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articles

Factors Influencing 4.0 Technology Adoption in Manufacturing SMEs in an Emerging Country

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Purpose

By considering the lack of studies of the factors that influence the adoption of 4.0 technologies in manufacturing SMEs, this study proposes a model that examines the aspects that motivate, benefit and obstruct the implementation of emerging technologies, as well as the role of the institutional environment, for a developing country.

Methodology

A qualitative approach and interview method were used to study 4.0 technologies in the "core" productive processes adopted in 25 SMEs. The gathered data were analysed and processed in NVivo 12 software.

Results

Two groups of categories (nodes) were obtained, within which related subcategories (subnodes) were located. These two groups are existing and emerging categories, which reflect the aspects that motivate, benefit and obstruct the adoption of 4.0 emerging technologies.

Conclusions

The identification of an emerging variable in the study of inhibitors and facilitators of the adoption and implementation of 4.0 technologies is a valuable contribution because it allows us to account for the problematisation of financing as an important variable in the processes of introduction into Industry 4.0 for SMEs. This proposal may facilitate public policies at regional and national level to promote and advance in this area of innovation for SMEs.

Introduction

Industry 4.0 and technologies derived from that notion have demonstrated adoption ease for large firms and services small and medium-sized enterprises (SMEs) (Masood & Sonntag, 2020), especially in developed countries. In addition, the study of the implementation of technologies in SMEs has several lines of work. There is also a large body of literature dedicated to the study of the adoption, implementation or acceptance of mature technologies, such as e-business or ICT in general (Bakar et al., 2020; Cassetta et al., 2020). Likewise, although the literature recognises the growing interest in not only digital technologies but also in the smart factory concept that is associated with Industry 4.0, few manufacturing SMEs have achieved the proper transition to this technological evolution (Nwaiwu et al., 2020), even when it enhances innovation and competitiveness for this type of organisation (Dewi et al., 2020; Teh & Kee, 2020). Another line of work has attempted to account for specific cases of the use, implementation or adop-

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tion of specific parts of Industry 4. 0, such as IoT (Osman et al., 2020), cloud computing (Alismaili et al., 2020), big data (Liu et al., 2020; Tien et al., 2020; Vitale et al., 2020), blockchain (Nuryyev et al., 2020), and additive manufacturing (Angrisani et al., 2020).

The role of SMEs in strengthening economies has been recognised to have an impact on GDP, employment generation and the creation of conditions for strengthening chains, especially in Latin America (Betov, 2020). According to figures from the National Administrative Department of Statistics (DANE), SMEs represent more than 90% of the national productive sector and generate 35% of the GDP and 80% of employment in all of Colombia (DANE, 2020). Therefore, SMEs are considered to be the basis of modern economies, and their momentum and growth is associated with economic growth in the long term (Ardic et al., 2011). Therefore, considering that the business transformation of the last 60 years in Columbia has been strengthened by the impact of SMEs as drivers of this economy (Moreno, 2019), their weaknesses must be recognised, especially in their ability to adapt and make decisions.

Some studies have attempted to identify the critical success factors, risks and opportunities of the so-called Industry 4.0 in SMEs from a managerial and strategic perspective (Dewi et al., 2020; Moeuf et al., 2020; Teh & Kee, 2020). Although most literature is located in developed countries (Cimini et al., 2020), there are also precedents for other countries, apparently not classified in industrialised or high-tech ones (Dutta et al., 2020; Ingaldi & Ulewicz, 2019; Nwaiwu et al., 2020; Sahi et al., 2020). However, few studies have used in-depth interviews with entrepreneurs of SMEs located in Latin America to account for the facilitators and inhibitors of the incursion into these technologies from the internal and external perspective of the organisation.

Some of the few studies that have attempted to approach this topic include Rojas-Berrio et al. (2020), where there is concrete data in the form of qualitative analysis of 22 SMEs, who were implementing 4.0 technologies for their business processes in 2019. However, a classification is not offered in this study. Meanwhile, Obermayer et al. (2022) conduct research on how Hungarian manufacturing companies interpret two important factors—technology and human resources—in terms of Industry 4.0. Through 23 semi-structured interviews with entrepreneurs, they determine key evidence for the adoption of technology and human factors as driving forces and barriers in terms of Industry 4.0 implementation. However, this study lacks research of other factors that have an influence in the implementation of 4.0 technologies.

Huang et al. (2019), through semi-structured interviews, approached entrepreneurs of 49 Peruvian SMEs in the manufacturing sector in search of the schematization of factors that hinder the implementation of 4.0 technologies. The authors conclude that the lack of financing, lack of advanced technology, poor management vision, and lack of skilled labour can hinder the process of incursion into industry 4.0. Despite including obstacles that are important in the process, this work lacks a critical view of how the economic, political, social and technological context influence adoption, and how the networks and collaboration between public and private institutions can be useful for the incursion in the 4.0 Industry. Finally, Han & Trimi (2022) carried out research in Greece, where some challenges are presented as inhibitors for the adoption of 4.0 technologies. However, the current scenario and the impact of these inhibitors on the technological transition of SMEs in this country are not studied in-depth.

There is still a lack of information regarding the level of adoption of 4.0 technologies by SMEs in the case of advanced or emerging technologies, where there are no concrete figures for SMEs beyond digital technology management indicators, which show that there is an evident gap in strategy, governance and human capital (CCB-MINTIC, 2018). In this sense, it is evident that there is an absence of literature related to the level of maturity of these technologies in SMEs located in Latin America. Consequently, it is of great importance to develop studies of the business networks formed by these companies to precisely identify the level of adoption of 4.0 technologies to move towards a competitive model that promotes productivity and sustainability supported by Industry 4.0. In this way, the data and information will facilitate the design of strategies by the government and the business sector to facilitate the introduction of companies in this industry (Amaya, 2019).

In this sense, and given the absence and difficulty in accessing preliminary studies and figures on the level of adoption of 4.0 technologies in Colombian SMEs, the implementation of a qualitative methodology is important because it allows a closer approach to entrepreneurs, facilitates the characterization and classification of the problem, and facilitates the extraction and analysis of a large number of elements by allowing the responses of the interviewees to be open-ended.

This article seeks to address this lack of research by answering the following research question: What are the factors that influence the adoption of 4.0 technologies in manufacturing SMEs in Colombia? For this purpose, this paper has first reviewed the literature to give an approach to the topic, showing the concept that is taken for this paper. Additionally, three currents of study are presented, with the most representative authors of each one and at the same time, and four propositions are addressed to contribute to the topic. Likewise, the problem will be approached from an inductive and qualitative perspective. Subsequently, after an analysis of the in-depth interviews that were conducted for this study, using the NVivo tool, the results are presented through a series of existing and emerging categories. The discussion section will then present a contrast between the literature and results. Subsequently, the limitations of this study are presented, which are related to the sample chosen, and the theoretical and practical implications are then described. We draw our conclusions in the final section and make a number of recommendations for future research.

1. Literature Review

The literature review has three sections and is a result of a bibliometric analysis, as described in methodology section. The first section is designed to provide theoretical foundations to define the conceptual notions on which this study is based. The second section review the literature of

the use, management and adoption of technology in SMEs. Finally, the third section review this topic in emerging countries, which is the context of this study. Each section sets out the propositions that are raised and addressed by this study.

1.1. Theoretical Foundations

Industrial and technological revolutions can be viewed from many different perspectives, such as from the viewpoint of artifacts, technology itself, processes and actors. In the first instance, the artifact perspective proposed by Toffler & Toffler (2006) establishes that there are three moments that account for technological progress: the first being the wealth generated by agriculture, the second by industrialisation and the third by the intensive use of knowledge. Second, from the technological perspective, Ispizua (2018) identifies four moments: (1) refers to the creation of large companies with steam engines (in the United Kingdom initially); (2) involves other types of energies (e.g., electricity and oil) and the emergence of remote communications via telephone, telegraph, radio, and television, which led from the labour field to a specialisation of work; (3) was the migration to renewable energy, the clear integration of communications and the decentralization of processes; (4) which is the contemporary one, has processes and devices that lead towards intelligent cyber-physical systems. Third, from the perspective of processes, four trends are evident: the first is mechanization, the second is mass production, the third is microprocessing in production, and the fourth coincides with the previous, technological trend, in the conception of cyber-physical systems (Bothof & Hartmann, 2013). In the fourth instance, from the perspective of the actors involved in the fourth Industrial Revolution (4.0), which was formalized as a global trend for the first time at the Hannover Fair in Germany in 2011 (Cimini et al., 2020), human interaction is transversal and involves the capture of information and its digital trace, the generation of algorithms for decision making and, therefore, the discovery of relevant information. This is how the concept of Industry 4.0 arises, which takes advantage of communication technologies and connected devices to bring companies closer to a better productive performance. This model seeks to develop organisations that have "intelligent processes" which are based on their interconnected work thanks to the web.

This concept has been widely discussed by authors who have tried to capture some distinctive features of this disruptive industry. Thus, Kagermann et al. (2013) indicates that Industry 4.0 encompasses concepts such as smart factories, cyber-physical systems, self-organisation, new distribution systems and corporate social responsibility. Senvar & Akkartal (2018), meanwhile, indicate that this industry includes, in addition to cyber-physical systems, information and communication technologies, big data, cloud computing, simulation, among others. Accordingly, Wee et al. (2015) conceive Industry 4.0 as the digitization of the manufacturing sector, where cyber-physical systems and data analysis are required.

Sung (2018) makes mention of four disruptions that drive industry 4.0: the outstanding growth of the amount of data, computational power and connectivity; the emergence of business intelligence and data analytics; new forms of human-machine interaction; and improvements in the transfer of digital instructions to physical artifacts, such as robots. Additionally, Gubán & Kovács (2017) highlight that the essence of Industry 4.0 is related to the introduction of intelligent systems that are interrelated, which allows people, machines and equipment to communicate with each other:

> *Industry 4.0 is supported by the following advances, firstly "Internet of Things" (IoT), advanced and collaborative robotics; Big Data, Data Science or Data Mining; Cloud Computing, Artificial Intelligence and Automatic Learning (Machine Learning), Additive Printing or 3D, Virtual Reality and Augmented Reality, and other related technologies such as the integration of computer systems vertically (with suppliers or users) and horizontally (with other collaborating companies in the sector)*. (Motta et al., 2019, p. 6)

There is no consensus or clarity of the conceptual delimitation of Industry 4.0 (Nwaiwu et al., 2020). In this work, we assume that artificial intelligence is at the core of Industry 4.0, which derives decisions in real time with possible applications such as robotics (from a perspective of autonomy, to differentiate it from the traditional), Internet of Things (IoT), virtual and augmented reality, cybersecurity and biometrics, cloud computing, big data, analytics and simulation; as well as other decisions that do not necessarily have to be made in real time, as is the case of additive manufacturing (e.g., 3D printing in more than one material), and laser or plasma cutting. This leads to our first proposition:

> *Proposition 1: There is diversity 4.0 Industry technologies that have been implemented by SMEs.*

1.2. Use, Management and Adoption of Technology in SMEs

In the literature referring to the use, management and adoption of technology in SMEs, and specifically 4.0 technologies, through an analysis of co-occurrences among the citations, three currents can be recognised: the first refers to collective-learning processes, the second to information management in SMEs, and the third to technology as a function of the organisation's strategy. In the first, Keeble et al. (1999) work studies technology-based SMEs and, from a descriptive perspective, the nature and scope of collective-learning mechanisms and, consequently, the generation of networks in these organisations.

The second current is information management in SMEs. The first antecedents on the subject are the works of Powell (1992) and Iacovou et al. (1995). In the former, although no direct reference is made to SMEs, it justifies why the scope of an organisation's strategy should be mediated by investment in technology, which basically has to generate competitive advantages. The second focuses on the adoption of technologies for electronic data interchange, which is a document prepared at the beginning of the Internet but is the first precedent in reviewing the adoption (Iacovou et al., 1995).

The third current shows how technology should be a function of strategy. Brynjolfsson & Hitt (1998) analyse the relationship between organisational design and technology adoption in areas such as ways of working and how this affects the demand for technology in organisations. The second seminal work in the latter current is that of Raymond & Bergeron (2008) in which, from the same approach, e-business for SMEs is reviewed from the strategic contingency approach. Although there are previous precedents that address the use of this type of technologies in them, this is the document that raises it from the capabilities of SMEs in alignment with the strategy. This leads to our second proposition:

> *Proposition 2*: *Companies implementing 4.0 technologies meet motivations, benefits and obstacles during the process, which are associated with collective-learning processes, the second with information management in SMEs, and the third with technology as a function of organisational strategy.*

According to the mapping of Co-authorship Countries, although Germany was the first place in the world where the study and policies of 4.0 technologies were clearly introduced, in the field of SMEs, the United Kingdom is the central node of academic collaboration between countries. This situation is also evident in the Citation Country behaviour and in the Bibliographic Coupling Countries index, although in the latter the most recent node is in Indonesia. Likewise, according to the Co-occurrence index keywords mapping, there are five clusters in the subject, the first dedicated to thinking about the competitiveness of SMEs, the second to commercial issues, the third to technological adoption, the fourth to strategic planning and the last to information management.

The Citation Sources and Citation Authors behaviour show great dispersion between sources and authors, respectively. However, in first measure, the bibliographic coupling documents indicator does show commonalities between the sources cited by the authors with collective learning being the common point with the largest and oldest node size (Keeble et al., 1999), and industrial management of SMEs (Moeuf et al., 2017) is the most recent with significant size. In addition, in the Co-citation cited authors has three main groups, the first shows the methodological line to address technological adoption (Davis, 1989; Hair et al., 2013; Venkatesh et al., 2003), the second shows seminal works on information management in SMEs (Iacovou et al., 1995; Powell, 1992) and the third shows works about technology in coherence with strategy and organisation in SMEs (Brynjolfsson & Hitt, 1998; Raymond & Bergeron, 2008). Likewise, in the bibliographic coupling sources presents commonalities in the Journal of Small Business Management and in the Journal Processes, although in the Co-citation cited sources has a greater variety of journals.

1.3. 4.0 Industry in Emerging Countries

There are various classifications and notions of what an emerging country or market is, but for the purposes of this paper we will consider the classification indicated by FTSE Group (FTSE Russell, 2022). In this classification, a distinction is made between advanced and secondary emerging markets—the former being middle to high income with incipient or medium market development, while the latter may have medium to low income and intermediate market or infrastructure development. Consequently, this section presents recent literature relevant to the problem being addressed and which represents the state of the art in Industry 4.0 for SMEs in this economic context.

From the three currents found in bibliometric analysis, more recent works have been derived that have empirical validations which aim to account for the critical success factors, opportunities and risks of Industry 4.0 in SMEs in emerging countries. First, specifically from a Delphi type panel of experts with an Abaque-type scale, Moeuf et al. (2020) show how the main difficulties are the lack of expertise, skilled workers and short-term strategic thinking. These obstacles were also noted by Huang et al. (2019) in Peru. However, this study was done in a context in which economic development has a favourable public policy that aims to help SMEs to be competitive and to implement emerging technologies to become more competitive. The panel of experts shows three types of experts: academics, SMEs managers and experts in industry 4.0. However, they do not tell us if the SMEs selected for the time of the study had implemented this type of technology.

Second, Nwaiwu et al. (2020), based on a literature review process and a scale applied to 134 SMEs, show the influence on the management model of Industry 4.0 of the following variables: Strategy, Organisational Fit, Operations, Human Resources and Competitiveness. The latter is paradoxically the only variable that has no influence on the model. Similarly, this model does not clearly describe the influence of factors external to the organisation that could be determinant for the implementation of emerging technologies in this type of company.

Ingaldi & Ulewicz (2019) conducted a three-phase study, which reviewed the current state of SMEs in Czestochowa Industrial District for 2018. The problems encountered for this transformation were investigated in interviews with experts, and in a third phase they captured the opinion of businessmen and entrepreneurs focusing on the willingness to use shared resources to insert 4.0 technologies in their processes. The findings show that both the lack of financial resources and specialised support greatly influence the process of productive transformation. This leads to the following subpropositions:

> *Proposition 2.1: The lack of skilled workers is one of the main obstacles when implementing 4.0 technologies in SMEs, and the technology as a function of organisational strategy.*
> *Proposition 2.2: Financial support for implementing 4.0 technologies in SMEs is crucial to develop successful projects*

Similarly, Dutta et al. (2020) investigate the priorities of digital transformation for SMEs. The authors account for the adoption gaps based on a comparison of the current sophistication and competencies, with the expectations and purposes of adoption. As a result, they propose a method for assessing the maturity for technological adoption of 4.0 technologies.

In Greece, Han & Trimi (2022) stated that some of the difficulties in implementing 4.0 technologies in SMEs are technological, trust and big data challenges. They proposed the application of road mapping technologies, enhancing collaboration, standardization with partners and the improvement of big data platforms as possible solutions. In China, Wang et al. (2021) argue that, despite the difficulties and costs, SMEs have the enthusiasm to see the benefits and positive impacts of digital transformation with 4.0 technologies. The most important are flexibility and cost reduction, the latter being a relevant variable that is also found in Malaysia and Nigeria (Gbadebo et al., 2019). This leads to the third subproposition:

> *Proposition 2.3: The perceived benefits of implementing 4.0 technologies are flexibility and cost reduction.*

In Colombia, support for SMEs is considered in Article 333 of the Political Constitution of Colombia (1991), due to their leading role in the development of the country's socioeconomic system (Moreno, 2019). One of the supports that can help the industry is the implementation of a major support in the 4.0 industry. The World Economic Forum (WEF) (2018) points out that potential for interconnection can help industry. However, only 25 countries in the world are well positioned. In the Colombian case, the SMEs would benefit from the implementation of industry 4.0 processes, no matter the sector. In total, 39% of Colombian SMEs say they need to have knowledgeable personnel in digital marketing and 84% believe that digital and social network skills are important when hiring new employees (Dinero, 2018). Serna-Gómez et al. (2020) identified that of the country's micro and small businesses, 26.3% have access to the Internet, 5.7% have social networks, 7.4% engage in e-commerce and 10.9% purchase supplies. With regard to the most important digital challenges in SMEs, they point out that 58% of companies do not have personnel trained to perform ICT tasks, 12% do not use any digital tools, 39% said they needed staff with digital marketing skills, 33% mention that with digital tools they seek to promote their products, 39% said that they manage social networks and 30% web pages and 33% of the companies do not have any systematized process. Additionally, the main benefits of the industry 4.0 are a higher productivity, a more efficient decision making, an optimal and integrated production processes, a massive and personalized production, a direct communication between clients and organisations, a reduction of production time, percentage of defects in the processes and production costs, also an improvement in efficiency and (finally) an improvement in internal communication.

Rojas-Berrio et al. (2020) point out that there are three phases for the implementation and adoption of 4.0 technologies, which begin with the establishment of physical infrastructures for the use of the information derived from automation to reach real-time decision making. Nevertheless, in SMEs, the implementation or insertion of this type of technology in other contexts has been previously studied. This suggests that this is a successful process to the extent that the factors internal and external to the organisation converge to achieve this challenge (Cimini et al., 2020; Dutta et al., 2020; Peukert et al., 2020; Vitale et al., 2020).

2. Methodology

Given the nature of the problem, it will be reviewed from the interpretative paradigm with an inductive approach, which is based on a documentary research strategy and in-depth interviews. The secondary sources derived from the documentary research contributed to the delimitation of the problem and the justification of the context with data from official and non-official sources, and arbitrated and non-arbitrated academic sources, while the in-depth interviews allowed validation in the field of concern.

2.1. Documentary Research Strategy

The theoretical approach presented in the literature review follows an exploratory documentary methodology, which is focused mainly on performing a bibliometric analysis of the academic contribution to the relationship between 4.0 technologies and SMEs. This exercise was supported in the bibliometrix package, which is part of the R-Studio software.

Aria & Cuccurullo (2017) state that bibliometrix allows the user to perform different descriptive analyses, build collaborative networks and identify conceptual structures of the scientific literature (i.e., databases imported from Scopus, Web of Sciences, PubMed or Cochrane, among others). Additionally, the web application biblioshiny was used, which incorporates the source code of the statistical package with the interactivity of the web environment to facilitate visualization for non-coders.

SMEs and technology 4.0, and their related thesaurus, were defined as keywords in the Web of Science with the following search query (TITLE (SME OR {Small and medium-sized enterprise} OR {Small enterprise} OR {medium enterprise} OR {medium enterprise}) AND TITLE (technology OR 4.0 OR ai OR {artificial intelligence} OR IOT OR {Internet of Things} OR AR OR {augmented reality} OR vr OR {virtual reality} OR {3D printing} OR {big data} OR {block chain} OR {block chain} OR {additive manufacturing} OR {cloud computing} OR {cloud computing})). A total of 147 documents published since 2001 were analysed, concentrating on the participation of 382 authors and 120 indexed journals. This documentary analysis strategy also allowed the recognition of the seminal literature of the area by analysing the sources cited by the documents.

2.2. Interview Strategy

In consideration of the inclusion and exclusion criteria for what is considered for this research as an SME in Colombia, Decree 957 of June 5, (2019), issued by the Ministry of Commerce, Industry and Tourism was followed, which regulates the classification of micro, small, medium and large enterprises, taking into account the criterion of gross sales, assimilated to the income from ordinary annual activities, in accordance with the provisions of Article 2 of Law 590 of 2000, amended by Article 43 of Law 1450 of 2011. Meanwhile, an enterprise is considered as an organisation that is in the process of being constituted but with a validated business plan and at least a minimum viable product.

The criteria of rigor and sample size considered the approaches proposed for it in the previous methodological lit-

erature (Kornbluh, 2015; Robinson, 2014; Salgado, 2007). Consequently, they were recorded and transcribed faithfully, and open, selective and axial coding was done (Strauss & Corbin, 2008). In addition, the snowball strategy and in total 25 SMEs were addressed and interviewed by the end of 2019 (the information is detailed in the following subsection).

2.3. Participants

Through the contact made to the public and private representation offices in Colombia, 25 interviews were carried out with SMEs involved in the adoption of 4.0 Technologies in "core" productive processes. Once the established filters are in place, a total of 22 SMEs and enterprises that have appropriated new technologies or base their business models on the future implementation within their value chain were found, either from a manufacturing or service perspective. General data of the enterprises are given in Table 1.

2.4. NVivo 12 Analysis

The analysis of the interviews was developed based on a comparison between the existing literature on the implementation of 4.0 technologies in SMEs and the findings obtained from the coding of the in-depth interviews. With this comparison, similarities and differences were found between the existing research on Industry 4.0 and the emerging patterns of the findings (Corbin & Strauss, 2008).

Initially, regarding literature analysis, some ideas, concepts and relevant conclusions about the adoption of Industry 4.0 technologies in SMEs around the world were identified. Subsequently, the in-depth interviews were analysed in NVivo 12 software. First, the transcripts were automatically coded under six categories representing the main themes addressed. These were: implementation of 4.0 technologies, obstacles to implementation (internal and external), funding, institutional environment, motivations and benefits. A second coding process was carried out to obtain a set of subcategories on which relevant findings were identified. The subcategories obtained were subsequently contrasted with the findings in the literature, following the methodology of Glaser & Strauss (2009) with respect to theoretical coding. In this sense, similarities were identified between the experiences of SMEs during their process of adopting 4.0 technologies, as recorded in the literature, and those reported by the SMEs analysed in this study.

3. Results

Two groups of categories (nodes) were obtained from the coding of the interviews, within which related subcategories (subnodes) were located. The following section presents these findings, considering that the two groups of categories correspond to existing and emerging categories or subcategories. The former refers to those codifications made on the interviews, which are already documented in the literature review. The emerging categories correspond to those that have not yet been problematised and studied and, therefore, would constitute a contribution to the literature by the present study.

3.1. Existing Categories

The findings show the name of the categories and subcategories obtained, the authors that have studied these topics, the codifications made in NVivo 12, and one Verbatim. Table 2 shows the findings for the 4.0 technology implementation category. From this category, nine relevant subcategories were obtained. For *cloud computing* more than 50% of the companies that we analysed have adopted this technology. The interviewees report an increase in the accessibility of information thanks to the portability that this technology offers. Regarding *Sensors and Internet of Things* some of the companies that have implemented IOT in their processes highlight that thanks to this technology it is possible to obtain information in real time. This has allowed them to improve efficiency and have control over some processes such as machine maintenance, personnel response to customer requests, sales and machine inventory. The use of *Radio Frequency Identification* (RFID) was reported for the management and control of inventories, from the moment that the raw material is received to the delivery of the final product.

Some of the uses of *Robots* in SMEs are related to the automation of certain tasks to increase their efficiency, reduce execution times and possible mistakes that a person could make during the development of the tasks. Only one company had implemented *augmented reality* and the advantages that they reported are related to the possibility of bringing together the real context with specific digital information. The companies that have implemented *3D* printing highlight its advantages compared to the design of prototypes, assemblies or parts. They mention that thanks to the use of this technology, it is easier to customize products, in aspects such as shape or size. The interviewees expressed the implementation of *Big Data* for the analysis of large amounts of data, which may be obtained from intelligent platforms or products that companies have already adopted. Those entrepreneurs who have adopted *artificial intelligence* use it for the analysis of large volumes of data to detect patterns and predict consumer behaviours. Finally, although *Blockchain* technology was mentioned less frequently by the interviewees, it was related to the certification of different types of documents and electronic records.

Table 3 shows the findings for the obstacles category. For the *Lack of qualified staff* subcategory, interviewees report that university education is insufficient due to the lack of teaching certain skills that are necessary for the management of new technologies in SMEs. Additionally, education at universities is very theoretical and not very practical. In the *Lack of knowledge of technologies and technical problems* subcategory some interviewees reported that companies do not implement the technologies 4.0 because they are unaware of its existence in the market and therefore they ignore the possibility to adapt these tools to their business.

In the third category, motivations show those drivers that boosted the interviewee's decision to adopt 4.0 technologies, either for a project that was already in execution or to implement in the short term. The answers given were subclassified under five categories, as shown in Table 4. *Innovation* was related to the desire of entrepreneurs to create

Table 1. Characteristics of the effective sample

Participant	Location	Sector/Activity	Market Experience	Employees	Annual Sales
1	Andina, Cundinamarca	Agriculture	3 years	7	N.R.
2	Andina, Bogotá D.C.	Development and marketing of technology and IoT	3 years	2	$ 122.500.000
3	Andina, Bogotá D.C.	Sport and training	4 years	3	$ 4.000.000.000
4	Andina, Cundinamarca	Development and commercialization of technology for agriculture	6 years	8	$ 1.000.000.000
5	Andina, Bogotá D.C.	Development and commercialization of technology in analytical video and artificial intelligence	3 years	8	N.R.
6	Andina, Bogotá D.C.	Development and commercialization of technology in artificial intelligence	4 years	3	$ 85.000.000
7	Andina, Bogotá D.C.	Development and commercialization of technology in monitoring and telemetry	4 years	4	$ 190.000.000
8	Pacífico, Valle del Cauca	Development and marketing of biometrics software and equipment	15 years	11	$ 1.000.000.000
9	Andina, Bogotá D.C.	Communications and software development	12 years	N.R.	N.R.
10	Andina, Bogotá D.C.	Metalworking and manufacturing industry, mechanical products and metals	3 years	3	$ 75.000.000
11	Andina, Bogotá D.C.	Hosting providers and custom software development	4 years	6	$ 50.000.000
12	Andina, Bogotá D.C.	Specialised software development, application and website development	2 years	10	$ 160.000.000
13	Andina y Pacífico, Bogotá D.C., Antioquia y Valle del Cauca	Provision of services related to infrastructure and blockchain	11 years	73	N.R.
14	Andina, Bogotá D.C.	Software development and technology infrastructure integration	7 years	5	$ 124.000.000
15	Andina, Bogotá D.C.	Software development in automatic communication interfaces or chatbots	2 years	2	N.R.
16	Andina, Antioquia	Manufacture of board games, puzzles and didactic	47 years	50-200	N.R.
17	Andina, Bogotá D.C.	Business transformation by implementing digital transformation-oriented technologies	3 years	23	$ 3.000.000.000
18	Andina, Bogotá D.C.	Cutting Edge technology solutions in companies based on IoT (RFID)	5 years	22	$ 1.300.000.000
19	Andina, Bogotá D.C.	Human talent service companies	14 years	20	$ 2.400.000.000
20	Andina, Antioquia	Support and contracting platform in horizontal property	1 year	6	$ 62.000.000
21	Andina, Bogotá D.C.	Metrology and calibration laboratory company	5 years	6	$ 370.000.000

Participant	Location	Sector/Activity	Market Experience	Employees	Annual Sales
22	Andina, Bogotá D.C.	Metrology and calibration laboratory company	9 years	10-50	N.R.

Table 3. Obstacles Category

Category	Subcategory	NVivo's codifications	Authors	Verbatim
Obstacles	Lack of qualified staff	9	Orzes et al. (2020)	"The lack of knowledge in the sense that suddenly the new technologies are being updated, let's say, for the development of applications, but the guys we are working with, who are developers, are not the coolest, they are also in a learning process. " (Interviewee 1, 2019)
	Lack of knowledge of technologies and technical problems	4	Ingaldi & Ulewicz (2019)	"What did I notice? Ignorance of the materials, of the filament of the printer, you have seen a 3D printer, it has a spool, the 3D printer like any other needs an ink, but here the ink is a filament, a spool, imagine it as if it were a cord, that cord can be of different types of plastic and each plastic with its properties. So, the lack of knowledge of the thermal and mechanical properties of these materials makes you make mistakes. " (Interviewee 4, 2019)

new products and find new ways of executing processes. In *efficiency*, companies sought to optimize processes, reduce time and costs, and increase productivity by making more efficient use of resources. The entrepreneurs also look for the *automation* of the different processes, so that most of them are executed, controlled and monitored by the different technologies Finally, in this category, *quality* is an important motivation because it guarantees that the end customer will receive a product with fewer defects that meets their needs.

The benefits category reports the positive effects that entrepreneurs have perceived after adopting 4.0 technologies, which are related to *a better use of data and information* thanks to the technologies; the possibility of gather information about customers, thus facilitating the development of products that more in line with their requirements and with that is possible *improved customer relationships*; *process optimization* thanks to the elimination of useless tasks and the control over different areas of the business; and *decrease in costs* due to a better use of all resources. The findings are shown in Table 5.

The last category is the institutional environment. This environment is where companies build relationships with other organisations to have partners or strategic allies in different sectors, which constitute an important source of financial resources, qualified personnel, knowledge and technical support. For the *Academy-private sector relationship* subcategory the interviewees stated that it would be possible to achieve greater technological development if the relationship between companies and academia were strengthened. Universities should provide their knowledge to the private sector to promote the development of innovation projects and train human resources in the use of new technologies. Regarding *support from private and public institutions*, some of the interviewees highlight the support received from institutions such as SENA, Tecnoparque and Colciencias, through technical assistance and provision of resources necessary for the process of adopting 4.0 technologies. Those insights are shown in Table 6.

3.2. Emerging Categories and Subcategories

It was also possible to identify the funding of SMEs as an emerging category that has not yet been systematically studied. Additionally, infrastructure issues, as a subcategory of the obstacles, is not mentioned in the reviewed literature.

Table 7 shows the two subcategories for funding. In the case of *Banks*, there is a negative perception on the part of several interviewees, who stated that they have encountered certain barriers or impediments to access resources to finance the implementation of 4.0 technologies. Regarding *government*, some interviewees express a negative perception regarding the lack of financial support provided by the government to companies in their process of acquiring 4.0 technologies.

For the *infrastructure issues* subcategory was an additional obstacle for the 4.0 Technologies implementation because Colombia's poor infrastructure hinders the implementation of 4.0 technologies.

4. Discussion and Contributions

The authors cited earlier allow us to foresee some of the findings that were found for the present study. In that sense, and referring to the first current of study of technological adoption in SMEs, Keeble et al. (1999) in their study carried out in the United Kingdom anticipate how technology-based SMEs are strengthened by collective-learning processes. In the results of the analysis of the interviews, it was found how entrepreneurs express the need to establish connections with the academic world to create networks that facilitate these learning processes, leading to higher levels of research and innovation. Likewise, the re-

Table 2. 4.0 Technology Implementation Category

Category	Subcategory	Authors	NVivo's codifications	Verbatim
4.0 Technology Implementation	Cloud computing	Moeuf et al. (2020)	5	".Well, the whole process is done in the cloud (i.e., the whole tool is hosted on a server), so we could talk about cloud computing. There it is done absolutely; that is, users can access from any device without the need to install any additional software, then everything is done there." (Interviewee 11, 2019)
	Sensors and Internet of Things	Sopadang et al. (2020)	6	"Well let's say that the main functionality of ordenab* is focused on companies in the electronic security sector, which are currently handling the whole issue of IOT, so they are doing all the installation, maintenance and repair of these devices. The idea is that ordenab* is a management tool that allows us to optimize response times in what has to do with personnel." (Interviewee 12, 2019)
	Radio Frequency identification	Moeuf et al. (2020)	1	"Yes, look at the RFID solution, we developed this platform so that a company that manages inventories can also do all its inventory control and management with radio frequency identification, from the receipt of purchases to delivery to the end customer." (Interviewee 18, 2019).
	Robotic	Dutta et al. (2020)	4	"The idea is to be able to integrate robots that perform tasks on all accounting tasks by integrating with different rpa in the market, and the idea is to sell it as a service to SMEs to avoid overloading people and make the work of accounting analysts and accounting assistants in the industry more productive." (Interviewee 17, 2019)
	Augmented reality	Dutta et al. (2020)	2	"We found that augmented reality technology allowed us to do what we wanted, which was not to move directly to a totally digital approach away from what we knew how to do and had done for so many years, physical products, especially board games where there is interaction between people, and we found that with augmented reality we could give added value." (Interviewee 16, 2019)
	3D Printing	Rauch et al. (2018)	4	"Actually, 3D printing is the ease of making small parts, well whatever the printer allows, for example what I initially needed were small parts for adaptation and I needed a card holder that we made with 3D printer." (Interviewee 4, 2019)
	Data Analytics – Big Data	Dutta et al. (2020)	4	"This issue of big Data allows you to have the information online, a recurring problem is that mayors for example sometimes do not know how the finances of the municipality are, they have a notion but they are not clear how much money has been executed, how much money they have left, how they can make those changes." (Interviewee 20, 2019)
	Artificial Intelligence	Prem (2019)	7	"What we are looking for is to be able to determine or anticipate a little bit with Artificial Intelligence the needs of a customer, you can arrive at a kiosk in an airport or anywhere and just by approaching you it can determine that you are a woman, without knowing who you are, it does not touch any kind of sensitive or privileged data of yours, it just determined that you are a woman and immediately changes its interface to possibly offer you products aimed at your segment." (Interviewee 5, 2019)
	Blockchain	Lee et al. (2019)	2	"Right now, what we are also doing is connecting all that movement that is backed by radio frequency traceability, connecting it with blockchain so that we start replacing paper with electronic records." (Interviewee 18, 2019)

sults show the importance of creating these collaborative networks to achieve greater technological development.

Nwaiwu et al. (2020) established a series of elements that influence the mentioned process, such as strategy, organ-

Table 4. Motivations Category

Category	Subcategory	Authors	Codifications in NVivo	Verbatim
Motivations	Innovation	Moeuf et al. (2020)	7	"Technologies was one of the objectives at the beginning, innovate in the product and innovate in the market, having the robot and having the beacons was an innovation differentiator against our competition and in the market." (Interviewee 10, 2019)
	Efficiency	Moeuf et al. (2020)	9	"3D prototyping lowers the cost of full-size manufacturing, and applying specialised robotic-built parts improves efficiency, which means the tunnel will be more cost-effective and safer. " (Interviewee 3, 2019)
	Automation	Sopadang et al. (2020)	2	"In our software we are creating a database to keep track of the different parameters of the crop, where the collaborator or the partner we have in each production unit or in each esag* as we call it, agroecological production unit*, can manually and automatically keep that control of parameters or that traceability, right, then we save it to generate daily, weekly, monthly, semiannual and annual reports." (Interviewee 1, 2019)
	Quality	Moeuf et al. (2017); Segura et al. (2016)	7	"I summarise it in one word, quality, it is a service that is guaranteed in quality, there are many techniques to optimize something, a productive system can be optimized in many ways, you find optimization theories, parameter control, whatever you want, but that software is contributing in quality, as simple as that." (Interviewee 22, 2019)
	Skilled workforce	Sopadang et al. (2020)	3	"Beyond replacing personnel, because if it is understood that sometimes these machines or technology begins to replace people, it is converting or transforming people's jobs into something more important for companies, leaving aside this operational part of people." (Interviewee 2, 2019)

Table 6. Institutional Environment category

Category	Subcategory	Authors	NVivo's codifications	Verbatim
Institutional Environment	Academy - private sector relationship	Dutta et al. (2020)	8	"Few technologies are developed within the country as such, and it is always seen to be in academia, there is no link as such between business and academia, together let's develop something, let's show something together and that slows down the technological development of a country." (Interviewee 18, 2019)
	Support from private and public institutions	Keeble et al. (1999)	2	"Then I decided to formulate my productive project, with the entrepreneurship office of the Sena, they assigned me a manager, they gave me accompaniment, a sincere kindness, I knocked on the doors of the technopark network with which I have been working for 3 years now, I presented the project, they quite liked it, they have been supporting me in the industrial engineering part, in chemistry, in the automation part, in mechatronics and electronics engineering." (Interviewee 1, 2019)

isation, competitiveness, operations, human resources. In this sense, entrepreneurs, for their part, mention them as facilitators or inhibitors of the adoption of technologies. Thus, it is possible to provide evidence of the proposed propositions

According to the propositions, first, Proposition 1 was verified because the 4.0 Technology Implementation Category was found in the research, which brings together the different technologies implemented by Colombian SMEs. This category validates the perspectives proposed by Sung (2018), Senvar & Akkartal (2018), and Gubán & Kovács (2017), who indicate that the accumulation of data (e.g., sensors, IoT or cloud computing), the data analytics and big data, human-machine interaction and transfer of digital instructions to physical artifacts (e.g., augmented reality, artificial intelligence or robotics) are essential features of Industry 4.0. Additionally, according to Motta et al. (2019) definition of this industry and the technologies that this concept encompasses, it can be evidenced that there is coincidence with the 4.0 technologies adopted by the interviewed entrepreneurs in this research.

Table 5. Benefits subcategory

Category	Subcategory	Authors	NVivo's codifications	Verbatim
Benefits	Better use of data and information	Sopadang et al. (2020)	4	"Before data analytics there was no centralized information, there was no information first of all, there was not even a way to obtain something in a database, the dispersion what it did was to generate economic losses, time losses, and obviously having everything centralized in a database, relevant information for the company, where to do all the analytical part, what comes is that after having all this centralized information, it will be possible to do all the exploitation or, what do you call it, data mining." (Interviewee 12, 2019)
	Improved customer relations	Orzes et al. (2020)	5	"It is more to offer an extra to the customer and to be able to give them a product that they need in less time. Normally people want everything for now and it is mostly to supply the customer's need for immediacy." (Interviewee 10, 2019)
	Process optimization	Saenz de Ugarte et al. (2011)	8	"What we intend is to optimize processes in the customer's production chain, click and collect machines for example optimize logistics processes and also help in reverse logistics issues and at the same time let's say that vending machines have two differentials with traditional vending machines: one is the cost, we managed to make a vending machine at one sixth of a traditional one in terms of cost, and the other is that by being connected to the internet we have the traceability of sales and inventory of the machines." (Interviewee 2, 2019)
	Decrease in costs	Moeuf et al. (2017)	8	"The idea is that with this type of technology, one can further optimize the budget one has for plant nutrition and for phytosanitary treatment and that there will be cost savings and greater productivity to achieve an increase in the average tons obtained by the crop per hectare basically." (Interviewee 17, 2019)

Table 7. Emerging category and subcategories

Category	Subcategory	NVivo's codifications	Verbatim
Funding	Banks	7	"Yes, it is a problem because banks do not lend to entrepreneurs, they do not understand business models, they do not understand what is being done, and they go on insurance, you sell a billion and I lend you 10% which is 100 million in annual sales. So, when you go with an enterprise of these characteristics, they say no." (Interviewee 7, 2019)
	Government	6	"No, with the government we have not been able to, we tried once to enter the fund to undertake another project, at that time we were not thinking about the machines, but we were looking for funding and the processes really take from six months to a year and we needed that now because the request was for now, so we had to look everywhere until we finally succeeded." (Interviewee 10, 2019)
Obstacles	Infrastructure issues	4	"The problem is in rural areas and that can have an impact for example on agricultural projects, and at this moment we have not had it because we do not have clients in the agricultural sector, we have not looked for them and they have not come to us, but I would say that this can be a problem in rural areas, because let's say that a chatbot can be very useful for people in the countryside, for information professionals, whatever, but if they don't have connectivity there is no way, in that sense the chatbot does not exist without internet, without internet connectivity the chatbot does not exist." (Interviewee 15, 2019)

Second, the interview process brings evidence to support Proposition 2. Accordingly, the previous literature (e.g., Iacovou et al., 1995) show the importance of data and information exchange in SMEs, and how this is enhanced by new technologies. In this regard, the results of the analysis of the in-depth interviews show how the exchange and management of data allow the increase in the quality of information, reduction of inventory levels, and costs reduction. Likewise, the results show the importance of traceability and process control, and how these actions are possible thanks to the implementation of 4.0 technologies because they allow us to obtain relevant data from the different processes of a business, and thus analyse their performance and seek their continuous improvement.

Moeuf et al. (2020) anticipate several of the difficulties that the interviewed entrepreneurs mentioned in the process of technological adoption. In this sense, Obermayer et al. (2022), state that the lack of trained personnel constitutes an obstacle in the process of adopting 4.0 technologies. Therefore, Proposition 2.1 has evidence because the findings of the present study agree that lack of experience and lack of methods and procedures are the main obstacles that weaken this process of incursion into 4.0 technologies for SMEs.

Continuing with inhibitors, the article offers the study of an emerging category (funding) and a subcategory (infrastructure issues), which is part of the category. Accordingly, Proposition 2.2 is validated and supported by Ingaldi & Ulewicz (2019). In particular, the lack of financial resources and specialised support impact on the core process in these SMEs. In addition, Obermayer et al. (2022) mentioned how funding is a key factor in the success of the 4.0 technology implementation process.

Regarding Proposition 2.3 and the benefits that SMEs can perceive while they are implementing these new technologies, Wang et al. (2021) argue that despite the difficulties and costs, SMEs have the enthusiasm to see the benefits and positive impacts of digital transformation with 4.0 technologies, the most important of which are flexibility and cost reduction. In addition, this research validates the proposition because benefits are one the existing categories presented, and the flexibility and cost decrease during the process are included in it.

Dutta et al. (2020) mention as areas of greatest impact of the implementation of Industry 4.0 the digitization, optimization and customization of production; automation and adaptation; human-machine interaction; value-added services; and automatic data exchange and communication. These are mentioned in the interviews as the main motivators and benefits found by the entrepreneurs in their transition to Industry 4.0. This emphasises that they have allowed greater efficiency and quality in the processes, and therefore in the good or service offered by the SMEs that are part of this study.

Brynjolfsson & Hitt (1998) found that there was a relationship between organisational design and technology adoption; however, this aspect is not very evident in this study. The internal organisation of the companies and their levels of centralization or decentralization, as mentioned by the authors were not investigated in-depth during this study. Consequently, these variables represent an opportunity for future research. Meanwhile, this study complements Raymond & Bergeron (2008) because they also emphasise the capacity that SMEs should have to adapt to change. At the same time, Han & Trimi (2022) proposed some strategies that could be implemented to overcome the challenges brought about by this technological change. Likewise, the results of this study show the need for SMEs to adapt to Industry 4.0, recognising the benefits of its implementation in the core business processes. The need of change some internal process to make the process of adopting 4.0 technologies successful is also mentioned.

The present research demonstrates the scope and value of these elements in the 4.0 technology adoption process, considering the experiences and perspectives mentioned by the business owners themselves. In this way, the need to carry out more research in this topic is latent, especially to analyse the causality of these inhibitors in relation to the economic, political, social and technological conditions of the country where SMEs and are located, as well as their impact on the technological transition process.

5. Theoretical and Practical Implications for Policy Makers

The results of this research generate diverse contributions to the study of the adoption of 4.0 technologies in SMEs. From a theoretical point of view, the case studies allow us to compare the behaviour of this type of organisations in similar and homologous contexts (i.e., emergent countries). Additionally, two emerging categories to be developed and explored in-depth in the literature are presented: financing and infrastructure problems.

In relation to practical contributions, this study presents the experience of different Colombian SMEs (case studies) that have adopted this type of technology within an emerging context. It also shows the lack of knowledge of SMEs about technologies and technical problems, thus raising the need to bring the business community closer to the technology dissemination fairs. In addition, an educational marketing strategy is required for this type of organisations for the recognition of benefits, obstacles and motivations.

Finally, the contributions for public policy focus on the evident need to strengthen personnel qualification schemes in 4.0 technologies. Likewise, institutional environment should articulate the development of a financial ecosystem for these implementations. However, this research showed that technical assistance and the provision of resources should focus on the development of entrepreneurial capabilities, thus avoiding a welfare approach.

6. Conclusions and Future Research

The main contribution of this study is that it identifies an emerging variable in the study of inhibitors and facilitators of the adoption and implementation of 4.0 technologies, which allows us to account for the problematisation of financing as an important variable in the processes of incursion into Industry 4.0 for SMEs. In this sense it is understandable that this variable has not been problematised so far, especially when considering that access to financial resources is not the same in all countries because it depends on the level of development, institutional environment, level of investment in technology, among other factors. Hence, the value of an in-depth study of this category, especially in developing countries such as Colombia whose level of technology maturity and investment in technology is not comparable to that of countries that are leading the process of adopting 4.0 technologies. Added to this is the fact that SMEs, due to their structure and resources, have limitations in processes that involve a certain level of complexity, such as the implementation of new tools that can drastically change their business processes.

It should be noted that the lack of resources to make the investment (a common factor in any technological venture or innovation) is a common obstacle for all of the cases

that we analysed. Nevertheless, most consolidated organisations in the market suggest that it is a minor obstacle compared to other obstacles, such as the lack of connectivity, lack of knowledge of technology or resistance to change. These factors affect two fronts: internal to the organisation and external to it.

The lack of connectivity is an inherent issue in government policies because it is an issue that companies could not control, given the large investments required to achieve it. Likewise, the lack of knowledge of technology can be a factor given by the inherent novelty in them and the gaps in higher education for the subject. Meanwhile, resistance to change is an inherent issue and a challenge for organisations of any size.

Although the sample size could be considered to be a limitation, it should be kept in mind that a rigorous and exhaustive search of cases was made, including the accompaniment of all the entities that have knowledge and registration of this type of organisation. The difficulty lies in the low adoption of this type of technology, which is highly related to the country's incipient scientific development.

Future lines of research can be summarised in three areas. First, the present research encourages us to delve deeper into the two emerging categories: funding and infrastructure issues. The implementation of these technologies requires us to pay special attention to other types of variables that arise in contexts that differ from those that are commonly analysed (i.e., industrialised countries).

Second, the results show the need to identify and confirm the new relationships associated with the emerging elements presented in Figure 1. The conclusions show the need to contrast the impact of motivations, benefits, obstacles, institutional environment and financing on the implementation of 4.0 technologies by SMEs in other contexts.

Finally, future studies should contrast the view of the case studies proposed in this article versus the institutional analysis of public policy makers, and even the experience of 4.0 technology developers. This triangulation of information could provide a glimpse of the facilitating and inhibiting elements in the process of implementing 4.0 technologies in SMEs.

7. Limitations

This research has observed several limitations in the methodology and results presented. The most important limitation is that most of the companies that were part of the sample are located in Bogota, the capital of Colombia. Therefore, the elements mentioned could vary, and even new emerging categories could be found if this type of study were carried out in other cities of the country, especially, in those where the economic, political and social conditions differ from those prevailing in the capital.

Although the sample presented may be considered small, it represents the reality faced by SMEs in the country, considering the environment in which they operate, which has a significant influence on this technological adoption process. However, research considering a quantitative approach or larger number of cases of Colombian SMEs would make a contribution to the literature. Nevertheless, this kind of report must wait until the existence of more cases of SMEs implementing 4.0 technologies.

Finally, this study contributes several findings to the literature regarding the implementation processes of 4.0 technologies in SMEs, however it may contain some limitations because most of the companies that we are analysed are located in the capital of the country, which is the largest business centre in Colombia. Consequently, we would not be able to make assertions regarding the level of adoption of 4.0 technologies throughout the country, or regarding the facilitators or inhibitors in this process.

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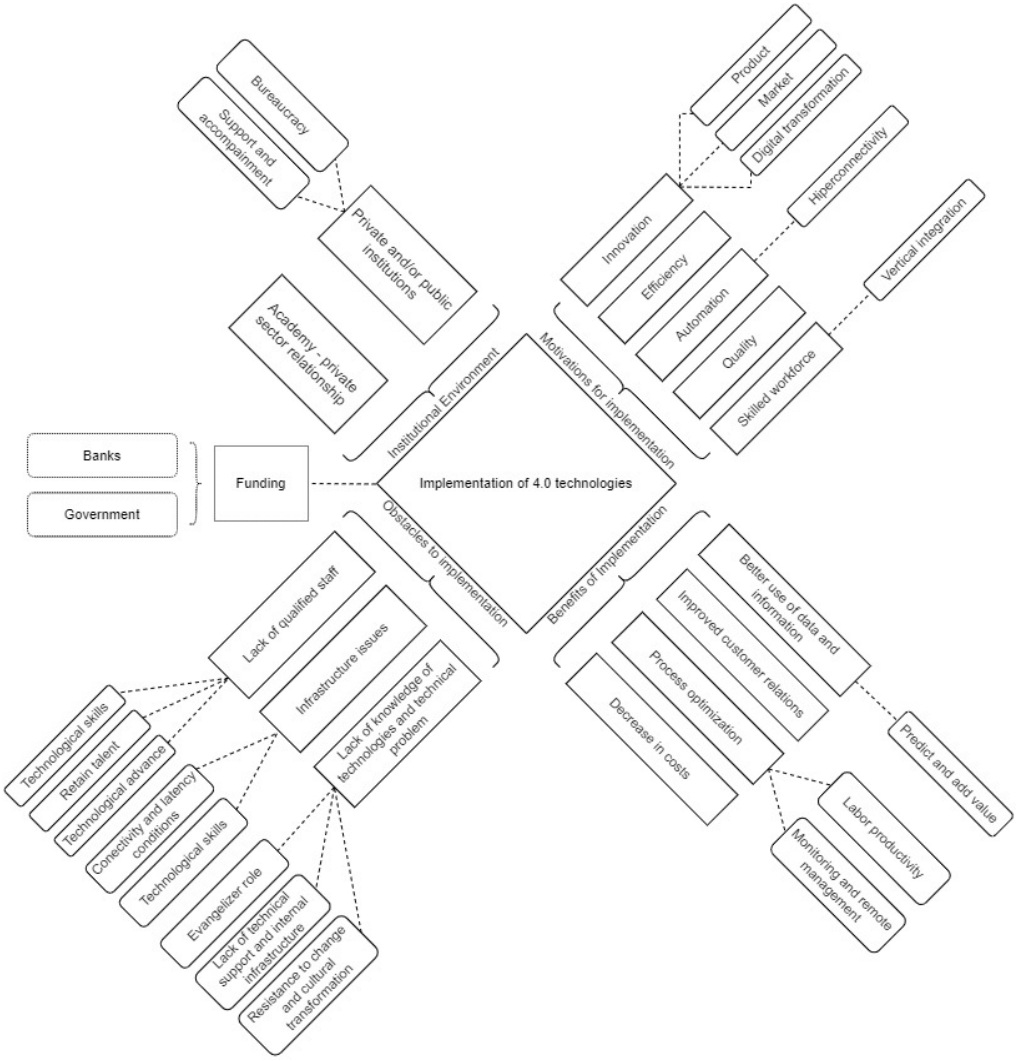

Figure 1. Factors that influence on the implementation and plans for the insertion of 4.0 technologies in SMEs in Colombia

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