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The impact of ICT and knowledge management on open innovation: Empirical evidence from Mexico

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Abstract

In the last few decades in the business environment, a shift from closed innovation to open innovation has been identified in organizations. The objective of the study is to explain some antecedents of open innovation (OI) by analyzing two relevant constructs in the current context of the environmental dynamism of organizations. One of the primary purpose of this study to enable the manufacturing industry to understand what strategies are required to foster open innovation within their organizations. A research model that integrates sociodemographic data, corporate information and measuring scales to evaluate the relationships raised through multivariate analysis in 290 Small and Medium Enterprises (SMEs) is incorporated. The model uses an instrument with 23 items on the Likert scale. For data analysis, it was applied to managers or owners who have firsthand knowledge of the company. The structural equation technique was used with the Analysis of Moment Structures (AMOS) software. The results indicate that ICT operations have a positive and significant impact on KM. Evidence exists that there is a positive and significant relationship between KM and OI. The study contributes to the background knowledge that impacts OI in a sector such as manufacturing SMEs in an emerging country (Mexico). It concludes the need to use ICT in the company's value chain operations to have the necessary information input for KM that allows the development of OI inbound and outbound practices.

Keywords: Inbound practices, Information communication technologies, Knowledge management, Open innovation, Outbound practices, Small and medium enterprises.

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1. Introduction

Organizations always needed to be aware of external events that have an impact on them. The different types of changes caused by the pandemic of COVID-19 such as those in geopolitics or the food supply make more and more evident the need to search for external information, besides having the possibility to learn from it, manage the acquired knowledge and promote collaborations in innovation that develop necessary to rethink the strategies that allow them to remain and grow.

The abovementioned does not only apply to large companies. SMEs represent a strategic element for the growth of emerging countries such as Mexico. Since 99.8% of companies are SMEs, they generate 67.9% of employment in the country and represent an aggregate value of 45.3%. Economic units represent 12.1% and 23.9% of the employed employees in the manufacturing industry particularly in the state of Aguascalientes where 99.7% is occupied by SMEs of which 10.15% are manufacturing companies. It is also important to mention that the state belongs to the Midwest region which is the second region with the highest gross productivity in the manufacturing industry [1]. To compete with global companies, they must build collaboration networks to benefit from this relationship.

Regarding SMEs, there is still insufficient evidence on the role played by ICT and the effect of other variables that support a more efficient and effective organization [2]. Another problem identified in SMEs is the lack of investment and necessary training in ICT which represents an invaluable asset and an important resource that adds value to products and services [3] as well as the correct decisions made by firms. However, despite these barriers to the use of ICT in SMEs in the last decade, SMEs have been motivated to adopt ICT [4].

On the other hand, studies that examine innovation from closed to open and how technology has contributed to this change [5]. Changing from the perspective that innovation arises mainly from research and development within the firm, to one in which they integrate external sources of information into their internal capabilities to accelerate innovation and benefit from them. This change has caused the interest of researchers in knowing how to generate OI.

OI can be understood as the organized efforts in a company that use knowledge (inputs and outputs) to improve and accelerate the innovation process and expand markets to use it [6]. Firms can explore external knowledge and with their internal capabilities gain competitive advantages.

Given the innovation process in the digital context and the limited resources that SMEs have therefore, in order to increase the sources of innovation, external sources of knowledge will play a key role in this process. [7, 8].

Few studies have analyzed OI in SMEs especially the role of KM as an antecedent to OI as well as some internal capabilities that can promote its development as is the case with ICT operations which due to globalization have put pressure mainly on SMEs [9]. In this same sense, it has also been identified that studies on KM have focused on large companies and have left aside what happens in SMEs which are characterized by having less evolved authority, taking more risks and being able to react more quickly in the business environment [7]. In fact, there is little research on the relationship between KM and OI particularly in SMEs [10, 11].

KM is considered a capability within organizations to capture, use and transfer knowledge [12]. ICT represents an enabler to create, disseminate or search for knowledge and is one of the enablers in KM [13]. Although, they have been associated with both constructs. It is still unknown what the real impact is between them. Since the role of ICT in KM has been hardly analyzed [14] and several researchers have called for understanding how ICT operations create value through KM and innovation [15-17]. Since there is little knowledge of how ICT operations influence knowledge absorption. It is difficult to develop processes for product design, distribution, marketing, purchasing and storage. In addition, it is important to explore more about the situation experienced by manufacturing SMEs in other contexts and with various forms of innovation [16, 18].

The study contributes to the analysis of the relationship between ICT and operations throughout the value chain of the firm that allows the creation, sharing and use of knowledge beyond the functional limits from an organizational perspective and thereby promotes the development of an OI by analyzing the inbound and outbound practices of OI. Since it is not yet known in detail in different contexts which elements promote the KM necessary to cause an OI [12].

The objective of this article is to develop and test a research model to analyze how ICT in KM affect SMEs's OI in the manufacturing industry. This study is supported by the theory of the knowledge-based view because it considers it a relevant resource to promote OI and by the theory of contingency it analyzes OI as a flow of inbound and outbound practices.

This paper is divided into five parts: the first, a review of the literature in terms of knowledge management, information technology operations, open innovation, the relationship of information and communication technologies with knowledge management and the relationship of knowledge management and open innovation in SMEs; the second, presents the research methodology; the third, the results obtained through the statistical techniques of the study; the fourth is the discussion and conclusion and finally the implications and limitations.

2. Literature Review and Hypotheses

2.1. Knowledge Management

KM is "an organizational capacity to create new knowledge, disseminate it and transfer it into products, services and systems" [19]. For several authors, KM is linked to gaining competitive advantage either by its holistic approach using expertise [20] or by the ability it gives the organization for the exploration and exploitation of collective knowledge [21] by being a strategy that transfers, stores and implements knowledge [22] tacit and explicit knowledge that adds value to the organization can be cultivated, expanded and applied [8]. It exists when knowledge flows in the organization [23] as a

result of three interdependent activities, creation, dissemination and use of knowledge [2, 24-26]. Various authors include different stages in the process of KM such as creation, acquisition, documentation, storage, electronic exchange, face-to-face interaction, application and reuse of knowledge [27] or other stages such as acquire, retain, share and apply knowledge [3, 28]. However, everyone agrees that KM developed with good performance generates competitive advantages for the company [29, 30].

Existing knowledge can generate value. It is necessary that it may be used in decision making that implies incorporating processes, strategies and having experience and resources so that an effective and efficient KM can be promoted for the solution of problems [8, 19] which involves internal resources to increase several performance measures [30-32] for its application. There are two strategies: tacit and explicit knowledge [33].

On the other hand, Ode and Ayavoo [34] indicate the absence of a universally accepted concept of KM. However, in this study, knowledge management capacity will be considered " the degree to which the firm creates, shares and utilizes knowledge resources across its functional boundaries [35]. This definition focuses on the knowledge management activities of firms at the organizational level rather than at the department, team or individual levels" [24] cited by Martinez-Conesa, et al. [16]; Liao, et al. [36]. In other words, it emphasizes the creation, sharing and use of knowledge from an organizational perspective.

Knowledge creation outside functional boundaries is achieved if the company can use existing knowledge and take advantage of the new potential skills that it has [36, 37].

The information mentioned above indicates that they can distribute knowledge and learning among departments since it allows things to be done better as a team [16, 36]. This facilitates cross-functional interaction, collaboration and understanding of the whole process. The degree to which a firm applies knowledge across departments is referred as to knowledge utilization [36].

2.2. Information and Communication Technologies

ICT are technologies that "regardless of time and space allow the transmission of data, emphasize the use of digital and or electronic instruments" [38] cited by Ocaña-Fernández, et al. [39]. With a great diversity of uses and the effectiveness of how it is managed will be affected by the capacity of those who manage the firm [40]; ICT is defined as "the ability of the firm to mobilize and organize ICT-based resources and has been associated with better performance and innovation" [41] Different terms such as “ICT capabilities, e-business, ICT infrastructure, ICT management, e-commerce”, Enterprise Resource Planning (ERP) capabilities are distinguished in the literature [42] cited by Gaviria-Marin, et al. [17].

In the same manner, it is noted that "the use of these ICT media generates new forms of communication, forms of application and interactions in different situations that depend on the conditions of both the environment and the community" [43] cited by Ocaña-Fernández, et al. [39]. The stages of creating and transforming information to create and distribute knowledge are expected to flow and the use of this knowledge generates value and innovation [44].

López, et al. [45] consider three dimensions in ICT: 1) IT competencies on knowledge, 2) operations and 3) infrastructure. Other authors divide them into two dimensions a) "Information and communication technology (ICT) requirements for KM in organizations and b) market monitoring for products or services” [46]. There is an additional perspective on the study of ICT based on the concept given by Bharadwaj [47] that considers them as capabilities resulting from the mobilization and organization of resource-based ICT in combination with other resources and capabilities. However, there are few studies on how it influences the value chain within the firm and in different contexts [9, 18] which identify a positive effect on innovation in the firm both in product design, manufacturing, logistics, marketing, coordination with suppliers and after-sales service [9].

2.3. Open Innovation

Recently, it has been identified in the management of companies that they are transitioning from a closed innovation (internal environment to the company) to an OI (looking for interconnectivity with the external environment). Nowadays, it is possible to obtain greater knowledge and learn more from the external environment and seek greater opportunities [48]. Since internal and external knowledge is integrated [49] the sources for the development of innovation activities are the company's stakeholders, collaborators and the environment in which the company's business is developed [50].

The OI model emphasizes the change to open activities and makes use of external knowledge resources to achieve its objectives of accelerating innovation [5] which implies constant interaction with various actors involved in the company's intercommunications [51].

It is assumed that innovation is developed within firms with the technology and processes to create innovations according to their internal research and development capacity. However, OI refers to a company's knowledge input flow to create new satisfied customers in the market. The topic of OI has focused on large companies and it is still difficult to establish a concept about OI [7, 52].

In OI, external processes (external knowledge through communication with suppliers, customers and or collaborators with other institutions), internal processes (transferring innovative ideas to the market that generate or accelerate profit for firms) and joint processes (co-creation with collaborators such as value channels, clusters, alliances and cooperation) are identified [53] cited by Grimsdottir and Edvardsson [7]. According to some authors, SMEs gain more from OI since they have less evolved authority, take more risks and can react faster in the business environment [54] cited by Grimsdottir and Edvardsson [7].

Other authors have noted that OI strategies have to do with the inputs of the flow of knowledge and technology to the inside of the company (Inbound Open Innovation) or when working strategically on the outputs of the flow of knowledge

and technology to the outside of the company (Outbound Open Innovation) [30, 55] or it has also been found that it can be mixed [6, 30] when it is in both directions. OI factors are flexibility, business model, intellectual property, intellectual property sales and technology transfer [56-58].

In terms of measurement perspectives, a combination of internal and external dimensions is found in OI [59]. There are inbound and outbound activities and the two are not mutually exclusive [60].

It is very important that the organizations explore the knowledge of their external collaborators like suppliers, customers, competitors or governments and just these types of activities [16] and radical innovations would be expected. Outbound activities involve the exploitation of internal ideas such as licenses or rights for the sale of knowledge which can increase innovation performance in a short time [16, 55, 61]. However, it is necessary for the firm to use its capabilities for OI management.

3. Hypothesis

3.1. Information and Communication Technologies and Knowledge Management

In the literature review, there is sufficient support for the relationship between ICT and KM from different perspectives in terms of its ability as a quick tool to obtain information and knowledge in the company. It transfers to the whole team and allows for support in processes and systems [62].

Results of the moderating role of ICT in strengthening learning to provoke knowledge assimilation are also shown [5] with a positive relationship between KM and performance [4].

In a study based on the systematic review of literature taken from the Social Sciences Citation Index (SSCI) database on the results obtained in various researches. They found that "management practices related to applications and tools, databases, communities of practice, frameworks and networks applied in real business contexts, promote the achievement of good results in the processes associated with knowledge management" [12] especially because they promote individual knowledge and the sustainability of companies. Since they generate knowledge assets, store and facilitate access to them.

Toulson and Castaneda [33] found in a study of 217 New Zealand knowledge workers that not all ICT allow tacit knowledge to be shared and currently there is a need to facilitate the sharing of tacit and explicit knowledge [63] since they support collaborative work among SMEs and achieve important advantages such as the development of knowledge and innovation [64] also identify as a key element to achieve the transition to the circular economy and sustainability [65, 66] and significantly impact competitive advantages and KM in which mediates the relationship of ICT and organizational outcomes [3].

On the other hand, ICT guide the co-invention and assimilation of knowledge [5] such as Velasquez, et al. [65] conclude after a systematic literature review that ICT provide valuable information to transform and disseminate knowledge for the improvement of the business model. Therefore, they facilitate the processes of KM distribution and use [67, 68].

There is also a study carried out in 200 organizations in Bangkok in which they conclude that business performance has improved through digital technologies in KM [69]. In the same manner, a study conducted by Gaviria-Marin, et al. [17] on a group of 130 SMEs in Ibero-America. It showed the influence of ICT enablement (recognized as a low-order capability) on higher-order capabilities such as KM and flexibility in product innovation as moderating variables. It improves performance through the innovation of firms. Sarka, et al. [13] identify which ICT resources are necessary for the advancement of KM in the organization.

In the same manner, a study examined published articles and books from 2000 to 2017 to determine the role of ICT in KM. The results indicate that ICT has proven to be an important tool to advance KM and its processes, which supports in simplifying, selecting and capturing timely in the creation, transfer and reuse of knowledge [14]. Therefore, they are efficient for the distribution of knowledge otherwise, knowledge is lost [70]. Digital technologies allow the firm to have the capacity to promote the creation of knowledge to support different objectives and efficiently use its internal resources [71].

The above provides support for the following hypothesis:

H1: ICT operations have a positive and significant influence on knowledge management.

3.2. Knowledge Management and Open Innovation

OI is understood as a dynamic process that requires knowledge from external resources, it is oriented to external learning [72] when it reuses or recombines knowledge.

The findings of Yousaf and Ali [73] indicate that the acquisition, distribution and response of knowledge significantly impact the firm's innovation performance. The success of organizations to a large extent is because of good KM as an intangible resource of the organization [74] and achieving innovation continuously through activity on a continuous basis [69, 75] Both sharing and applying knowledge have been confirmed to influence the level of innovation [76, 77] due to new techniques or products, improved operations or cost reduction [34].

According to Jasimuddin and Naqshbandi [78], KM influences OI and success in organizations. It has also been confirmed that it manages to influence sustainable competitive advantages positively and significantly when associated with OI. On the other hand, in the review of empirical results from a two-case study in Iceland, they report that SMEs can benefit from OI. However, in the conclusion, the authors point out that by not having formal KM strategies, a lot of knowledge is lost [7]. It is advisable to develop KM capacity if you want to carry out an OI strategy.

In the same manner, in a study that aimed to investigate the effects of OI and big data analytics (BDA) on reflective knowledge sharing in the context of complex collaborative networks with data from 27 European Union (EU) countries, the

results suggest that OI collaborative modes have a strong effect on innovation performance, stimulating the search for reflexive knowledge sharing [79].

On the other hand, the results of a study with 80 agri-food companies to find out about the relationship between KM and OI point to a positive impact on knowledge exploration in OI practices and IT-based knowledge exploitation [59]. Another study empirically tests the positive impact of "organizational culture, employee attitudes, knowledge and rewards on the adoption of an OI paradigm in organizations" as antecedents and mediators of OI adoption in organizations [80].

The above provides support for the following hypothesis:

H2: Knowledge management has a positive and significant influence on open innovation.

4. Research Methodology

4.1. Data and Sample

This study is quantitative and cross-sectional in nature. For the reliability and validity of the instrument, it was evaluated with different procedures and with the use of two software programs, Statistical Package for the Social Sciences (SPSS) version 23.0 and Analysis of Moment Structures (AMOS) version 26. The information obtained from the data collection was analyzed with the structural equation technique.

The study population were the SMEs in the manufacturing industry in Mexico, particularly in a state located in the Midwest of the country, Aguascalientes, for which the stratification of companies by sector was taken which was published in the Official Journal of the Federation (OJF) on June 30, 2009 in terms of number of workers which classifies industrial SMEs with 0-10 workers as microenterprises, 11-50 workers as small enterprises and 51 to 250 workers as medium enterprises.

A sample of 1,725 companies in the state of Aguascalientes was randomly selected from a list of 5,828 manufacturing SMEs obtained from the National Statistical Directory of Economic Units (DENUE) of the National Institute of Statistics and Geography (INEGI) [81]. It was decided to include in the study SMEs with more than 5 employees to ensure a minimum structure in the firms and up to 250 employees as a maximum limit in a final sample size of more than 296 surveys. According to theory, 200 surveys are an adequate number for the use of structural equations [82]. Structural Equation Modeling (SEM) analysis will be used for the development of this study. The key respondent was the owner or manager making decisions related to the company's strategic innovation activities in addition to have an integral vision of the firm's capabilities and resources.

A pilot test was first carried out on a random sample of 20 SMEs located in Aguascalientes to collect data. In this pilot test, the items proved to be consistent and without problems in their application to the selected sample. The survey was administered from February to May 2022. The key subjects were previously contacted to request their support through an official letter that explained the objective of the study via e-mail, and then confirmed through a telephone call their participation in the study and the development of the survey.

The identified sample was contacted resulting a 17.1% response level which is slightly higher than 15% using the same method and similar scales [16, 83]. There were no problems with nonresponse pathways affecting the results of the study.

From the information gathered regarding the characteristics of the SMEs surveyed, 79% are small companies and 21% are medium-sized companies of which 72.4% are legally constituted as company (two or more partners) and the rest as companies with a single partner or owner. In addition, 37.8% of the companies participating in this study have been in business for 1 to 10 years, 26.2% for 11 to 20 years and 36.1% for more than 20 years and it can be confirmed that 71.1% of these companies are run by a family member with majority management control. Finally, it was found that 82.7% of the management in SMEs is led by men.

Regarding the economic activities of the manufacturing industry of the SMEs contacted, the industrial classification system of North America, Mexico [84] followed by INEGI in the DENUE was used with 9.1% corresponding to the economic activity of the food industry and agribusiness, 13.2% to textiles and clothing, 20.9% to the manufacture of machinery and equipment, the manufacture of transport equipment represented 6.8%, 22.3% in the manufacture of metal products and basic metal industries, 7.4% to the activity manufacture of furniture, mattresses and blinds, 6.1% in the manufacture of plastic and rubber, 5.7% in the chemical industry, 4.1% in the manufacture of paper and cardboard products, and finally, 4.4% corresponds to other manufacturing industries dedicated to the manufacture of toys, manufacture of articles and accessories for writing, painting and office activities and the manufacture of advertisements and signs. The manufacturing sector is characterized by its high diversification and according to the 2019 economic census is the most important in total gross production 48.2% of the national total [1].

4.2. Measurement

The scales for the study were selected through a careful review of the antecedent literature on the different topics to be addressed whose results in previous studies have shown good validity and reliability. The scales were translated from English into Spanish and then presented to 5 researchers about the subject to identify possible words that could present problems for their understanding of the key subject and to ensure the correct application of the instrument.

The instrument was developed in three blocks, the first block included sociodemographic information of the key respondents, the second block included company information and finally the third block included the selected measurement scales which were Likert-type multi-item scales from 1-5.

The ICT operations construct was measured based on the scale adapted by Martinez-Conesa, et al. [16] from the scales developed by Sohi and Tippins [85]; Popa, et al. [18]; Soto-Acosta, et al. [9] which includes six items to measure the

degree of ICT use in business processes throughout the value chain such as product design, manufacturing, logistics distribution, marketing, purchasing and inventories in relation to coordination with suppliers and support for human resource management service.

The construct of KM capacity proposed by Liao, et al. [36] has been measured using a nine-item scale that measures the degree of utilization of different KM practices (create, share and apply knowledge) across functional boundaries from the organizational perspective.

In the case of the OI construct, the scale proposed by Cheng and Shiu [55] and used by Martinez-Conesa, et al. [16] was considered which is made up of two dimensions: inbound practices that allow generating and exploring knowledge from external sources and outbound practices that seek to know the achievement of firms in the commercialization of innovations developed by their firm. Both dimensions are made up of four items.

4.3. Validation of the Instrument

The information from the surveys was coded and entered into the SPSS software (version 23). Once the information was captured, the data was cleaned and the univariate and multivariate normality distributions were evaluated.

According to the literature, outliers can cause certain conflicts in the results [86]. That is why the detection of these outliers was verified using the Mahalanobis test in the AMOS software. The Mahalanobis distance (MD) approach is a measure that distinguishes multivariate data sets using a univariate distance measure. This procedure allows the distance to be calculated from multiple parameter measurements [87]. To confirm if there is univariate normality, the skewness and kurtosis indices were observed for each variable, considering the criteria of George and Mallery [88] who mention that the value should be less than 1.6. In this case the data complied with univariate normality.

Regarding multivariate normality, the criterion was considered in which several authors [89, 90] suggest that a Mardia Multivariate Kurtosis index collected in the AMOS software should not exceed the indicative value of 70 in the maximum likelihood estimation for adequate results. The kurtosis resulted in values far from normality (multivariate kurtosis = 109.43) from the study's initial base. The Mahalanobis distance (D^2) was checked to improve the distribution and the most outlying outliers were discarded preserving adequate values of multivariate normality (multivariate kurtosis = 70.14), that is 6 out of 296 cases were eliminated leaving a total of 290 cases for the sample of this study.

Subsequently, the SEM analysis was developed in two stages: in the first stage, a confirmatory factor analysis (CFA) was performed for the group of variables which allowed verifying the convergent and discriminant validity and the reliability of the constructs and in the second stage, the adjusted models of the SEM analysis were verified and the confirmation of the hypotheses [91].

Cronbach's alpha was estimated to verify the reliability of the items for this index levels higher than 0.7 are recommended [92]. As a result, it is confirmed that the scales reach an adequate level with values between 0.70 and 0.90 to calculate the composite reliability index (CRI). The literature considers it convenient that the value is higher than 0.60 [93]. The results range between 0.81 and 0.90 confirming the reliability of the measurement scales. For the Average Variance Extracted (AVE) the values of the construct resulted higher than 0.5 except for ICT whose AVE is 0.47. Although, the value of the AVE is established. According to the theory, it should be greater than 0.5. 0.47 is accepted since Fornell and Larcker [94] and Wang, et al. [95] point out that values lower than 0.5 can be accepted if the value of the CRI is greater than 0.6 for the ICT construct. So, it is considered to have an adequate 0.81 convergent validity Table 1.

Table 1.
Reliability and convergent validation of measurement scales.

Factor	Item	Factorial loading	Average load	Cronbach's alpha	CRI	AVE
Information communication technologies	ITO2	0.67***	0.68	0.78	0.81	0.47
	ITO3	0.64***				
	ITO4	0.72				
	ITO5	0.69***				
	ITO6	0.69***				
Knowledge manegement	KM1	0.79***	0.78	0.90	0.90	0.61
	KM3	0.71***				
	KM4	0.78				
	KM6	0.82***				
	KM8	0.81***				
	KM9	0.76***				
Inbound practices	PE1	0.98***	0.74	0.74	0.84	0.57
	PE2	0.75				
	PE3	0.69***				
	PE4	0.53***				
Outbound practices	PS1	0.67***	0.78	0.70	0.83	0.62
	PS2	0.84				
	PS4	0.84***				

Note: Overall model fit measures: Chi^2/df =2.97 (p= 0.000); RMSEA=0.08; IFI=0.91; TLI= 0.88; CFI=0.91; Significance values: ***= p < 0.001.

The goodness of fit of the measurement model was evaluated through various indices such as the RMSEA (Root Mean Error of Approximation) which was 0.08; chi-square or degree of freedom which was 2.98, the IFI (Incremental Fit Index) which was 0.91, the TLI (Tuckcr-Lewis Index) which was 0.88 and the (Comparative Fit Index) with an index of 0.91. According to the theory, for the root mean square error of approximation (RMSEA) values should be between 0.05 and 0.08 [96] in the ratio (Chi^2 /df) the value should be below the threshold of 5. While the IFI, TLI and CFI should be close to 1 to indicate a good fit [97]. The above confirms that the measurement model has a good fit because all indices are acceptable.

The reliability and validity of the constructs comprising ICT operations, KM capacity and OI were verified. The model consisted of 18 items in total (Table 1) after the CFA adjustment process, 5 items for the ICT operations variable, 6 items for KM capacity and within the OI variable 4 items for inbound and 3 items for outbound practices.

For the discriminant validity analysis, the criterion of Fornell and Larcker [94] was followed, according to which the square root of the mean AVE for each construct (values on the diagonal of Table 2) must be greater than the absolute value of the bivariate correlations between the constructs (items below the diagonal). As a result, this criterion was met. In this case, the variables with the highest correlation were KM capacity and innovation-inbound practices (r=0.48), while ICT operations and inbound practices (r=0.25) were the two least correlated variables, however, the value is significant. The rest of the variables and descriptive values such as mean and standard deviation can be seen in Table 2. Given the observed data and the criteria set by the authors mentioned previously, it can be inferred that the tests measure the constructs they were designed to measure which means that they have discriminant validity. When the correlation of the factors is analyzed, we consider the theory that indicates that values higher than r>0.85 indicate potential problems [98] confirming that there are no multicollinearity problems.

Table 2.
Analysis of discriminant validity and correlations.

Factor	Mean	S. E	ICT	KM	OI-IP	OI-OP
ICT	3.68	1.70	0.71	0.28-0.52	0.12-0.38	0.17-0.44
KM	3.97	1.11	0.40***	0.78	0.35-0.62	0.14-0.36
OI-IP	2.94	1.35	0.25***	0.48***	0.75	0.25-0.55
OI-OP	1.95	1.27	0.30***	0.25***	0.40***	0.79

Note: 290 cases: ***= $p < 0.001$.
ICT= Information and communication technologies; KM=Knowledge management; OI-IP=Open innovation-inbound practices; OI-OP= Open innovation-outbound practices.

It was observed that there were no multicollinearity problems by means of the Variance Inflation Factor (VIF) and that the values should be less than 10 [86]. The VIF values in this study ranged from 1.24 to 4.36. Similarly, by having a high correlation between the factors, the theory establishes that the results of "r" greater than 0.90 [99] show some problem of common method bias. In this case, after verifying the results, it can be confirmed that they did not exceed 0.90 (Table 3), thus confirming that the results of the study are not affected by the common method bias.

Likewise, the confidence interval test was used in which the correlation between the factors was calculated and the confidence intervals of the correlations between all the factors of the study were constructed. There will be discriminant validity once the correlated confidence intervals do not include the value of 1. [91] The results presented confirm that there is discriminant validity since the confidence intervals do not include. The descriptive results analyzed in terms of the mean and standard deviation of the variables can also be observed in Table 2.

5. Results

After examining the reliability and discriminant and convergent validity of the model proposed by the study, we proceeded with the structural analysis of the relationships presented. It is important to note that structural modeling as a multivariate technique implies the use of statistical models where different variables are analyzed simultaneously. This technique makes it possible to measure unobservable variables (constructs) and their relationships with others. In this study, the modeling was carried out using the AMOS software in its version 26.0 using the maximum likelihood estimation technique.

The results are shown in Table 3. According to the indices, the goodness of fit of the analyzed structural model is confirmed where the Chi^2/df is equal to 2.95, IFI=0.91, TLI=0.88, CFI=0.91 and RMSEA=0.08. The indices are within the appropriate range as indicated by theory.

Hypothesis 1 recognizes a positive and significant influence 0.001(***= $p < 0.001$) between ICT operations and KM. Since the standardized coefficient is 0.42 with a t-value =5.82 and the R^2 =0.17 which confirms its acceptance for this study.

Hypothesis 2 stated that KM has a positive and significant influence (***=$p<0.001$) on OI with at-value of 4.09, a standardized coefficient=0.31 and R^2 =0.33. In this case, the standardized coefficient of the impact of KM on OI was 0.57. These results allow the acceptance of the second hypothesis.

Cohen [100] establishes that coefficients with values less than 0.10 show that there is less effect up to 0.30 medium and coefficients with absolute values greater than 0.50 indicate large effects. AMOS allows to know the indirect effects so, it is interesting to see the results of the medium indirect effects between ICT and OI (0.24), KM with Open Innovation-outbound practices (OI-OP), (0.27) and KM with Open Innovation-inbound practices (OI-IP), (0.48).

Table 3.
Results of the hypothesis testing in the structural equation model.

Structural relationship				Standardized coefficient (t)	R^2	p	Result
H1	Information communication technologies	→	Knowledge management	0.42(5.82)	0.17	***	Accepted
H2	Knowledge management	→	Open innovation	0.31(4.09)	0.33	***	Accepted

Note: Goodness of fit measures: Chi^2/df =2.95(p= 0.000); RMSEA= 0.08; IFI =0.91; TLI 0.88; CFI=0.91; Significance Values: ***= p < 0.001.

6. Discussion and Conclusion

OI requires the use of both inbound and outbound practices, so it is necessary to constantly monitor the organization's environment. On the other hand, ICT operations are constantly evolving and it is necessary that they cause a constant flow of information that allows the necessary learning for renewed knowledge. In this sense, the contingency theory was used, which points out that the organization's internal environment has a complex relationship with the environment [101]. The study of the influence of KM on OI was analyzed from the knowledge-based view of the company which points out that knowledge is the strategic resource of the company [102] to generate competitive advantages.

A research model was developed that examined some OI antecedents that previous studies had pointed out were important to replicate in other contexts. The relationship of ICT operations in KM was positive and significant and it was the one with the strongest relationship in the model which means that SMEs in the manufacturing industry that strongly use ICT operations in the business value chain will allow them to be more able to create, share and apply knowledge beyond their functional boundaries, which coincides with the results of Alegre and Pérez-López [103] and Martinez-Conesa, et al. [16] On the other hand, they relate from different perspectives to ICT that place it as an important tool to increase and advance in KM processes [8, 13, 21, 33, 65, 67, 70, 104].

The findings of Martinez-Conesa, et al. [16]; Cillo, et al. [59]; Papa, et al. [79]; Alassaf, et al. [80] are confirmed within the results which also support the positive relationship of KM on OI. Moreover, from the general view, KM is key to successfully promote innovation capability in organizations [34, 69, 75, 76]. The results of the positive effect of KM on OI indicate that SMEs in the manufacturing industry with strong KM capabilities beyond their functional boundaries that open their innovation strategies are more likely to develop OI capability by achieving the benefits it brings.

The study contributes to the management of SMEs that decide to move from closed innovation to open innovation. The topic is new in its application to SMEs in Mexico. International studies have focused on the study of open innovation in large companies but very little literature indicates studies in SMEs in emerging countries, so the results also have a contribution in this regard.

7. Implications and Limitations

Executives must be aware that efficiently managing the creation, sharing and application of knowledge outside their functional boundaries is key to the shift towards OI. On the other hand, there has been an increase in the use of ICT in SMEs according to INEGI statistics records in México. However, it should not only be seen as a need for investment in ICT infrastructure but also as a need to make the company's value chain more efficient, generating possibilities for capacity development such as that of KM. It is necessary to promote knowledge management (both in its input and output practices). The foregoing will serve as support for the implementation of OI in organizations from the inbound perspective that will help in the rapid attention to market needs and the outbound perspective that will serve to obtain benefits through different mechanisms with partners from other institutions.

The study looks at SMEs in a single sector and in one state in the Midwest region. It would be convenient to conduct it in different sectors and in diverse regions with different contexts.

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