Analysis of the Variables Leading to the Identification and Incorporation of Innovation Capabilities by Firms in the Colombian ICT Sector*

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Abstract: Due to the rapid and constant changes in the market, organizations are increasingly forced to develop innovative products or services with added value. In Colombia, a large percentage of information and communications technology (ICT) firms concentrate in the city of Medellín. For these organizations, developing and implementing innovation capabilities (ICs) is considered strategic and essential to strengthen their competitiveness and the economic contribution of the ICT sector to the city and the country, which is reflected in the national GDP. Therefore, the purpose of this paper is to analyze the variables that lead to the identification and incorporation of ICs by firms in the ICT sector through a systematic literature review (SLR) in the 6 most relevant bibliographic databases. The results obtained were used for the analysis of the ICT sector in Medellín. According to our findings, firms must possess the necessary innovation capabilities and competencies to develop skills and knowledge oriented to research and development and to be competitive in the market, considering the transformations of the industry. In addition, identifying and incorporating ICs into their organizational structures allow them to improve decision-making and create strategies that contribute to strengthening their innovation activity and competitive advantage.

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* This work is part of a research study to obtain the degree of Master in Technological Innovation Management, Cooperation and Regional Development at Instituto Tecnológico Metropolitano (Medellín, Colombia).

Introduction

Different authors have studied innovation capabilities (ICs); among these, some authors consider seven constituent ICs (Yam *et al.*, 2004). These capabilities involve each organizational area and work in conjunction so that firms can achieve innovative results and be more competitive. ICs can be defined as the abilities of an organization to deploy and coordinate its various resources (usually in combination) to attain its goal (AlNuaimi & Khan, 2019). Their importance lies in the fact that they make it possible to determine a firms' level of innovation. However, the development of ICs in a firm requires quite a long time and cannot be merely attributed to the existence (or lack) of institutional incentives to build or develop them (Zhang & Merchant, 2020). Thus, organizations must deeply recognize their tangible and intangible resources, as well as their skills and knowledge, since resources that are valuable, rare, inimitable, or inherent in the organization (i.e., nonmarketable) are essential for a superior performance over competitors (Zhang & Merchant, 2020).

Knowledge is one of firms' main assets, and their learning capability is vital for knowledge development and growth. As stated by Zhang and Hartley (2018), ICs accumulate and change over time as organizational learning takes place. Therefore, they constitute a dynamic capability. With that in mind, addressing ICs becomes essential for strengthening the information and communications technology (ICT) sector. For instance, in Colombia, the sales of this economic sector —which consists of approximately 4,000 firms— amounted to COP 8.98 trillion in 2014 (MinTIC, 2019a). In addition, the contribution of the ICT sector to the country's GDP grew by 4.04% in the first two quarters of 2019 (MinTIC, 2019b). This industry is highly relevant given the current demand for technologies —the focus of the Fourth Industrial Revolution— in all production and knowledge areas, as the emergence of this revolution has led to a greater use of digital tools in various fields and at different levels. High-tech digital devices, platforms, and environments are increasingly being implemented to improve productivity, efficiency, and sustainability (Balogun *et al.*, 2020). Furthermore, this sector is considered to be one of the most productive due to its technological base and automation-oriented approach.

Several studies into ICs in ICT firms have been developed around the world. Nevertheless, only a small group of authors in Colombia has specifically focused on studying these capabilities, mainly from a technological perspective (Arias & Castaño, 2014). Hence, in light of the studies conducted so far, theoretical contributions regarding ICs applicable to this sector and with a highly representative power in the local and global economy must be made. For this reason, in this paper we will examine the variables leading to the identification and incorporation of ICs by ICT firms, applying these variables to the specific case of the city of Medellín, Colombia.

In line with the above, targeting this study to the case of the ICT sector in Medellín turns out to be relevant not only because this city is the epicenter of the Fourth Industrial Revolution in Colombia, but also because Medellín is the city that invests the most in science, technology, and innovation activities (ACTi) in the country, according to the Observatorio Colombiano de Ciencia y Tecnología (2019). In addition, as a strategic line for economic and territorial development from a knowledge management approach, Medellín has been proposed as the Software Valley (Alcaldía de Medellín, 2020).

Through a systematic literature review (SLR) in the 6 most relevant international bibliographic databases, we can contribute to the analysis of the state-of-the-art on ICs within the ICT sector. This methodology seeks to reduce the biases inherent to subjective reviews. In addition, an SLR helps to conduct an auditable, orderly, and reproducible search process in order to critically assess the studies that satisfy the predefined research needs and questions (Macias *et al.*, 2018). Additionally, it allows to approach some of the main focuses and determinants in the incorporation of these capabilities into the organizational structures of firms in the ICT sector. As a result of this incorporation, firms could strengthen their competitiveness in said sector. Finally, this type of research contributes to the analysis and interpretation of the literature on ICs across different production sectors, making it a relevant and representative topic to be addressed.

Theoretical basis

Literature review on innovation capabilities

Nowadays, firms face stiff competition. The need to be flexible and quickly respond to changes requires them to diversify and transform themselves. In this regard, innovation allows firms to add value to their services, products, or processes in order to differentiate in the market and achieve a competitive advantage. According to Chen and Cates (2018), the innovation capacity is a vital element for the competitiveness of organizations. In other words, "the more innovative a firm is, the more dynamic capabilities it possesses and the more likely it is to have superior performance" (Zhang & Merchant, 2020, p. 2). Therefore, a firm's ability to innovate is a critical success factor for its growth and performance (AlNuaimi & Khan, 2019).

In fact, in his five-forces framework, Porter makes it very clear that a fundamental aspect to define a firm's strategy is "to identify those strategic innovations that would most improve the industry's — and its own— profitability" (Porter, 1985, p. 7). Nonetheless, some characteristics prior to innovation, as well as a firm's own competencies and skills, allow them to be innovative. An innovation capability (IC) can be understood as the result of a nonlinear and cumulative learning process that is difficult to transfer (OECD & Eurostat, 2007).

Moreover, since innovation leads organizations to achieve a competitive advantage through investment in different resources and research and development (R&D) projects, ICs enable firms to have higher profits and returns on investment, as well as a greater positioning in the market (Macias *et al.*, 2018). The R&D globalization phenomenon has actually been increasingly used to improve firms' ICs, increase their foreign market share, attract talents, and reduce R&D costs (Fan *et al.*, 2019).

Other authors define ICs as a "comprehensive set of characteristics of a firm that facilities and supports its technological innovation strategies" (Burgelman *et al.*, 2008, p. 1). For this reason, an IC "accumulates as a result of the various internal and external inputs" (Romijn & Albaladejo, 2002, p. 1056). From the resource-based view (RBV), those internal inputs are made up of the firm's human capital, which is understood as the employees' knowledge, skills, and internal efforts to improve firms' technology and technological tools. This translates into resources that are valuable, rare, inimitable, or inherent in the organization and essential to achieve a superior performance over competitors (Zhang & Merchant, 2020).

According to García-Osorio *et al.* (2014), ICs can be defined as a set of characteristics or competencies that, when managed correctly, allow firms to have a good competitive performance. Thus, ICs enable organizations, through the improvement of their daily skills, to foster dynamic and absorptive capabilities to achieve better financial results (Felício *et al.*, 2019).

Consequently, in order to provide an in-depth analysis of ICs, these concepts should be defined, or the metrics that have been proposed to assess them must be addressed. Regarding the latter, studies into ICs have applied different metrics to quantify the level of accumulation of capabilities with respect to an ideal or reference value (Robledo *et al.*, 2010), and most authors usually follow the metrics proposed by Yam *et al.* (2004). However, there are other metrics that are also often used, such as the Capability Maturity Model (CMM) adapted by the Business Process Management (BPM) discipline and introduced by Wang *et al.* (2008).

Table 1 provides a list of ICs along with their definition, based on the models proposed by each author. We may assert that all the proposed models are closely related and that the differences among them are few. For instance, they all include R&D, marketing, strategic planning, and resource allocation capabilities. It should be noted that the learning capability is one of the most important because knowledge absorption and accumulation is materialized in the different activities carried out by organizations (OECD & Eurostat, 2007). In addition, knowledge as a basis for change in companies allows firms to act effectively in order to obtain results in a rapidly changing environment (Gutierrez, 2019).

Table 1.

Definition of the various innovation capabilities and relationship between the different proposed models.

	Yam *et al.* (2004)	Wang *et al.* (2008)	CMM	Definition
Constituent capability	Learning capability		Organizational learning capability	In both proposals, it refers to a firm's ability to capture new (tacit or explicit) knowledge.
	R&D capability	R&D capability	R&D capability	Corresponds to a firm's ability to transform its R&D results into innovative products or services.
	Resource allocation capability	Capital capability	Resource management capability	Firm's ability to manage and strategically allocate its resources to innovation projects.
	Manufacturing capability	Manufacturing capability	Production capability	Refers to a firm's ability to turn its R&D results into innovative products.
	Marketing capability	Marketing capability	Marketing capability	Corresponds to a firm's ability to introduce innovations into the market and commercialize them.
	Organizing capability			Firm's ability to orient its work towards innovation.
	Strategic planning capability	Innovation decision capability	Strategic planning capability	Firm's ability to propose and implement strategic plans that foster innovation.
			Relationship capability	Firm's ability to build strategic relationships in order to achieve innovative results.

Source: authors.

Based on the above, firms should incorporate these ICs into their daily activities and adopt them as a routine so that they can grow and strengthen their IC to achieve consistent innovative results (Essmann & Preez, 2009). Considering that ICs represent a key learning capability that is built from firms' R&D activities and innovative experiences (López-Mielgo *et al.*, 2012), it is important to recognize that the more difficult it is to understand knowledge, the more likely it is that a firm's R&D result will become a private asset with a greater indirect effect (Kim & Park, 2019). However, the R&D capability remains one of the scantest because it "tends to be concentrated in relatively few entities, particularly in the Business enterprise sector" (OECD, 2015, p. 180).

In this same vein, it is relevant to indicate that absorption capacity turns out to be a vital component so that the organization can continue to build on the knowledge of the company and continue to nurture this component, strengthening not only its internal but also external capacity (Monferrer *et al.*, 2013). On the other hand, being able to increase the level of absorption capacity would allow improving a firm's innovation capacity and knowledge, therefore translating absorption, as

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indicated by Urgal *et al.* (2011), into a moderate factor between the capacity for innovation and the sustainability of the organization, since if firms manage to develop the ability to use and combine their resources in a source of innovation for their products, processes or services, they can improve not only their performance but also develop a sustainable competitive advantage.

In conclusion, besides requiring a certain degree specific skills by firms, IC also depends on some characteristics of the territory and economic sectors. This is why "the notion that regional factors can influence the innovative capacity of firms has led to increasing interest in analyzing innovation at the regional level" (OECD & Eurostat, 2007, p. 39). Based on this, the purpose of this study is to analyze the variables that lead to the identification and incorporation of ICs in ICT firms, applying these variables to the specific case of the city of Medellín, considering that Colombia has been implementing strategies to strengthen such capabilities. For instance, the most representative endeavor was the creation of the Ministry of Science, Technology, and Innovation (Minciencias, in Spanish) (Congreso de Colombia, 2019), which used to be an administrative department. One goal of this entity is to bridge the gaps between the different regions and economic sectors in terms of science, technology, and innovation capabilities through the design of public policies. Furthermore, Medellín is currently recognized as the epicenter of the Fourth Industrial Revolution in Latin America.

Overall context of the information and communications technology sector

The adoption of ICTs is regarded as an important factor in the market's innovation strategy. According to a report by the World Bank, "Latin America and the Caribbean has lower rates of digital technology adoption than similar countries in the Organization for Economic Co-operation and Development (OECD), providing ample space to increase productivity" (The World Bank, 2018). The digital economy is gaining momentum, and ICTs are getting exponentially involved in every economic sector. In 2016, the global digital economy was worth USD 11.5 trillion, i.e., 15.5% of the world's GDP. This figure is expected to reach 25% in less than a decade (The World Bank, 2019).

As specified in Law 1341 of 2009 (or the ICT Law), in Colombia, the Ministry of Information and Communications Technologies (MinTIC, in Spanish) is responsible for designing, adopting, and promoting policies, plans, programs, and projects targeted at the ICT sector (MinTIC, 2018). This entity works in coordination with the country's Superintendence of Industry and Commerce, the Ministry of Industry, Commerce, and Tourism, and the Communications Regulation Commission to promote economic development in terms of new technologies and also increase the participation of actors interested in competing in the context of technological innovation and the digital economy.

A census carried out by the MinTIC, partnering with the Colombian Software and IT Industry Association (Fedesoft, in Spanish) and the National Training Service (SENA, in Spanish), revealed that

approximately 4,016 firms in Colombia performed telecommunications and software development activities in 2014. The majority of these firms are located in the central region of the country, especially in the department of Antioquia, with most of them (80%) headquartered in the city of Medellín. Their most representative activity is software development (29.7%), which is worth COP 989,768,275,000. However, the most offered service is data center management (SENA *et al.*, 2015), as observed in table 2.

Table 2.

Product/service offered by firms by department.

City/ department	Product/service						
	Development	**Data center**	**Software testing**	**Infrastructure as a service**	**Consultancy and implementation**	**Help desks**	**Others**
Bogotá	450	528	192	181	105	294	333
Antioquia	119	129	63	43	18	91	66
Atlántico	18	30	14	11	0	9	13
Bolívar	12	6	2	4	0	5	1
Caldas	13	16	8	9	1	7	3
Quindío	7	2	2	0	2	2	6
Risaralda	32	10	2	5	0	4	13
Santander	21	33	6	8	2	14	17
Valle del Cauca	51	49	25	21	8	21	34

Source: authors, with information from SENA *et al.* (2015).

Most ICT firms in Colombia are small, since only 280 report sales of over COP 3 billion annually. This is also evidenced in their number of employees, considering that more than 60% of these firms have less than 10 employees and only 293 of them have more than 50 employees, according to Carrillo *et al.* (2016), as observed in figure 1.
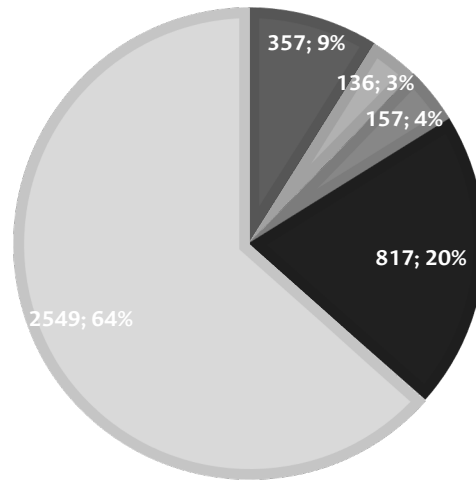
Figure 1. Share of ICT firms in Colombia by number of employees. Source: authors, with information from Carrillo *et al.* (2016).

Furthermore, Antioquia's broadband penetration rate was 16.85 and 17.17% in the second and third quarters of 2018, respectively, while Medellín reached 22.86 and 23.59% in the same timeframe. These figures, compared to those of Bogotá (22.43 and 22.75%, respectively), reflect Medellín's increased coverage and penetration. It should be noted that revenue from telecommunications services amounted to COP 4.23 trillion in the third quarter of 2018 (MinTIC, 2019). Additionally, the Latin American Development Bank conducted a study into broadband expansion in Latin America, where Medellín ranked first in terms of infrastructure within Colombia and 22nd in Latin America (Deloitte, 2017).

Finally, the existence of cloud services and contents, as well as of Industry 4.0 technologies (e.g., artificial intelligence, BigData, blockchain, internet of things, machine learning, and process automation), has increased the demand for Internet access and created the need for more and more users to be connected. This, in turn, has led to a greater dynamics and more investment in the ICT sector (CRC, 2017). As for Medellín, the center for the Fourth Industrial Revolution, according to the World Economic Forum, the evolution of these technologies represents an opportunity to present, to all firms, "different alternatives for digital transformation that allow them to enter the future with a clear competitive advantage" (Ruta N, 2019).

Innovation capabilities in the ICT ***sector and innovation indicators for Medellín,***
Colombia

In the ICT world, ICs should not only be considered a strategic option but also elements that are embedded and constantly executed in organizations. People's strength and skills make a big difference for firms to define their competitive advantage because IC is widespread and accessible to every organization (Hari *et al.*, 2014). A clear example of the importance of ICs is the case of firms such as Motorola, Nokia, and Blackberry. Some of their products became obsolete because their innovation strategy could not anticipate the rapid technological changes that were coming. Therefore, organizations must create strong management processes to maintain a competitive advantage and constantly foresee emerging technologies (Hari *et al.*, 2014).

Since Colombia is a developing country, building or strengthening IC in its production sector could be even more complex, since new firms often enter the industries with a delay. Moreover, it is clear that every innovation demands openness, willingness to take risks, and trust, and this latter is only built after a long relationship (Román *et al.*, 2013). This situation is decisive in Medellín as emerging ICT firms arrive to the market with a disadvantage in terms of integration. This is reflected in the time they take to start competing with their products or services (compared to firms in the same sector worldwide), which hinders their innovative activity. Hence, it is an observable fact that organizations that cannot maintain satisfactory IC levels over time show a weak performance in terms of competitiveness and financial results (Zollo & Raffa, 1988). However, "in the last two decades, a group of studies has been emphasizing that the information technologies (ITs) present a 'window of opportunities' for latecomer countries to catch-up by developing indigenous software industries" (Rousseva, 2008, p. 1008). Software production and development could be understood as an innovation activity, since it requires developing new products, which is why firms must possess ICs (Rousseva, 2008).

Within the framework of Colombia's public policy, the ICT industry has been strategically selected to project itself as a "world-class sector" with important challenges regarding competitiveness and increased sales and exports in the long term (Villalba *et al.*, 2016). According to the Albis *et al.* (2017), 140 firms developed innovations in the 2014-2015 period, for a total of 445 innovations, a very small number considering that this sector is made up of around 4,016 firms.

Moreover, the Technological Development and Innovation Survey (EDIT, in Spanish) IV to VII and the Technological Development and Innovation Service Survey (EDIT-S, in Spanish) II to V, conducted by the National Bureau of Statistics (DANE, in Spanish), reported that only 77 firms (out of 249) considered it important to have an R&D department as a source of innovation (OCyT, 2017). Regarding external relationships, such as strategic alliances, the survey revealed that during the 2014-2015 period only

110 firms in the sector worked in cooperation with other stakeholders to carry out innovation-related activities. Additionally, as stated by the OCyT (2017), the number of graduates in this area of knowledge from public and private institutions in Medellín was 1,675 in 2015, while in Bogotá this figure reached 4,604 graduates.

The aforementioned can be considered a flaw given that building strategic alliances allows firms to be more innovative, since they could acquire different types of knowledge through their interaction (Calderón, 2010). This is also possible through knowledge transfer, a tool that enhances a firm's learning capability, which, according to AlNuaimi and Khan (2019), can be understood as a strategy for organizations to improve their IC and, therefore, drive sales growth (Villalba *et al.*, 2016). Likewise, despite the recent growing application of concepts and methodologies related to innovation management at the organizational, sectoral, and regional levels in Colombia (Tarapuez *et al.*, 2016), investment by companies in innovation or R&D is complex because generally its returns are not immediately reflected (García-Manjón & Romero-Merino, 2010).

Given its constant evolution, the ICT sector must develop fast and agile strategies in terms of innovation because "the consequences of the technological changes drastically and directly impact the Information Communication and Technology (ICT) domain more fiercely than any other sector" (Hari *et al.*, 2014, p. 442). Consequently, firms in the ICT sector must integrate their ICs with the information technology capability (ITC), which refers to a firm's ability to use its own technological resources (Guisao *et al.*, 2017). This capability is characteristic of the dynamics in information technology (IT) business development. However, innovation development is not possible without strongly established capabilities, of which organizational and managerial capabilities tend to fail the most: management structures and styles are not conducive. Most of the failures are caused by poor planning and management strategies, rather than the lack of resources or poor technological choices (Finquelievich, 2010).

After analyzing the situation of the Colombian ICT sector, its increased technological complexity can be determined by the following three main factors (Rohrbeck, 2010):

- R&D globalization

- Specialization of R&D regions

- Convergence of technologies

In conclusion, despite the positive role that governments can play by designing strategies that allow knowledge accumulation in the region and that can be used by organizations (Fan, 2006), the

factors mentioned above have an influential position. Consequently, these factors must be considered so that strategies can be adequately incorporated in order to strengthen the competitiveness of the ICT industry. Other authors consider open innovation (OI) to be a key strategy for firms to develop ICs because it is "a knowledge management strategy [...] that aims at the efficient and effective creation of knowledge from different intra- and inter-organizational sources, as well as at augmenting learning capacity" (Adamides & Karacapilidis, 2020, p. 3). Besides, according to Capaldo *et al.* (2003), firms in the ICT sector should maintain a constant dynamic capability to cope with extremely rapid changes that require an innovative technological and management response and, as a result, successfully adapt to the environment.

Methodology (systematic literature review)

Under the SLR method, a literature search in scientific databases is performed to gather the existing information on a particular topic (Manterola *et al.*, 2013). It is an observational and retrospective research design that synthesizes the results of multiple primary studies based on evidence, given its rigorous methodology, and identifies relevant works to answer specific questions (Beltrán, 2005). Added to this, the content analysis method was used for the selection and identification of variables. The steps that we followed to conduct the SLR are described below.

Definition of the search strategy

Based on the research criteria, and keeping in mind the information required, we defined a search strategy that would allow us to obtain the most accurate results (Barderas *et al.*, 2009). Subsequently, we selected the databases relevant to our research topic and formulated the search equations using specific keywords aimed at answering and solving the research problem. Additionally, we included papers from other sources that we considered could contain important information for the SLR. Table 3 shows the results of this process.

Table 3.

Search equation for each scientific database use.

Database	Equation	Years	Results
Science Direct	TITLE-ABS-KEY (("innovation capacity" OR "innovation capability" OR "capacidad de innovación") AND ("ICT organizations" OR "organizaciones de TIC" OR "empresas de TIC" OR "ICT companies" OR "ICT business" OR "information and communication technology companies" OR "information and communication technology organizations" OR "ICT industry" OR "industria TIC" OR "ICT sector" OR "sector TIC")) AND (EXCLUDE (PUBYEAR , 2007)) AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR	2010-2020	22

	LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2010))		
Scopus	("innovation capacity" OR "innovation capability" OR "capacidad de innovación") AND ("ICT industry" OR "industria TIC" OR "ICT sector" OR "information and communication technology organizations" OR "ICT organizations" OR "organizaciones TIC")	2010-2020	19
Web of Science	TOPIC: (("innovation capacity" OR "innovation capability" OR "capacidad de innovación") AND ("ICT organizations" OR "organizaciones de TIC" OR "empresas de TIC" OR "ICT companies" OR "ICT business" OR "information and communication technology companies" OR "information and communication technology organizations" OR "ICT industry" OR "industria TIC" OR "ICT sector" OR "sector TIC")) Time frame: all years. Indices: SCI-EXPANDED, SSCI, A&HCI, ESCI.	2010-2020	5
ProQuest	ab(("innovation capacity" OR "innovation capability" OR "capacidad de innovación") AND ("ICT organizations" OR "organizaciones de TIC" OR "empresas de TIC" OR "ICT companies" OR "ICT business" OR "information and communication technology companies" OR "information and communication technology organizations" OR "ICT industry" OR "industria TIC" OR "ICT sector" OR "sector TIC"))	2010-2020	7
Redalyc	("innovation capacity" OR "innovation capability" OR "capacidad de innovación") AND ("ICT industry" OR "industria TIC" OR "ICT sector" OR "information and communication technology organizations" OR "ICT organizations" OR "organizaciones TIC") Total	2010-2020	13
Other sources	Papers from other search sources	2010-2020	4
Total			**70**

Source: authors, based on the SLR methodology.

Study selection

After the database search, we selected the papers that were more likely to respond to our research problem based on the information they contained, mainly their results (Moncada-Hernández, 2014). For such selection, we considered the following criteria:

- The journals in which the papers were published must be ranked in the Q1, Q2, Q3, and Q4 quartiles of the SCImago Journal & Country (SJC) Rank platform in order to make the research more rigorous and obtain quality results. Also, all the selected papers must be indexed in Scopus, regardless of the database from which they were obtained, since the SJR platform takes data from Scopus. Based on this criterion, 45% of the total papers were published in Q1 journals, 22% in Q3 journals, 20% in Q2 journals, and 13% in Q4 journals.

- Papers in the fields of social sciences, administration, finance, economics, computer sciences, electronic engineering, telecommunications, or systems were eligible since these areas are related to our research topic.

- Papers should address issues related to ICs in organizations, regardless of their sector.

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- It will be taken into account that the theoretical foundations of the studies are organizations with a technological base or the ICT sector.

We reviewed 70 papers published in 40 indexed journals; 30 of these were excluded because they did not meet the specified criteria. In the end, we selected a total of 40 papers, 35 of which were published in indexed journals.

Data collection

After searching and compiling the papers, we proceeded to analyze their content and identify the variables to be studied. To process the data, we created a database in Excel considering two types of data that we will refer to as "variables." Each variable is detailed below.

Paper characterization variables

The following variables help to recognize and identify each reviewed paper, thus making it possible to conduct a literature review with high quality standards and minimize potential biases:

- id
- Source
- Journal name
- Year of publication
- Journal impact factor
- sjr
- H-Index
- Paper title
- Area of knowledge
- Methodological design
- Data analysis method
- Population under analysis
- Is it a technology-based organization?

Relational variables for the identification and incorporation of ICs

The following variables were defined in order to solve the research problem:

- It associates IC with competitiveness
- Resource-based view?

- Variables identified in the papers (which were divided into three main groups: capability-related variables, knowledge-related variables, and cooperation-related and organizational variables)
- Variable definition
- Variable assessment method
- Variables that are causally related to the specified variable

Results

Based on the SLR and data automation process, the results for the two variables mentioned above are presented below.

Paper characterization variables

For the variable "year of publication," 2019 was found to be the year that mostly appeared (18%) in the selected papers published between 2010 and 2020, followed by 2016, 2014 and 2018 (13% and 10%, respectively), 2020 and 2017 (8% each), 2010, 2011, 2012 and 2013 (7% each), and 2015 (5%).

With respect to the variable "journal name," we did not observe a representative trend regarding their selection. However, the *Journal of Business Research, Journal of Cleaner Production, R&D Management*, and the *Venezuelan Management Journal* reported the most appearances (2 each one).

As for the variable "area of knowledge," the business, administration and accounting area was that with the highest percentage of papers published in related journals (77%). The other areas are included in the remaining 23%, as shown in table 4.

Table 4.

Areas of knowledge of the journals in which the selected papers were published.

Area	Number of papers	Share
Environmental sciences	2	5%
Computer sciences	2	5%
Social sciences	2	5%
Economics, econometrics, and finance	2	5%
Business, administration, and accounting	31	77%
Psychology	1	3%
Total	**40**	**100%**

Source: authors, based on the SLR methodology.

For the variable "methodological design," questionnaire-based survey was the most widely implemented technique (52%), followed by literature review (18%), interview (10%), analysis of state sources (5%), and the remaining seven methods, which together accounted for 15%. Regarding the variable "data analysis method," structural equation modelling was the most widely used (36%),

followed by the binomial logistic regression model (14%), comparative analysis of multiple cases (11%), econometric studies and open coding (7% each), and the ten remaining analysis methods, which together accounted for 25%.

With respect to "population under analysis," firms in the ICT sector were the most common study population (37%), followed by companies from other sectors and countries (18% each), small and medium-sized enterprises (12%), cities and start-ups (5%), retailers (3%), and university institutions (2%).

Regarding the variable "resource-based view," 45% of the studies consider such framework to be key for IC development. In addition, in 70% of the selected papers, firms' IC development is regarded as important to promote and strengthen competitiveness.

As mentioned above, the relational variables for the identification and incorporation of ICs were classified into the following three main groups, which address a specific need in IC development:

- Group 1: capability-related variables

- Group 2: knowledge-related variables

- Group 3: cooperation-related and organizational variables

The information obtained from the analysis for each group is detailed below for each group and presented in a tabulated way organized in 3 columns. The first columns indicate the name of the variable. The second column shows how many times the variable was used; it is an interesting criterion because it indicates the number of studies in which the A variable has been taken into account as an object or focus of study and this may indicate a trend towards the analysis of capabilities or the sector from this aspect or as a new source of knowledge development. The third column indicates the percentage corresponding to the repetition of each variable.

Group 1: Capability-related variables

This category groups the different variables that involve the development of different skills that contribute directly to increase the different constituent capacities. We identified 10 variables related to capability development in the selected papers, of which the most representative were technological innovation capability (63%), dynamic capabilities (11%), and R&D capability and improvisation capability (5% each). Table 5 provides a complete list of the capability-related variables.

Table 5.

Capability-related variables identified in the selected papers.

Variables	Times the variable was used	Share
Regional innovation capability	1	2%
Ability to export	1	2%
Dynamic capabilities	5	11%
Technological innovation capability	29	63%
Open innovation capability	1	2%
Ambidextrous capability	1	2%
Absorptive capacity	1	2%
R&D capability	2	5%
Improvisation capability	2	5%
Operational capabilities	1	2%
Adaptability	1	2%
Competitive capabilities	1	2%
10	46	100%

Source: authors, based on the SLR methodology.

In view of the above, the definitions of the most representative capability-related variables are presented below.

- Technological innovation capability: Defined as a firm's ability to drive innovation. This resource can be developed by separating the different organizational silos, improving the interpretive innovation processes, and using customers and employees as sources of innovation to facilitate organizational learning (AlNuaimi & Khan, 2019).

- Dynamic capabilities: This was the second most discussed variable in the selected papers. It refers to a firm's ability to accept changes and adapt to them through rapid learning. By means of knowledge absorption and integration and organizational learning, dynamic capabilities enable a different distribution and configuration of the firm's resources and skills to achieve novel results and, thus, a competitive advantage (Gutierrez-Gutierrez *et al.*, 2019).

- Absorptive capacity: It concerns a firm's ability to identify, absorb and understand transmitted knowledge and learn new concepts. It is understood as a firm's ability to assimilate and recognize external information and transform and adapt it to generate added value (Guisao *et al.*, 2017).

- R&D capability: It is the ability to produce new knowledge, whether through the exploitation of licenses or the local generation of knowledge (Fan *et al.*, 2019).

- Improvisation capability: Refers to a firm's ability to premeditatedly reconfigure its existing resources, skills and competencies in order to be competitive and adopt changes that allow responding to different situations that may arise in its environment (Zhang & Merchant, 2020).

Group 2: Knowledge-related variables

Within this category are those variables that contribute to the strengthening of knowledge or that correspond directly to knowledge resources. We found nine knowledge-related variables in the selected papers, of which the most representative were knowledge transfer (27%), knowledge (20%), and intellectual capital (13%), as observed in table 6.

Table 6.

Knowledge-related variables identified in the selected papers.

Variables	Times the variable was used	Share
Quality of links	1	6%
Intellectual capital	2	13%
Anticipatory skills	1	6%
Knowledge	3	20%
R&D cooperation	1	7%
Knowledge management	1	7%
Proactivity	1	7%
Technological scouting	1	7%
Knowledge transfer	4	27%
Total	**15**	**100%**

Source: authors, based on the SLR methodology.

Based on the above, the most representative knowledge-related variables are described below.

- Knowledge transfer: Can be defined as a learning process or method through which knowledge is gained to drive innovation (Hansen *et al.*, 2020). In this process, knowledge is acquired and delivered by means of various organizational, technological, and individual components (Podrug *et al.*, 2017).

- Knowledge: Besides being one of the most important variables in all types of capabilities, it is one of firms' main resources. It refers to new concepts or processes learned through different means such as R&D or internal or external cooperation with other stakeholders (Grillitsch *et al.*, 2015), and concerns the "know-how" and "know-why" of processes such as adaptation, experimentation, development, design, and R&D for products, processes and services (Figueiredo & Brito, 2012).

- Intellectual capital: it refers to resources linked to human capital, which are the basis for the generation of sustainable competitive advantages (Ugalde-Binda *et al.*, 2014).

Group 3: Cooperation-related and organizational variables

This category corresponds to the variables that directly interfere with the performance of the organization and the establishment of networks and cooperation links. We identified 13 cooperation-related and organizational variables in the selected papers, of which the most representative were cooperation networks (25%), followed by organizational performance (15%), and cooperation-based policies (10%), as shown in table 7.

Table 7.

Cooperation-related and organizational variables found in the selected papers.

Variables	Times the variable was used	Share
Organizational capability	1	6%
Clusters	1	6%
Organizational performance	3	17%
Organizational strategy	1	6%
Collaborative strategies	1	6%
External technology sources	1	6%
Open innovation	1	6%
Leadership in innovation	1	6%
Cooperative networks	5	29%
Quality management	1	6%
R&D cooperation	1	6%
Total	**17**	**100%**

Source: authors, based on the SLR methodology.

In view of the above, a brief description of the most representative cooperation-related and organizational variables is provided below.

- Cooperation networks: Refers to the networks and alliances built by the different stakeholders and firms to make progress in knowledge generation and achieve innovation (Duysters & Lokshin, 2011).

- Organizational performance: Concerns the firm as a whole, i.e., its ability to make improvements based on its management activities, competitiveness, and competence to generate innovative results (Svensson *et al.*, 2019). It is defined as the obtained results (whether financial or not) that have an impact on the organization (Guisao *et al.*, 2017).

Discussion and conclusions

Firms in the ICT industry make up one of the largest communities of the Fourth Industrial Revolution in Colombia, and Medellín, as its epicenter in Latin America, must now competitively respond to the emerging ICT innovations. Thus, the ICs of these organizations have become a key factor in their innovation strategy for them to face changes and innovate their services or products. This suggests that a firms' improvisation capability represents an essential tool for the ICT sector.

According to the innovation indicators, ICT firms do not consider building alliances or establishing cooperation networks to be important in order to innovate. However, according to the results of the SLR we conducted, this causal capability is necessary for organizations to generate knowledge and have a greater opportunity to achieve innovative results. If no alliances or cooperation agreements are forged, developing their R&D capability becomes more complex. Hence, the ICT sector in Medellín must be aware of this aspect.

Moreover, Colombia (specifically Medellín) has limited human resources trained to make contributions on this matter. Therefore, the local academic offer in this field must be improved, and strategies created to foster human talent in the ICT industry. Human capital is one of the most important causal variables because it is where knowledge —a fundamental factor to promote ICs— accumulates. Thus, the ICT sector should also increasingly work on this latter factor. As a recommendation, this industry could develop a strategy, in conjunction with the Ministry of Education, MinTIC and Minciencias, in order to strengthen the human capital qualified in this area.

Another aspect to highlight is the fact that the ICT industry may be regarded as a sector that needs to strengthen and incorporate greater elements of the R&D capability because a very low percentage of ICT firms think it is relevant to have a R&D department. In addition, these firms do not consider the allocation of resources for innovation to be important. Consequently, it becomes crucial to emphasize that the R&D capability is one of the most necessary to promote knowledge and directly achieve innovative results. Likewise, ICT firms should promote and give greater importance to this paramount aspect.

Nevertheless, due to the economic contribution of this sector to the country, the improvisation and dynamic capabilities, for instance, may play a greater role. In addition, they could allow this industry to stay in the market and come forward as a sector that enables the country to improve its capabilities and support the growth of the other economic sectors.

Furthermore, even though Medellín concentrates a large number of the country's leading organizations in terms of research, development and innovation, there are few studies into ICs (Arias &

Castaño, 2014). Therefore, it is necessary to review, based on previous studies, which ICs local firms have been able to develop, given the large concentration of firms dedicated to science, technology, innovation, research and development activities, as well as technology-based ICT firms. This is because the results of the SLR we performed show that only 37% of the selected studies used the ICT sector as their study population.

Regarding the other results obtained from the SLR, the fact that 2019 was the year with the highest number of publications suggests that the study of ICs is gaining more and more relevance in the business, administration and economy field. Moreover, a significant percentage of the selected papers indicates that competitiveness is highly strengthened by developing ICs. Also, they state that, from the resource-based view, human capital and knowledge are a firm's essential assets for IC development. These two aspects could be separately analyzed in future research in the ICT sector.

Taking into account the results sent from the SLR, where the relevance of the variables is highlighted, technological innovation capacity and dynamic capacities are proved to directly influence innovation capacity. Then, knowledge capacity, knowledge and intellectual capital are directly transferred to learning capacity. To finish, cooperation networks support the performance of strategic planning and R&D capacity. It is appropriate to indicate that these variables are those that directly impact the Colombian ICT sector. Consequently, said sector must implement strategies to increase their application, according to the data provided by OCyT (2017), where lower results were found for companies that carried out activities related to innovation. Hence, this group of firms should consider the incorporation and implementation of an R + D + i department within their organizational structures, as well as the establishment of strategic alliances, cooperation networks and specialized staff in this area of knowledge.

In accordance with the above, conducting an analysis based on these causal variables in the ICT sector represents a strategic aspect, given the demands and evolution of the market for this industry. In addition, its consideration for development and improvement is representative. In the execution of innovation capacities, this leads companies directly —through the information provided from the analysis of these capacities— to make strategic decisions and identify and strengthen specific aspects related to ICs, thus contributing to this industry's growth and development at a local, regional and national scale, with which better results can be obtained in innovation, making of this sector, as indicated by the strategies and development plans, a world-class industry (Villalba *et al.*, 2016).

Despite the above, it is relevant that exports have been one of the least frequent results in the study of the ICT sector from the perspective of innovation capacities, considering that exports can be stimulated from organizational capacity or through planning and resource allocation, stimulating the

establishment of alliances and cooperation that allow strengthening R&D and the transfer and exchange of research results, as well as technologies and knowledge, which will later become export agreements or negotiations.

The foregoing could be an advantage for the city of Medellín, since as the epicenter of the Fourth Industrial Revolution and being the "Valle del Software," and with the help of *Ruta N*, the amount of possible international relationships that could be established from the growth of innovation capacities by the ICT sector would be strongly notable.

Based on current figures on innovation for this city and the most relevant variables of the SRL, it would be possible to propose and implement policies that allow and improve the establishment of cooperation networks between local and multinational companies, the State, higher education institutions, and companies in the ICT sector. These networks must seek not only the establishment of R&D strategies and the capture of resources, but they must also be focused on the transfer of knowledge and the increase of dynamic capacities, from which intellectual capital and organizational performance will surely be improved.

In this way, focused on the aforementioned factors as the main variables identified in the SRL, it is possible to work a large part of innovation capacities and, specifically, in the establishment of cooperation networks, which is one of the aspects that will allow Medellín to continue being recognized globally for its technological capacity and for having one of the main sources of GDP within the local ICT sector.

Finally, firms should recognize their innovation capabilities because, although some of them have the necessary skills to strengthen them, they have not yet identified their potentialities. Hence, these firms are not aware of the importance of devising strengthening strategies to achieve a competitive advantage in an industry that, due to its characteristics, is called upon to innovate and adapt strategically to changing environments. We emphasize that this type of study not only makes contributions to a specific region but also reflects on the panorama of a country such as Colombia, which is currently developing initiatives to strengthen its industries, specifically the ICT sector.

This work focused on the city of Medellín for three reasons. First, the importance of its ICT sector over other regions of the country, based on the number of organizations located in the city when compared to those found in other regions, with the exception of Bogotá. The second is that Medellín is carrying out different strategies to communicate its ICT sector as an international benchmark. The third reason is based on the deployment of other strategies such as *Valle del Software* and *Ruta N*, which allow us to continue nurturing and strengthening the sector. Besides that, the effort that this sector and the

city are making for digital-skills training in order to strengthen the intellectual capital in this branch of knowledge is one to highlight.

As part of future works, the literature search could be extended to more local and international databases, re-structuring the search equations and changing the time intervals in order to obtain broader and more up-to-date results.

One of the main limitations for the development of this study was finding that there are not enough current studies and data for the ICT sector, which is an inconvenience when carrying out a more specific analysis of the current situation of this industry.

Disclosures

Authors declare no institutional or personal conflicts of interest.

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