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Effect of ICT integration on SC flexibility, agility and company' performance: the Mexican maquiladora experience

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Abstract

This article reports a structural equation model (SEM) with four latent variables to measure the relationship between information and communication technologies (ICT) integration with supply chain flexibility, supply chain agility, and company's performance. The SEM integrates six hypotheses with relationships among variables and is validated with 378 responses from manufacturing sector to a questionnaire and partial least squares technique is used to evaluate it and test the hypotheses statistically. A sensitivity analysis is conducted in different scenarios to know conditional probabilities of occurrence of dependent variables, since a scenario has occurred in the independent variable with low and high success level. Findings indicate that ICT integration in supply chain facilitate to monitoring the production process, partners integration and have a direct effect on agility and flexibility for manufacturers, providing an active material' or sub-assemblies' flow among partners with greater visibility and making agile and joint decision-making.

Keywords ICT · SC agility · SC flexibility · SC performance · Tracking and visibility

1 Introduction

A supply chain (SC) is defined as a sequential network of partners involved in production processes that includes activities related to design, manufacturing, and delivery

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processes, where raw materials are transformed into finished goods or services, in order to satisfy consumer demands [1, 2]. Nowadays, a SC is a critical element that allows companies to achieve a competitive advantage, improve the customization of products, reduce the life cycle, establish closer relationships with suppliers and distributors; however, information and communication technology (ICT) must be used by partners to exchange information and plan their activities together [3].

Specially, use of ICT is justified in current globalized production systems, because some components in a final product come from different geographical regions that later are assembled and sold in others, so the integration of all the members in a SC is required. Specifically, in Mexico the maquiladora industries have boomed, which are foreign-owned companies that import raw materials from different regions, assembly a final product and export them to others, taking advantage of skilled and low-cost labor and preferential tariffs in customs due trade agreements. In 2018, there were 5074 companies of this type in Mexico, and 482 were in Chihuahua state and specifically, 326 were in Ciudad Juarez and that is the main industry, occupying more than 217,000 direct employees. For the proper SC functioning in the raw materials importing processes and finished products exporting from these maquiladoras, the use of ICT is widely required to guarantee synchronization and control the information uncertainty, material and financial resources flow [4].

Resuming, *ICT integration* increase the level of efficiency and support a better market position, facilitating the communication between partners in a SC [5] and enterprises decide to invest on it. However, traditionally investment in ICT has a high cost, so it is necessary to research the benefits in a SC because flexibility, agility, and economic performance depend on it [6].

Monostori [7] reports that ICT offers a great opportunity to acquire flexibility in globalized markets, while Mensah et al. [8] claims that ICT helps companies to recover resilience in uncertainty demands because sharing information is associated to a fast decision-making process. Also, Zhang and Cao [9] indicate that ICT is supporting SC integration with a fast collaboration among partners and Swafford et al. [10] argues that ICT is an essential tool for achieving *SC agility* and demonstrate that *ICT integration*, *SC flexibility*, *SC agility* and *Company's performance* are associated using information from companies in United States of America and using a structural equation model.

This paper replicates the study from Swafford et al. [10] in maquiladora companies stablished in Mexico, due to the high emphasis of import and export activities they execute in SC, where ICT is highly used and flexibility and agility are parameters of interest for managers looking for have a synchronized SC with partners in other countries. However, this paper is different because it analyzed a special industrial sector (Mexican maquiladora) that is totally integrated in globalized SC, have a high volume in raw materials importation and finished products exportation, with complex SC and partners around the world, the current technological development in ICT is higher than 10 years ago and the integration of SC members is more crucial.

Also, this paper reports a sensitivity analysis, and this is among the first papers to do it. The sensibility analysis is based on conditional probability to analyze the effects that an independent variable may have on another dependent variable, which is performed for high and low levels. This sensitivity analysis allows managers to identify the success' probabilities or risk in activities that they perform for better performance.

2 Literature review and hypotheses statement

2.1 ICT integration in SC

ICT is defined as a set of computer platforms, devices, and communication protocols based on the Internet to manipulate, store, retrieve, and communicate data and information [11]. Companies use ICT for integrating their internal functions, which allow them to gain benefits as productivity and quick response to customers [12]. Furthermore, ICT allows the achievement of a wide SC visibility [13] and a better forecasting, acquisition, and material resources management because there is a better information flow and sharing among partners [14]. The use of ICT can be along the SC, as procurement [15], production process and distribution [16], giving visibility among SC and makes easy to track products and components using technologies as RFID (Radio Frequency Identification) and know specific geographic position, probable arriving time, among others [17, 18]. From the manufacturer point of view, ICT allows to make designs and quick modifications to products with software associated to Computer Aid Design (CAD) [19], plan in a better way with MRP (Material Requirement Planning) [20], coordinate the production processes with isolated numerical control equipment (CNC) or with integrated computer integrated manufacturing (CIM). Therefore, it is concluded that managers must strive to integrate ICT in their SC in order to obtain its benefits associated as flexibility, agility and a better performance.

2.2 SC flexibility

SC flexibility can be defined as how organizations may change while trying to react to uncertainties in an

economical, reactive, and proactive way in order to adapt themselves to customer needs [21]. So, flexibility is originated as response to customers, since they are the ones who ask for variety, quality, competitive prices, and immediate deliveries. Commonly, flexibility is classified as manufacturing flexibility (product flexibility, new product introduction flexibility and volume flexibility) and logistics flexibility (distribution flexibility) [10, 22]. Manufacturing flexibility refers to the manufacturer's capacity to work along with the production processes and new products development, whereas logistic flexibility reflects the ability to respond and deliver different production orders in an appropriate way, quickly and efficiently [23].

The main benefit from SC flexibility is that offers different alternatives or methods for make adjustments to complex patterns of consumer demand, boost company value because can accept more production orders and combat increased market volatility [24]. So, nowadays, ICT contribute to organizations' ability to change quantity and delivery time from suppliers because there is an efficient information flow [23]. But also, using ICT such as the CAM and Computer-Aided Process Planning (CAPP) is possible to become more flexible, changing the production volume, products mixtures and reduce the cycle time [21]. Even when flexibility may have several sources, in this research the following hypothesis is presented:

H_1 *ICT integration* in maquiladora's supply chain has a positive and direct impact on *SC flexibility*.

2.3 SC agility

SC agility refers to the capacity that includes organizational structures, information systems, and a sets of minds to respond to the market uncertainties and potential disruptions by turning them into competitive opportunities [25] and consequently, agility is considered as a precedent of responsibility and a pillar of customer satisfaction. Specifically, it refers to the ability of companies to adapt to changes, by capturing, processing, and sharing large amounts of information and coordinating intra and inter-organizational processes, for improve the SC efficiency [26].

In general, agility addresses the speed of response from a company to several aspects, such as reducing lead and cycle time, increasing the introduction and production of innovative high-tech products, improve the customization level for customers [27], adjust the delivery capacity and keeping the reliability. However, Iqbal et al. [28] declare that an agile company must maintain an efficient customer service without sacrifice the speed in a dynamic market.

In order to act in an agile and efficient way, different partners in a SC must be in constant communication, and thus all information (inventories records, supply products, and demand) must be available and shared at any time, as well as in the shortest time, which may be possible through the *ICT integration* among them [4]. As result from a fast flow of information, SC partners can monitor the market needs and relocate resources in a fast and joint decision making process [25]. For example, Wu et al. [29] and Swafford et al. [10] report that sharing information using ICT creates opportunities to increase the *SC agility*, as well as speed, since it helps to get product development, acquisitions, and manufacturing [10]. In that sense, the following hypothesis can be established:

H_2 *ICT integration* in maquiladora's SC has a direct and positive impact on *SC agility*.

SC agility is considered a type of flexibility that has the capacity to help companies to reflect the fast-changing market need, and prevent the disruption between SC partners [29], because flexibility is one of the antecedents of agility and sometimes those terms are confused [10, 30]. However, flexibility is related to different states that a manufacturing system may adopt, such as the ability to move from one product to another and the ability to produce good quality products within a specific range [31]. On the other hand, the *SC agility* is a coordination and philosophy integration that involves all members in the companies' value chain with high speed [25].

In other words, flexibility refers to the different methods associated to solve a problem and agility refers to speed to do that. For this reason, companies must have several alternative methods to solve production problems related to demand from customers, which gives speed in their production system as *SC agility* [32]. Therefore, the following hypothesis is presented:

H_3 *SC flexibility* in a maquiladora company has a direct and positive impact on the *SC agility*.

2.4 Company's performance

In general, companies seek to increase their performance through the integration of different techniques and methodologies, in fact, the performance indicates how the company is in terms of business. In addition, performance can be measured in two ways; financial or operational way. Financial performance can be measured by different indicators, such as return on investment (ROI), return on assets (ROA), return on sales (ROS), and cash flow, among others [33]; while the operational performance, although at the end ends up becoming economic benefits, it is mainly integrated by the quality of the product, costs, and delivery time, as well as the flow of material and information.

The performance in a company may have several sources, and studies are reporting that when companies use ICT, they gain benefits, both economically and operationally; for example, DeGroote and Marx [34] have reported that the proper use of ICT guarantees an appropriate *Company's performance*; however, as Pérez-López et al. [35] argue, that implementation process must be planned according to investment programs, due mainly to high cost. The relationship between *ICT integration* and *Company's performance* has been reported by X. Zhang and Yang [36] for reduce uncertainty with a fast information flow among partners in a SC and Claro et al. [37] indicate that ICT is essential in the buyer–seller relationship, because that represent a low lead time, better quality in products, major shared market and financial income for partners and then, the following hypothesis is proposed:

H_4 *ICT integration* in a maquiladora company has a direct and positive effect on the *Company's performance*.

According to Ravichandran [23], the capacity of transfer and access to information achieved by the ICT has a direct impact on *SC flexibility* in a company, because they get a better performance related to the main flexibilities associated with the development of products, production, suppliers, among others. That is why the company has different manufacturing methods, easily can change the supply orders with supplier, can make fast adjustments in the production system to meet the demand and can be possible to change the delivery times to customer.

Likewise, according to Sreedevi and Saranga [38], the *SC flexibility* is a key tool for mitigating financial risks in companies operating in highly uncertain environments, which helps to guarantee better incomes for the company due to a fast decision making process. Finally, Chan et al. [27] indicates that *SC flexibility* is a source of performance in the fashion industry and therefore, the following hypothesis is presented:

H_5 *SC flexibility* in a maquiladora company has a direct and positive impact on *Company's performance*.

The lead time reduction represents a fast delivery to customers, who pay for a product or services [39] and this guarantee sales and income for the company [40], so that speed or agility are characteristics that a manager should seek, although as mentioned by Um (2017), in this process companies must try to deliver customized products with high novelty level. However, that speed to make changes and deliver customized products should not represent a financial risk and managers should perform an economic analysis before making decisions [41]. Also, if an production order is not agility attended, then there is a risk to lost shared market [42].

The support from *SC agility* to *Company's performance* has been reported by Tse et al. [43] in the Chinese fashion industry, by Swafford et al. [10] in the American manufacturing industry and García-Alcaraz et al. [24] in the Spanish wine industry. Based on this, the following hypothesis is proposed:

H_6 *SC agility* in a maquiladora industry has a direct and positive impact on the *Company's performance*

Figure 1 illustrates a graphic representation of the proposed hypotheses described in previous paragraphs.

3 Methodology

Figure 1 represents a structural equation model (SEM), indicating that latent variables or constructs are related and for validate statistically it, then is necessary to access to information from the Mexican maquiladora sector and the following task were done.

3.1 Gathering data from companies

To validate the SEM in Fig. 1, it is necessary to get information from Mexican maquiladora industry, therefore, a questionnaire is designed for validating those established hypotheses. This research is a replication from the Swafford et al. [10] report and their survey used, which has been adapted to the local environment and items appears in Table 1. The questionnaire uses a five-point Likert response scale [44], where number one indicates that the activity is not important, or the benefit is not obtained, while number five indicates that the activity is always performed, or the benefit is always obtained.

The questionnaire has three sections: the first one includes demographic information, the second section

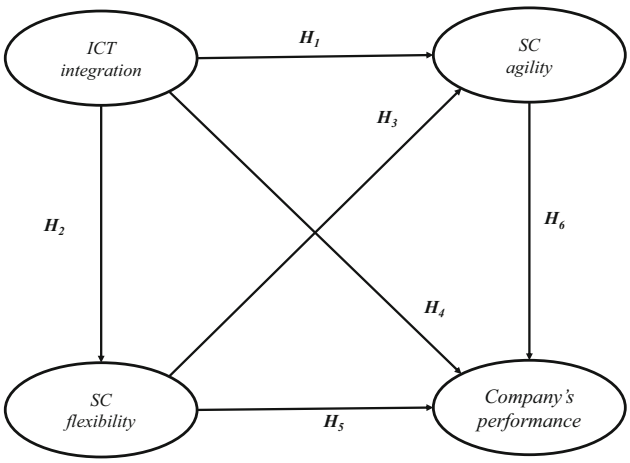

Fig. 1 Proposed model

Table 1 Construct, items and metrics

Construct/item	Factor loading (t-value)	Median	IQR
ICT integration			
ICT1. Use of ITC to coordinate/integrate activities in logistics and distribution	0.811 (17.672)	3.336	1.641
ICT2. Use of ITC to coordinate/integrate activities in procurement	0.845 (18.484)	3.418	1.586
ICT3. Use of enterprise resource planning or supply chain planning software for managerial decisions	0.813 (17.705)	3.445	1.719
ICT4. Use of ITC to coordinate/integrate activities in design and development	0.806 (17.53)	3.481	1.794
ICT5. Use of ITC to coordinate/integrate activities in manufacturing	0.769 (16.655)	3.540	1.832
SC flexibility			
FLE1. Ability to change quantity of supplier's order	0.778 (16.854)	3.363	1.726
FLE2. Ability to change delivery times of supplier's order	0.767 (16.607)	3.397	1.611
FLE3. Ability to alter deliver schedules to meet customer requirement	0.794 (17.248)	3.378	1.587
FLE4. Ability to change production volume capacity	0.789 (17.199)	3.400	1.665
FLE5. Ability to accommodate changes in production mix	0.775 (16.786)	3.417	1.680
FLE6. Ability to reduce manufacturing throughput times to satisfy customer delivery	0.773 (16.786)	3.426	1.672
FLE7. Ability to reduce development cycle times	0.778 (16.74)	3.372	1.673
SC agility			
AGI1. Speed in reducing manufacturing lead-time	0.717 (13.909)[a]	3.317	1.593
AGI2. Speed in reducing development cycle time	0.738 (15.401)	3.361	1.671
AGI3. Speed in increasing frequencies of new product introductions	0.773 (15.905)	3.442	1.692
AGI4. Speed in increasing levels of product customization	0.796 (16.737)	3.360	1.643
AGI5. Speed in adjusting delivery capability	0.803 (17.303)	3.357	1.506
AGI6. Speed in improving customer service	0.794 (17.455)	3.336	1.488
AGI7. Speed in improving delivery reliability	0.746 (17.241)	3.544	1.692
AGI8. Speed in improving responsiveness to changing market needs	0.717 (16.101)	3.469	1.686
Company's performance			
PER1. Return on global assets	0.855 (18.737)	3.307	1.958
PER2. Global market shared	0.893 (19.679)	3.281	1.855
PER3. Profit margins (Profitability)	0.877 (19.625)	3.315	1.660
PER4. Profit as sales/number of employees	0.839 (18.354)	3.155	2.203

[a]Eliminated due to collinearity problems

includes aspects related to the *ICT integration* (five items), *SC flexibility* (seven items), *SC agility* (eight items), and *Company's performance* (four items). Please review the questionnaire as complementary material.

The Mexican maquiladora sector is selected to collect the data, due to its high rates of ICT implementation, raw material importation and finished products exportation. The questionnaire is focused in SC managers using ICT in maquiladora industry. Responders are identified through associations and business groups and this represent a stratified sampling; however, some managers provide information about other colleagues in other companies who can participate in the research and then the snowball sampling is used. Every questionnaire is responded in a personal interview.

Finally, a database is designed to register the data in SPSS 24® software, and some debugging task are done [45]: missing values identification that are replaced by median values, outliers or extreme values, and non-compromised responders, among others.

3.2 Data analysis

A univariate analysis is carried out to identify the central tendency and dispersion measures for each item in the latent variables, where the median is used as a central tendency measure since the data is in an ordinal scale and the interquartile range (IQR) is used as dispersion measurement. Then, a multivariate analysis is performed, where the first tasks are executed to estimate the validity of the latent variables integrated in the model [46].

A factor analysis is carried out using the principal components technique with a promax rotation and items with cross loadings lower than 0.5 are eliminated. Table 1 reports the cross-loadings, t values for the statistical test, the median and IQR.

Also, several validity index must be fulfilling before any analysis. For convergent and discriminant validity, the Average Variance Extracted (AVE) is used and accepting values greater than 0.5. Also, the correlations among latent variables with square roots of AVE on the diagonal, are estimated for discriminant validity. Diagonal values should be higher than any of the correlations involving that latent variable. To measure the internal consistency, the Cronbach's Alpha and the Composite Reliability index are used and values greater than 0.7 are accepted. The Variance Inflation Factors (VIF) are used to measure collinearity within latent variables and the acceptable values must be less than 3.3.

For measure the parametric predictive validity, the R^2 and Adjusted-R^2 are used and must be greater than 0.2, while the Q^2 is used to measure the non-parametric predictive validity and must have similar values to R^2 values. Other additional reliability coefficients are reported as complementary material as: Dijkstra's PLS reliability, True composite reliability and Factor reliability.

The structural equation modeling technique (SEM) is chosen to validate the hypotheses between variables in Fig. 1, because the relationships between them are represented by regression equations [47] and allows a construct to play a double role, as an independent and as a dependent variable. The WarpPLS V.6® software is used to validate the model, because it involves algorithms based on partial least squares (PLS) combined with covariance analysis methods and ideal for ordinal data, non-normal distribution in items or small sample [46].

Before interpreting the model, several efficiency and quality indexes are used to determine its feasibility and they are performed with a 95% of reliability level [48], because of data is not feasible, then wrong conclusions are made. The Average Path Coefficient (APC) is used for a general validation of the relationships between latent variables and the decision is based on a p value, the Average R-Squared (ARS) and Average Adjusted R-Squared (AARS) are used for predictive validity of the model and have a p value associated, the Average Variance Inflation Factor (AVIF) and Average full Collinearity VIF (AFVIF) as used for as collinearity measure and accepting values under 3.3, the Tenenhaus index (GoF) to indicate the general adjustment of the data to the model, accepting values over 0.36. However, other additional reliability coefficients are reported as supplementary material as: Standardized root mean squared residual (SRMR), Standardized mean absolute residual (SMAR), Standardized Chi squared and degrees of freedom (SChS), Standardized threshold difference count ratio (STDCR) and Standardized threshold difference sum ratio (STDSR).

In the SEM model three types of effects between latent variables are evaluated; the direct effects are the direct or simple relationship, which are represented by arrows in Fig. 1, each one helps to statistically validate the hypotheses proposed using a β value or path coefficient. Likewise, the indirect effects through two or more segments between two or more variables, and finally, the total effects that show the sum of the indirect and direct effects and every β value has a p value associated. The null hypothesis to test is:

$$H_0.\beta = 0 \quad (1)$$

$$H1.\beta \neq 0 \quad (2)$$

In addition, each dependent variable is associated with a R^2 value, which represents the variance explained by the independent variables [49]. For instance, when a latent dependent variable is explained by more than one independent variable, then the effect size or portion of the variance that is explained by that variable is estimated. Finally, the total effect sizes in a dependent latent variable must be equal to R^2.

4 Results

4.1 Sample description

After 6 months questionnaire application in the Mexican maquiladora industry, 378 valid questionnaires were collected. Table 2 shows results by sector, the position held by participants and sample average. As it can be seen, most participants belong to the automotive sector with 228 participants, while the aeronautical sector was the one with a low participation, only five. Also, it should be noticed that this sample represents the local population, since they are proportional to the number of existing companies in the region. On the other hand, it is relevant that those who reported the most ICT usage in the companies were technicians in SC department with 179 participants (47.35%), while 141 (37.30% were managers and 58 (15.35%) were supervisors.

4.2 Statistical validation and descriptive analysis

Table 3 portrays the indexes for each latent variable after the validation process, and according to the described methodology each one is achieved, concluding that there is internal reliability, as well as composite reliability because the Cronbach's alpha and composite reliability values have

Table 2 Sample description

Sector	Manager	Supervisor	Technician	Total (%)
Automotive	88	22	118	228 (60.32%)
Others	28	7	8	43 (11.37%)
Machining	12	10	14	36 (9.53%)
Electrical/electronics	4	11	24	39 (10.32%)
Logistics	6	5	6	17 (4.5%)
Health	2	3	5	10 (2.64%)
Aeronautical	1	0	4	5 (1.32%)
Total	141 (37.30%)	58 (15.34%)	179 (47.35%)	378 (100.00%)

Table 3 Questionnaire validation

Index	ICT integration	SC flexibility	SC agility	Company's performance
R^2		0.421	0.603	0.437
Adjusted R^2		0.420	0.601	0.432
Composite reliability	0.905	0.903	0.909	0.923
Cronbach's alpha	0.868	0.871	0.883	0.889
Average variance extracted (AVE)	0.655	0.607	0.589	0.751
Full collinearity VIF	1.871	2.689	2.754	1.716
Q^2		0.424	0.603	0.439

values greater than 0.7. Similarly, there is an adequate convergent validity, since the AVE values are greater than 0.5, and according to the R^2 and Adjusted R^2 values, it is concluded that there is enough parametric predictive validity, because every latent variable is associated to values greater than 0.2. In addition, the Q^2 values are similar to the R^2 and greater than zero values, therefore, there is also nonparametric predictive validity, and finally, according to VIF values, there are no collinearity problems, because every variable have values lower than 3.3. In supplementary material readers can review the confidence intervals for cross loadings and correlation among latent variables with square root of AVE that confirm discriminant validity and some additional reliability coefficients for latent variables that indicate the structural equation model analysis.

4.3 Model evaluation

Since the latent variables have been validated, then they are integrated in the SEM. Table 4 indicates the efficiency indexes for the model, and all items have achieved the previously established values. For example, the APC index is 0371, a value greater than 0.2, the minimum admissible, ARS is 0.487 and AARS is 0484, indicating predictive validity in the model and the most important, the GoF is 0563, indicating an adequate fit from data to the model. In addition, those results allow to conclude that the model can be interpreted, and supplementary material illustrate five additional indices that confirm the quality model.

Figure 2 shows the evaluated model with the relationships (hypotheses) among latent variables analyzed. Each direct effect is represented with a β value or path coefficient as a dependence measure from an independent variable to another dependence variable in standard deviation units, a p value for the statistical test and a R^2 for dependent latent variables and indicates the amount of variance explained by all independent variables affecting it. Complementary material illustrates t-values and confidence intervals for path coefficients (β) at 95% confidence level for additional information for readers.

Information in Fig. 2 lets to conclude about the hypotheses. To illustrate, for H_2 the *ICT integration* effect on *SC agility* has a $\beta = 0.219$ and $p < 0.001$, it means that if the first latent variable increases its standard deviation by one unit, the second variable goes up by 0.219 units, being a significant relationship with 95% of confidence. A similar interpretation can be proposed for the other relationships between latent variables and Table 5 describes a summary for the hypotheses and reports the β values obtained in the model and by Swafford et al. [10] and it is easy to see that the current relationships among latent variables in maquiladora industry are higher than in the American manufacturing industry 10 years ago.

The effect size represents the contribution of an independent variable to the R^2 coefficient in a dependent

Table 4 Model fit and quality indexes

Index	Value	Criterion
Average path coefficient (APC)	0.371, $p < 0.001$	$p < 0.05$
Average R-squared (ARS	0.487 $p < 0.001$	$p < 0.05$
Average adjusted R-squared (AARS)	0.484 $p < 0.001$	$p < 0.05$
Average block VIF (AVIF)	2.069	Ideally <= 3.3
Average full collinearity VIF (AFVIF)	2.258	Ideally <= 3.3
Tenenhaus GoF (GoF)	0.563	Large > = 0.36

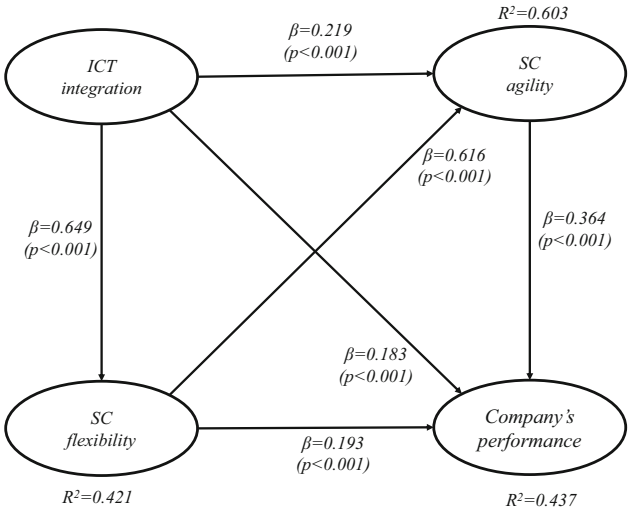

Fig. 2 Evaluated model

variable and Table 6 shows them for each simple relationship or direct effects. For example, the *ICT integration* variable explains 42.1% of *SC flexibility* ($R^2 = 0.421$). However, *SC agility* is explained in 60.3% by two variables, but 13.6% comes from *ICT integration,* and 46.7% from *SC flexibility*, which allows to conclude that managers that want to gain *SC agility*, must focus their attention on *SC agility* first.

Finally, 43.7% of the variance from *Company's performance* is explained by three variables, but *ICT integration* is responsible only for 9.7%, *SC flexibility* has 11.3% and finally, *SC agility* explains 22.7%, which indicates that in order to get an adequate performance, a proper *SC agility* is directly required because it has a bigger explanatory power. In other words, managers that want to gain *Company's performance* must focus their attention to SC agility, because this variable has the higher explanatory power.

Table 7 illustrates the total indirect effects among latent variables, as well as the associated *p* value, and the size effects as a measure of the variance explained. Here is important to mention that some indirect effects are higher that the direct effect, indicating the importance from mediating variables. For example, the direct effect between *ICT integration* and *SC agility* is only 0.219, but the indirect is 0.399 indicating the important roll from *SC*

Table 5 Conclusions about hypotheses

H_i	Independent variable	Dependent variable	β value		Conclusion
			Our model	Swafford et al.	
H_1	ICT integration	SC flexibility	0.649	0.205	Accept
H_2	ICT integration	SC agility	0.219	0.111	Accept
H_3	SC flexibility	SC agility	0.616	0.565	Accept
H_4	ICT integration	Company's performance	0.183	**	Accept
H_5	SC flexibility	Company's performance	0.193	0.167	Accept
H_6	SC agility	Company's performance	0.364	0.274	Accept

**Not analyzed

Table 6 Effect size for direct effects

To	From			R^2
	ICT integration	SC flexibility	SC agility	
SC flexibility	0.421			0.421
SC agility	0.136	0.467		0.603
Company's performance	0.097	0.113	0.227	0.437

Table 7 Sum of indirect and total effects

To	From		
	ICT integration	SC flexibility	SC agility
Indirect effects			
SC agility	0.399 ($p < 0.001$)		
	ES = 0.248		
Company's performance	0.351 ($p < 0.001$)	0.224 ($p < 0.001$)	
	ES = 0.187	ES = 0.131	
Total effects			
SC flexibility	0.649 ($p < 0.001$)		
	ES = 0.421		
SC agility	0.619 ($p < 0.001$)	0.616 ($p < 0.001$)	
	ES = 0.385	ES = 0.467	
Company's performance	0.534 ($p < 0.001$)	0.418 ($p < 0.001$)	0.364 ($p < 0.001$)
	ES = 0.284	ES = 0.243	ES = 0.227

flexibility as mediator. Another example is the relationship between ICT integration and Companýss performance, where the direct effect is only 0.183 and the sum of indirect effect is 0.351.

Also, Table 7 displays the total effects among variables (sum of total indirect and direct effects). For each total effect there is a β value, the *p* value associated to test the statistical significance, as well as the effect size. According to the analysis of this data, all indirect and total effects are statistically significant. Here is important to note that the higher total effects between ICT integration and all other variables, and this indicate the current importance that ICT is having in globalized production systems and SC.

4.4 Sensitivity analysis

Table 8 illustrates the performed sensitivity analysis for the low (p ($Z < -1$)) and high (p ($Z > 1$)) success levels in latent variables in the model, where columns represent the independent variables and the rows the dependent variables. In addition, the probability of occurrence for the variables in each level is reported independently or isolated at their low and high levels. The sensitivity analysis reports the probability of occurrence for these variables happening jointly (*&*), as well as the conditional probability of the occurrence for the dependent variable at its levels, since the independent variable has occurred at its level (*If*).

5 Discussion and industrial implications

As it was mentioned before, an appropriate information transfer and management brings benefits to SC. Therefore, the most significant contribution of the present research is reporting a measure about the impact of ICT directly or indirectly, in terms of flexibility, agility, and companýs performance for Mexican maquiladora industry, which may be a limitation, since, in another geographic and sector context, the results may be different. Specifically, the mentioned results along this research according to the dependencies between the variables agree with those obtained by Swafford et al. [10], showing different dependence values on the β parameters, been greater in our research and that can be due to the high technological improvement in 10 years.

From information in Table 8 it is observed that probability of having *SC flexibility* and *ICT integration* at their high level jointly is only 0.103 and that is a low value, but the probability that the first variable occur given the second one has occurred is 0.574, which indicates that managers must be focused on achieving an adequate *ICT integration* in their SC and productive system because as consequence there will be high *SC flexibility*. However, a company never will have high values in *SC flexibility* if there is a low *ICT integration* in the productive system, because the conditional probability of occurrence is zero.

Low level in *ICT integration* can have as consequence also low levels in *SC flexibility* because the conditional probability is 0.596, a high risk for SC managers, but a high level in *ICT integration* can guarantee a high level in *SC agility* because the conditional probability for that scenario is 0.544; however, that high level in first variable almost never is associated with low level in second variable, because the conditional probability is only 0.015 and that mean that managers can obtain not only flexibility, but agility in SC from *ICT integration.*

A low level in *ICT integration* has a lot risk for companies, because conditional probability associated with high level of *SC agility* is zero and this mean that ICT is a source of agility in a company. Also, a high level in *ICT*

Table 8 Sensitivity analysis

			Independent variable					
			ICT integration		SC flexibility		SC agility	
		Level	+	–	+	–	+	–
Dependent variable	Level	P(Z)	0.180	0.138	0.190	0.153	0.212	0.183
SC flexibility	+	0.190	& 0.103	& 0.000				
			If 0.574	If 0.000				
	–	0.153	& 0.003	& 0.082				
			If 0.015	If 0.596				
SC agility	+	0.212	& 0.098	& 0.000	& 0.116	& 0.000		
			If 0.544	If 0.00	If 0.611	If 0.000		
	–	0.183	& 0.003	& 0.082	& 0.000	& 0.103		
			If 0.015	If 0.596	If 0.000	If 0.672		
Company's performance	+	0.180	& 0.071	& 0.003	& 0.061	& 0.000	& 0.098	& 0.000
			If 0.397	If 0.019	If 0.319	If 0.000	If 0.463	If 0.000
	–	0.175	& 0.008	& 0.061	& 0.008	& 0.077	& 0.008	& 0.095
			If 0.044	If 0.442	If 0.042	If 0.500	If 0.037	If 0.522

integration is associated with high level in *Company's performance* because the conditional probability among those variables is 0.397, and that high level in first variable is not associated with low level in second variable, because the conditional probability is only 0.044, meaning that manager must focus in *ICT integration* process.

SC flexibility is a source of *SC agility* because the conditional probability for high level in first variable and high level of second variable is 0.611, and that high level in first variable never is associated with low level in second variable because the conditional probability is zero. Therefore, low level in *SC flexibility* never is associated to high level in *SC agility*. Also, there is a high risk that low level in *SC flexibility* generates a low level in *SC agility*, because the conditional probability is 0.672.

The greatest direct effect is the impact that *ICT integration* has on *SC flexibility* and this mean that ICT facilitates the process of planning the SC performance, which improves flexibility that can produce several combinations of products in a faster way, more efficiently and low cost, and this mean a better results for the company, as is also reported by Asad et al. [22]. Additionally, this indicates that companies that want high levels in flexibility should invest in *ICT integration* throughout their production process, including the SC from procurement services to distribution. However, justifying these investments in ICT is not an easy task, due to budget constraints and rapid depreciation or loss of value [50], however, it is really necessary because according to the sensitivity analysis, high levels in *SC flexibility* may occur with a probability of 0.547 if there is a high level of *ICT integration*, but if there is a low *ICT integration* due to low investments, then there is a probability of 0.596 to obtain low levels in the *SC flexibility* and that is a high risk for companies.

The *ICT integration* itself does not represent a benefit for the company. As Fig. 2 shows, the direct effect is only 0.183 standard deviations on *Company's performance*, but indirectly, by using *SC flexibility* and *SC agility* as mediating variables, it has an indirect effect of 0.351; therefore, the indirect effect is greater than the direct effect, which indicates that after and ICT investment, managers must focus to obtain greater flexibility and agility in SC, since, as a consequence, they may have an adequate indexes performance for the company. In other words, *ICT integration* must be focus first to gain *SC flexibility* and *SC agility*, and as consequence, the *Company's performance*.

In order to achieve an adequate *SC agility*, it is important to make an adequate *ICT integration*, which shows a direct effect equal to 0.219, as well as an adequate *SC flexibility* with a direct effect of 0.616, since these two variables can explain up to 60.3% of its variability (the highest in the model). However, when that variability is divided into its components, it is observed that *SC flexibility* is the most relevant variable for reach *SC agility* with 46.7%. Again, the conclusion is that managers must be focused on obtaining a greater *SC flexibility* in order to guarantee the *SC agility*.

According to the sensitivity analysis, it is observed that if there is a high level in the *SC flexibility*, then there is a probability of 0.611 to obtain a high level in the *SC agility*, because with a low level in the *SC flexibility* there will never be high levels in the *SC agility*, since the probability is zero. However, if there is a low level in the *SC flexibility*, there is a risk to obtain a low level in the *SC agility*, which is 0.672. As a conclusion, managers must be focused in

obtaining high levels of flexibility in their production lines because that guarantee *SC agility*.

Here is important to point out that the direct effect that *ICT integration* has on *SC agility* is only 0.219, which can be misleading, since the indirect effect between these variables is greater than that, having the *SC flexibility* as a moderating variable with a value equal to 0.399, which gives a total effect of 0.619. The previous information demonstrates the importance of the *SC flexibility* in obtaining *SC agility*, because according to sensitivity analysis, companies with high levels in *ICT integration* have a probability of 0.544 to obtain a high level in *SC agility,* and that is why managers must focus their attention on ICT investment programs. However, if the *ICT integration* is low, there is a risk of 0.596 to obtain low levels in the *SC agility*; these results agree with those reported by Ngai et al. [25]; however, they analyzed the *ICT integration* considering its direct and indirect effects, and the present research is reporting only its direct effects.

In this model, it has been assumed that the *Company's performance* has a direct effect from the three variables that precede it, but when observing the β-values, it can be concluded that the highest value is related to *SC agility,* since it has a value of 0.361, which allows to conclude that managers must be focus on achieving adequate agility in order to have the desired performance. The previous information is demonstrated by observing that the *Company's performance* is explained in 43.7% by the variables that precede it, but *SC agility* explains 22.7%; more than half of the total. This is confirmed by analyzing the conditional probabilities between variables, since if a company has high levels in the *SC agility*, then it has a probability of 0.463 to acquire also high levels in the *Company's performance*; however, if there is a low level in the *SC agility*, then there is a risk of 0.522 to obtain low levels in indexes performance.

Finally, according to the β values it is possible to create a critical path in the model. In this case, the path is *ICT Integration– Supply Chain Flexibility—Supply Chain Agility—Company's performance*, which demonstrates that managers must centered on *ICT integration* to guarantee a better flexibility and as consequence, a better agility and performance.

6 Conclusion

The *ICT integration* in a production system and are a source of flexibility and agility in the SC and even more in this globalized time, where raw materials, transformation processes, distribution and consumption are made in different geographical regions and traceability and visibility for SC are necessaries for partners. Based on the results obtained from the sensitivity analysis, it is concluded that maquiladoras that do not invest in ICT have a risk of having low levels of flexibility and agility and, as consequence can have low rates of financial performance. However, high levels in ICT are always associated to high levels in *SC flexibility* and *SC agility*, and as consequence, high financial income.

Finally, although the objective of this research was not to compare two industrial sectors, observing the values in direct effects obtained by Swafford et al. [10] model validated with information from American manufacturing industry and our model validated in the Mexican maquiladora industry, it is observed that there are similarities and differences simultaneously. One of the biggest differences is the relationship between the variables *ICT integration* and *SC flexibility*, since the value is considerably higher in the Mexican maquiladora industry, which can be due to two reasons; the first is that the Swafford et al. [10] report was carried out in 2008 and the ICT and its application on SC have evolved considerably, the second is due to the globalized nature of the Mexican maquiladora industry, which has a high level of raw material importation and finished products exportation, and its partners are geographically distributed in different countries and the use of ICT is essential. In conclusion, high β values in our model indicates that the ICT is the main resource for communication among partners in current globalized companies, as the Mexican maquiladoras.

Other difference among research is that the item *AGI1. Speed in reducing manufacturing lead-time* from latent variable *SC agility* was eliminated due to collinearity problems and our model is executed with only seven items or observed variables instead of eight, as occur in Swafford et al. [10].

7 Future research

In this current model, *ICT integration* has been presented as a latent variable explained by several items, however, other aspects associated with knowledge in its implementation, management, updated, and modernization levels, among others, have not been analyzed, and in future jobs, these variables will be integrated. Similarly, in this research, the *SC flexibility* is considered as a single latent variable, but Moon et al. [51] suggests that this flexibility has been categorized as a supply, operational, and distribution flexibility, thus, in future works, it is intended to generate a second-order structural equation model that allows the integration of these types of flexibility. Also, other competencies of the SC will be integrated, such as those reported by Ngai et al. [25] related to the employee

abilities on ICT, as well as the managerial commitment that is invested on them.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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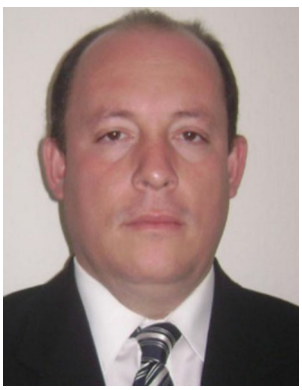

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