential for consulting services in digital transformation and software development. This sector is distinguished by its focus on innovation and adaptation to technological demands, which positions it as a key player in the regional economy. However, structural challenges persist. A small proportion of these companies are formally linked to the Novitas Cluster, suggesting an opportunity to strengthen sectoral coordination and collaboration. This greater integration could help overcome common obstacles, such as a lack of knowledge of export processes, the need for continuous improvement in service quality, and the promotion of innovation and collective technological development.

One of the main weaknesses identified is a shortage of human talent in programming and technological development, especially in English and in soft skills such as leadership and effective communication. This deficit directly affects the sector's competitiveness. The research underscores the critical need to strengthen human talent. Mastery of a second language, particularly English, emerges as the most in-demand technical and soft skill, essential for overcoming language barriers in international trade. The shortage of qualified personnel, both short- and long-term, is a critical issue that must be addressed urgently to consolidate a robust, globally competitive value proposition. These results reaffirm that, although Risaralda has a promising base of 4.0 service companies, overcoming weaknesses in internationalization, developing specialized human talent, and improving innovation management are critical for the sector to project itself effectively and contribute significantly to the country's regional and national economy.

The characterization also shows that the main product lines (CIIU 6201, 6202, 7020, 4741, and 7112) are in high demand in markets such as the United States, Japan, and Germany. However, only between 12 % and 28 % of Risaralda companies with similar product lines are linked to the Novitas Cluster, which represents a significant opportunity to foster business ties.

Regarding the current status of Industry 4.0 services in Risaralda in relation to exports, the results show a still limited export capacity, with only 19 % of companies participating in export activities. This low figure, coupled with widespread lack of awareness of the legal and regulatory requirements for exporting services, represents a significant impediment to the internationalization of the sector. This situation contrasts with the sector's identified potential to drive economic recovery and serve as a pillar of Colombia's integration into international trade. The absence of a clear and structured export plan is a direct factor limiting the exploitation of the already identified international demand.

It is concluded that the United States is consolidating as the most attractive market for the cluster's exporters, although with a low percentage of exports to Latin American countries and the Chamber of Commerce. This outlook suggests the need to strengthen diversification strategies and penetrate new markets.

It is essential to recognize the inherent limitations of this study, which not only define the scope of the results but also suggest directions for future research. First, the cross-sectional nature of the research, which collects data at a single point in time, makes it difficult to establish causal relationships or analyze the evolution of the aspects analyzed over time. A longitudinal approach could offer a deeper understanding of the dynamics of internationalization, human talent development, and innovation in the sector.

In addition to its economic and internationalization potential, the Industry 4.0 services sector in Risaralda represents an opportunity to contribute to health and well-being at the regional level. By fostering innovation, strengthening digital capabilities, and developing qualified human talent, this sector can support the development of technological solutions for health services, health education, and data management. These contributions align with Sustainable Development Goal 3, highlighting the relevance of Industry 4.0 services not only as drivers of competitiveness but also as enablers of social well-being and more resilient health systems.

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