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Factors that Influence ICT Adoption at the Country Level. PLS-SEM Modelling [1]

Factores que influyen en la adopción de innovaciones TIC a nivel de país. Aplicación del modelo PLS-SEM

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Abstract

This research models the factors influencing ICT innovation adoption in companies, hypothesizing a network of direct and indirect relations of factors, (consistent with TOE model), which channels influence on themselves and on ICT adoption. The hypotheses were tested using a sample of firms with aggregate information at the state level, and were estimated using PLS-SEM. The main results were that ICT adoption is very influenced by the extent of countries' globalization, and the accessibility to ICT capabilities of the country due to its important transmitting role of indirect effects from the other factors. The aggregated indirect influence of factors in the model was more important than the direct influence.

Keywords: ICT Adoption; Technology Organisation Environment (TOE); Globalisation; Indirect Effects; PLS-SEM.

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Resumen

Esta investigación ha modelizado los factores que influyen en la adopción de innovaciones TIC en las empresas, hipotetizando una red de relaciones directas e indirectas de factores, (coherentes con el modelo TOE), que ejercen influencia en sí mismos y en la adopción de ICT. Las hipótesis se probaron utilizando una muestra de empresas con información agregada a escala de país, y estimadas mediante PLS-SEM. Los resultados concluyeron que la adopción de TIC se explica por el grado de globalización de los países, el acceso a las capacidades TIC en el país, debido a su papel transmisor de los efectos indirectos de los otros factores. La influencia indirecta resultó ser más importante que la directa.

Palabras clave: Adopción de Innovaciones; Entorno-Tecnología-Organización (TOE); Globalización; Efectos Indirectos; PLS-SEM.

Clasificación JEL: O39.

1. Introduction

The ICT can be defined as a technology used to support information gathering, processing, distribution and use (Beckinsale and Ram, 2006). At the same time, ICTs are gaining a growing interest due to the effects they have on productivity (Oliveira *et al.*,2014; Buyya *et al.*,(2009); Škrinjar *et al.*, 2010), internationalisation, competitiveness, cost reduction and customer satisfaction (Ifinedo, 2011; Capó-Vicedo, 2007).

During recent decades, ICT have innovated production processes due to automation. This transformation of production processes has in turn led to an improvement in production efficiency and an increase in the internationalisation of the company. This has occurred in such a way that the symbiosis of both processes has given rise to the globalisation of production processes (Milberg and Winkler, 2013).Indeed, the concept of the globalisation of production processes is based on technological advances, on the capacity of countries to attract FDI, on how these territories interrelate this investment with the local productive fabric and on the emergence of the knowledge society; constituting key factors so that nations (Frenz and Letto-Gillies, 2009) develop abilities to internationalise by connecting to global networks.

Moreover, ICT technologies have made business-to-business (B2B) communication possible by contributing significantly to production synchronisation with suppliers and other organisations (Armbrust *et al.*, 2010) in different countries, as well as the synchronisation of the overall activity of multinationals, enhancing their role in globalisation (Palafox, 2017). Likewise, e-commerce has favoured access to remote clients by reducing the cost of making contact (Mayer *et al.*, 2013 Hong and Zhu, 2006).

In parallel with the introduction of these technologies, a growing disparity has emerged between companies that adopt them and those that do not (Bach *et al.*, 2013), and an increase in FDI flows from advanced countries to certain emerging nations (Chaminade,2012). The interrelation of both processes has led to an increase in the digital divide between states at the global level (Addison, and Heshmati, 2003; Ruiz-Rodriguez, *et al.* 2018). In view of this new situation, governments are concerned about mitigating the digital disparities between countries through policies of promotion and diffusion of ICT technologies in companies and in the administration (Addison and Heshmati, 2003).

However, the sector has continued to grow and has entered a dynamic in which new technologies are emerging, that may radically transform cur-

rent production systems (Lin and Lin, 2008; Tsai *et al.*,2010). In this sense, the appearance of new ICT technologies (Wang and Wang, 2016, Gutierrez-Puebla *et al.*, 2016) will lead to profound changes in current production processes.

Consequently, the scientific literature has put considerable effort into analysing the mechanisms that influence ICT adoption in firms. A significant part of the studies has focused on factors related to organisation and the technology to adopt (Oliveira *et al.*, 2014), highlighting the costs of adoption, reliability and security (Gupta *et al.*, 2013), or the lack of skills to implement the technology. Nevertheless, very few studies have conducted a comprehensive analysis, taking the country as unit of analysis, which includes aspects of nations' scientific and economic environment, the influence that globalisation exerts on firms and states adopting ICT, and the capacity to manage innovation in companies. In order to do such analysis, a PLS-SEM estimation is carried out in this paper, since this technique enables simultaneous analysis of systems of variables and highlights the possible mediating effects between latent constructs.

Thus, the following objectives are addressedin this research: 1. modelling the factors that influence the adoption of ICT innovations by means of SEM (Structural Equation Modelling) and PLS (Partial Least Squares) techniques, using the TOE (technology-environment-organisation) model as a reference framework. 2. Identification, through the modelling, of direct and indirect effects of the explanatory constructs on ICT innovation adoption.

2. Research Model and Hypothesis Development

The adoption of innovations by companies is an extensively researched phenomenon in the scientific literature. There is, however, much less research aimed at the analysis of the adoption of ICT innovations in countries.

There are several models that address the diffusion of ICT innovations, including the Technology-Organisation-Environment (TOE) framework (Tornatzky *et al.*, 1990) and Rogers' DOI model (1995). However, in accordance with the characteristics of this research, it is more appropriate to use the TOE model.

To this end, the country has been considered as a relational asset or relational space in permanent construction in accordance with globalisation, the economic-scientific dimension of each state, the ICT context and the capacity of firms to adopt ICT. Then the three TOE constructs - environmental context, technological context and organisational context - have been adapted to the problem under study.

ENVIRONMENTAL CONTEXT takes concrete form, according to Tornatzky *et al.* (1990), in the firms' environment, the characteristics of the sector, the degree of competition among companies, access to suppliers' resources and

negotiation with administrations. In this research, the factor has been subdivided into two constructs, Extent of firms' globalisation of a country (GLOBAL) and Country Economic and Scientific Environment (CESE)(Annex 1), due to the fact that the process of diffusion/adoption of knowledge has been accelerated by the international and commercial opening up of countries and also because globalisation and technological-scientific change are interrelated, and mutually reinforcing. In this respect, Enkel and Gassmann (2009) affirm that in the 21st century the processes of innovation/adoption are more and more open and companies/countries use the knowledge of external sources much more efficiently.

TECHNOLOGICAL CONTEXT represents the internal and external technologies relevant for the firm that are accessible, although in the market. It also includes aspects related to the technology to be adopted like the perceived benefits and costs. In this research, this factor has been termed Technological ICT Context (TIC).

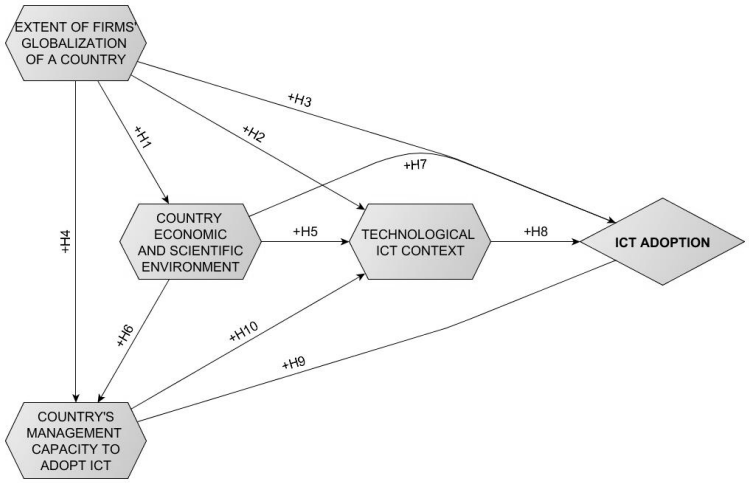
ORGANISATIONAL CONTEXT includes the size of the company and its environment; the degree of centralisation, qualification and complexity of the management structure; the skills of the human resources, firm absorption capacity, and the extent of availability of resources. In this research, it corresponds to the construct Country's Management Capacity to adopt ICT (CAPAC).

Finally, ICT Innovation Adoption (ADOPT) in the companies of each country has been considered as a dependent construct, understanding that the more ICT adoptions in a country the better this country is situated to access and use ICT. Indeed, the greater the dimension of the technological context, environmental context and the organisational context, the greater a country's facility to access ICT.

2.1. Hypotheses Development

The linkages and sense of direction of the factors or constructs represent the causal relationships between them. In accordance with the characteristics of the subject under study, the relationships between the constructs would have to be bidirectional, but to date the PLS-SEM models do not allow this, thus a unidirectional model was chosen. Consequently, on the basis of the bibliographical analysis undertaken, ten hypotheses were postulated on which the proposed model was constructed:

Fig. 1: The research model and the hypothesis development



Source: prepared by the authors

GLOBAL CONSTRUCT. The global environment of each country evolves in accordance with the volume of turnover of the multinationals outside their country of origin, the total value of the FDI of a country's firms abroad and the acquisition of technological knowledge through technological FDI (Palafox, 2017; Sahoo *et al.*, 2014; Nunnenkamp and Spatz, 2004; UNCTAD, 2013).

However, if countries are to successfully develop and maintain a significant global environment, internationalised companies must be constantly increasing their knowledge and developing and applying ICT (Gourlay and Pentecost, 2002; Bayo-Moriones and Lera-López, 2007; Wagner et al, 2003), using computer and telecommunication networks intensively (Atrostic and Nguyen 2007) and increasing the security of Internet servers.The GLOBAL construct may therefore influence TIC (annex 2).

Multinationals and internationalised companies need to develop organisational and coordination structures (Dyer and Singh, 1998) to build customer loyalty, create multidisciplinary R&D and innovation teams, form lasting links with suppliers, etc., in order to manage innovation and technology adoption well. The GLOBAL construct, therefore, influences CAPAC. Meanwhile, firms also need to have the ability to introduce themselves in global networks (Chaminade, 2012; Mas and Benagues, 2016). This also implies the development of new routines and processes to exchange crucial knowledge and information, over remote distances, which would be very difficult without the introduction of complex ICT technologies and without organisational and management capacity.

Therefore, the larger the business network in sectoral and geographical terms the greater knowledge the firm will have of the technologies available in the market, and the decision to adopt technology may be taken more promptly than in other firms with a more limited network (Abrahamson and Rosenkopf, 1997; Bayo-Moriones and Lera-López, 2007). In this sense, the introduction of a firm into a transnational network entails a challenge of coordination that can only be met through the use of ICT technologies. Hence these technologies are a great ally in the international expansion of companies (Santangelo, 2001; Akmanligil, and Palvia, 2004). Thus, the GLOBAL construct may influence TIC.

Furthermore, in the countries where these internationalised companies locate production plants, distribution networks etc., they need to find both a CESE and a TIC that are on a scale appropriate to the aim of these environments favouring ICT adoption,as digital infrastructures are vital to integrating local producers in the B2B networks and, thereby, attracting FDI (Addison and Heshmati, 2003; Hoti (2015); Raymond *et al.* (2005); Haller and Siedschlag (2011) and Hollenstein (2004).

Therefore, in accordance with this explanation, the following hypotheses are proposed:

H1. The GLOBAL construct is positively related to CESE.
H2. The GLOBAL construct is positively related to TIC.
H3. The GLOBAL construct is positively related to ADOPT.
H4. The GLOBAL construct is positively related to CAPAC.

CESE CONSTRUCT. The level of development of a country's economic and scientific environment has a positive influence on companies managing ICT innovation adoption well and on the amount of knowledge and ICT infrastructures in the country. In this respect, some authors (Blien and Maier, 2008; Nieto-Antolín and González-Álvarez, 2011; Bayo-Moriones and Lera-López, (2007); Billón *et al.* (2009); Oliveira *et al.* (2014) and Lin and Lin (2008) consider government policies to support the availability of ICT technologies and the existence of laws and regulations tailored to the use of these technologies to be fundamental for companies and for creating a conducive economic environment (annex 2).

Other authors (Morgan, 2007) believe that the development of policies promoting ICT must be complemented with the creation of a high density of high-quality research and innovation institutions, which generate cutting-edge ICT knowledge. Likewise, others argue that government acquisitions of advanced technology products stimulate the development of the TIC construct (Billón *et al.*,2009). All these elements, along with a high quality of management schools, build confidence in companies and improve the performance of the adopted ICT innovations.

Therefore, in accordance with these considerations, the following hypotheses are formulated:

H5. The CESE construct is positively related to TIC
H6. The CESE construct is positively related to CAPAC
H7. The CESE construct is positively related to ADOPT

TIC CONSTRUCT. The availability of ICT knowledge and infrastructures varies from country to country and is indispensable for the adoption of an ICT product or service by companies. The concept of technology availability (Bustamante-Donas, 2004) encompasses the degree of diffusion of the ICT technologies including the infrastructures, the number of ICT patent adoptions and the degree of Internet server security.

However, for these technologies to be adopted (Gupta *et al.*, 2013), they must be reliable in the sense that there is no loss of information, they offer an uninterrupted service and provide appropriate security conditions (annex 2).

Accordingly, the more important the ICT sector is in a country, and the more secure the ICT infrastructures are, the more substantial the accumulation of ICT knowledge, the larger the market of specialists and the higher the quality of ICT infrastructures may be. Moreover, the probability that companies in said country adopt an ICT product or service will be higher (Hollenstein, 2004; Tsai *et al.* (2010). Consequently, the possibility of externalities of ICT knowledge or spillovers being produced will increase.

Therefore, in line with this argument, the following hypothesis is formulated:

H8. The TIC construct is positively related to ADOPT

CAPAC CONSTRUCT. The success of the good management of ICT innovation adoption in companies depends on the capacity of business innovation, the skill level of those employed in ICT (Chun 2003; Hollenstein, 2004), the facility to obtain loans,the nature of the firms' competitive advantage and organisational capacity (Brynjolfsson and Hitt, 2000).This means that a company that complies with these characteristics has sufficient intangible resources to manage ICT innovation adoption Bayo-Moriones and Lera-López (2007), Billón *et al.* (2009) and Oliveira et al, (2014).Therefore, a company's capacity to manage ICT adoption well influences the level of development of the TIC construct and its scope (Gertler, 2003) (annex 2).

However, in spite of the advantages of ICT technologies, the volume of investment in these technologies varies substantially between countries, sectors and companies. The evidence suggests that not all companies in a country rush to adopt solutions based on ICT technologies (Trigueros-Preciado *et al.*,2013). For example, cloud computing is cutting-edge technology with problems that still need to be solved (absence of regulations, a high level of risk, high costs, etc.), and firms' knowledge of this technology is still limited (Oliveira *et al.*, 2014).

If we consider e-commerce, its adoption requires the company to have complex technical and organisational skills. Hence, for firms to transform their traditional value chain activities and move to electronic commerce they must master the integration of ICT technologies and electronic data interchange

(EDI), incorporate outsourcing partners and increase website costs (Weiyin Hong *et al.*,2006).

Therefore, in line with this reasoning, the following hypotheses are proposed:

H9. The CAPAC construct is positively related to ADOPT
H10.The CAPAC construct is positively related to TIC

THE ADOPT CONSTRUCT entails the adoption of ICT innovations. It comprises the B2B variable and also the extent to which IoT present in the market. The former represents the introduction of ICT into business routines and the latter may serve as a proxy to assess the introduction of the Internet of Things in different countries.

3. Data and Method

The lack of statistical sources has been a factor to take into account in carrying out this study, as most of the information available, which is also internationally comparable, is aggregated at the country level. This forced us to adopt the country as the unit of analysis, and to restrict the number of elements in the sample in accordance with the information available from these sources. For this reason, this sample is comprised of a group of developed countries and several developing economies.

The proposed model was tested by means of a sample created from four statistical sources at the latest available date: the World Competitiveness Report 2016, the Global Information Technology Report 2016, Ovum's Telecoms, Media and Entertainment Outlook 2015 and World Bank Statistics 2016. A database was created with the information from these sources, which consists of 16 variables (Annex 1) related to business management, economic-scientific environment, globalisation and availability of ICT technologies and infrastructures in the environment.

The methodology used[2] in the Glob Competitiveness Report and the Global Information Technology Report consists of 14,000 interviews repeated annually and targeting directors of corporations, spread over 138 countries. The World Bank conducts between 1,200 and 1,800 interviews per country, mainly targeting proprietors and top managers. Finally, a database was created with 83 cases (Annex3).

Lastly, it is important to point out that the IoT variable (Annex1) is not present in all the countries, hence the empty cases (15%) were estimated by means of an arithmetic mean of the geographical region they belong to. The following regions were considered: Europe, North America (except Mexico), Latin America, Asia and Oceania.

[2]The methodology used for Ovum's Telecoms, Media and Entertainment Outlook 2015 is not known.

The information obtained was analysed using PLS-SEM. This makes it possible, on the one hand, to relate the constructs designed; and on the other, it enables the validity of the causal synergies identified to be checked with each of the hypotheses presented in the previous section. This technique is especially appropriate for this research due to the size of the sample used (Green, 1991; Reinartz *et al.*,2009), and because it favours the simultaneous analysis of the systems of variables, while this is not possible, for example, with multiple regression (Caniëls *et al.*, 2015). Finally, the model used makes it possible to determine the mediating and moderating effect of the latent constructs (Hayes and Scharkow, 2013).

Another of the aspects to take into account has been the validity of the sample size. Thus, it was verified that this met conditions of reliability in accordance with Barclay *et al.*, (1995). The authors consider that the maximum number of cases to analyse per model is equal to 10 times the number of indicators of the largest formative construct, or ten times the construct with the largest number of incoming structural paths. Nevertheless, other authors, Roldán and Sánchez-Franco (2012), suggest that the estimation of the sample size in a PLS-SEM model requires a statistical power analysis performed on the construct with the largest number of predictors. In this way, the size of the sample was determined using power tables which for this model meant a minimum of 76 cases as the ADOPT construct consists of four predictors.

The estimation of the indirect effects was calculated in accordance with the methodology established by Nitzl *et al.* (2017). Specifically, the indirect effect was calculatedby means of the scalar product of the path coefficients of a and b, which are linked and connect the same source and destination constructs as path c'; therefore, the total effects (c) between the source and destination constructs would be represented as follows:

Eq. 1: total effect (c) = Indirect effect (axb) + direct effect (c')

The significance of the indirect effects was calculated by bootstrapping. Each subsample of *path a* was multiplied by the corresponding subsample of *path b*, in order to create the indirect effect *axb*. This product was used to calculate the confidence intervals (CI) as this was considered to be the most appropriate method to test the significance of the indirect effects (Wood, 2005). Moreover, it was convenient to correct the bias that is frequently produced when there is a difference between the bootstrapped distribution of the sample mean for the indirect effect ($a_M x b_M$) and the indirect effect estimated in the original sample ($a_0 x b_0$). Consequently, the significance of an indirect effect was defined according to Nitzl *et al.* (2016) as follows:

Eq. 2: $[k\ (0.5\text{-}CI\%/2))th + ((a_0 x b_0 - a_M x b_M);\ 1 + k\ (0.5 + CI\%/2))th + ((a_0 x b_0 - a_M x b_M)]$

The non-inclusion of the value 0 in the confidence interval will validate the significance of the indirect relationship axb.

4. Results

After having carried out the estimation of the model, first of all the parameters that assess the reliability of the constructs and the relationships between these (construct reliability, discriminant validity and multicollinearity) are presented. Second, the coefficients that assess the relationship between the constructs and their significance are shown (path model coefficients, indirect effects analysis).

4.1. Model Assessment

Table 1 shows the parameters used to validate the construct reliability and validity. Specifically, the measures used were Composite Reliability, Cronbach's Alpha, Rho A and Average Variance Extracted (AVE). The first three validate the internal consistency of the construct by determining whether the items that measure a construct have similar scores. On the contrary, the AVE parameter implies that a set of indicators represents a single underlying group due to its unidimensionality (Henseler *et al.*, 2009). After analysis of the results, it can be seen that all the constructs of the model exceed the values established for their validity (Henseler *et al.*, 2009) as all of them must exceed 0.7, 0.7, 0.7 and 0.5 respectively. Moreover, the results of r^2 were also included for each construct, where high values ranging between 0.53 and 0.83 can be seen.

The discriminant validity (Table 1) of the constructs was assessed using the Fornell-Larcker Criterion, which determines to what extent a construct is different from the others in order to highlight its singularity. The procedure consists in checking that the square root of the AVE of each construct is higher than the correlation of this construct with the other explanatory constructs.

Table 1. Construct reliability, validity and inter-construct correlations for reflective scales.

		CR. alpha	rhoA	CR	AVE	r^2	r^2 adj.	1	2	3	4	5
1	ADOPT	0.783	0.790	0.902	0.821	0.830	0.823	**0.906**				
2	CAPAC	0.870	0.894	0.911	0.722	0.627	0.619	0.751	**0.849**			
3	CESE	0.810	0.842	0.874	0.636	0.531	0.526	0.772	0.758	**0.797**		
4	GLOBAL	0.760	0.767	0.860	0.672	-	-	0.752	0.708	0.728	**0.819**	
5	TIC	0.874	0.884	0.922	0.798	0.685	0.675	0.892	0.763	0.762	0.721	**0,893**

Source: prepared by the authors

As can be seen in Table 1, the results of the model meet the criterion, and therefore contribute to validating the model.

The analysis of the multicollinearity of the constructs was conducted using two measures: the analysis of the correlations between exogenous constructs and the VIF indicator.

The correlation between the exogenous constructs is moderately high, the maximum value is 0.89 and the minimum 0.70 (Table1). Meanwhile, the VIF indicator shows values below 3.3 (Diamantopoulos and Siguaw, 2006) for all the predictors of the model (Annex 2). All this indicates that there is no multicollinearity in this model. Finally, it should be pointed out that the outer model meets the established validation criteria and confirms that all the indicators of constructs in Mode A have loadings above 0.7 and all of them are 99% statistically significant (Annex 2).

4.2. Analysis of the Hypothesis and Indirect Effects Analysis

The confirmation of the hypothesis was based on the analysis of the paths linking the *constructs* (Table 2). To this end it was necessary to analyse the significance of these paths using a bootstrap of 5,000 samples (Hair *et al.*; 2012)

Table 2. Path model coefficients and significance.

HYPOTHESIS	DEFINITION	PATH COEFFICIENT	t-statistic
H9	CAPAC→ICT ADOPTION	0.0520	0.7384
H8	TIC →ICT ADOPTION	0.6380	8.8307***
H5	CESE→TIC	0.3241	3.2927***
H6	CESE→CAPAC	0.5149	5.8367***
H1	GLOBAL →CESE	0.7286	17.4406***
H4	GLOBAL → CAPAC	0.3338	3.7839***
H2	GLOBAL → TIC	0.2379	2.42***
H7	CESE →ICT ADOPTION	0.1288	1.9958**
H3	GLOBAL → ICT ADOPTION	0.1619	3.0179***
H10	CAPAC→TIC	0.3491	4.727***

The asterisks, *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.
Source: prepared by the authors

Thus the constructs CAPAC, TIC, GLOBAL and CESEexplain 82% of the construct ADOPT,andthe hypotheses linked to the latter have been confirmed with99% significance: H8 ($p < 0.01$), H3 ($p < 0.01$);while H7 ($p < 0.05$) was confirmed with 95% significance and H9 ($p < 0.7$) was not significant.

The CAPAC construct is 62% explained by the GLOBAL and CESE constructs and the hypotheses that link H6 and H4 respectively are significant at 99% level: H6 ($p < 0.01$) and H4 ($p < 0.01$).

The TIC construct is 67% explained by the constructs CESE, GLOBAL and CAPAC. The relationships with these constructs have proved to be 99% significant in all cases: H5 ($p < 0.01$), H2 ($p < 0.01$) and H10 ($p < 0.01$).

Finally, the CESE construct is 52% explained by the GLOBAL construct and the hypothesis represented by this link has also proved to be significant: H1 ($p < 0.01$).

The intense relationship between the constructs that make up the model leads one to consider, on the one hand, the existence of indirect effects in the relationships between the constructs, and, on the other, that these help provide further explanations of the role of the constructs in the adoption of innovations. The results are shown in Table 3.

Table 3. Indirect effect analysis of constructs

ORI	Mediation	Direct effect			Indirect effect			CI1	CI	Type 2	Total effects
		Path	sig.	+/-	Path	sig	+/-	Inf	Sup		
GLOB	H1→H7	0.162	99	+	0.094	90	+	0.015	0.173	PC	0.641
GLOB	H1→H5 →H8		99	+	0.151	99	+	0.025	0.303	PC	
GLOB	H2→H8		99	+	0.151	95	+	0.027	0.272	PC	
GLOB	H1→H6→ H10→H8		99	+	0.083	99	+	0.032	0.156	PC	
CESE	H5→H8	0.128	95	+	0.206	99	+	0.033	0.411	PC	0.448
CESE	H6→H10 →H8		95	+	0.114	99	+	0.044	0.210	PC	
CAPAC	H10→H8	0.052	no	+	0.222	99	+	0.109	0.325	FM	0.274
TIC	H8	0.638	99	+	-	-	-	-	-	NM	0.638

1 CI: Coefficient interval bias corrected 2 Type of mediation: PC (Partial complementary), FM (Full Mediation), NM (No mediation).
Source: prepared by the authors.

Up to 7 possible indirect effects of the constructs GLOBAL, CESE and CAPAC on ADOPT have been found in the proposed model (Table 3). In all of them, except one in which partial mediations have been confirmed, it is therefore the mediation with origin in CAPAC that is total (full mediation).

The aggregation of the indirect path coefficients (Table 3) according to origin has made it possible to obtain the constructs with greater influence on ADOPT. These are: GLOBAL (0.479), CESE (0.32) and CAPAC (0.22). Therefore, GLOBAL has much greater indirect influence on the model than direct (0.48 indirect compared to 0.16 direct). Something similar occurs with CESE (0.32 indirect effect compared to 0.13 direct) and especially with CAPAC (0.22 indirect effect compared to 0.05 direct). It can thereforebe concluded that the indirect influence of these constructs on the adoption of innovations is much greater than the direct influence.

5. Discussion

The model obtained confirms, as has been demonstrated by other studies (Hair *et al.*, 2012), that the utility of the PLS-SEM models lies in offering an overall view of the phenomenon under consideration. The study of the indirect effects in the PLS-SEM modelling of ICT adoption, and the choice of the country scale as the scope of analysis provide a novel contribution to the scientific literature on the diffusion of ICT innovations. Most of the empirical studies have addressed ICT innovation adoption (Bayo-Moriones and Lera-López, 2007;Caniëls *et al.*, 2015; Billón *et al.*, 2009) using models that do not take into account the possible relationship between the explanatory constructs, or by using PLS-SEM models in which these indirect relationships have not been studied.

Below, the scientific contributions of this work are explained with regard to each construct of the model:

The GLOBAL construct. The analyses performed confirm that H3 is consistent with Hoti (2015); Raymond *et al.*(2005); Haller and Siedschlag (2011) and Hollenstein (2004). These demonstrate that the increase in the global and international projection of firms implies a greater tendency to adopt ICT technologies. Moreover, the influence of GLOBAL on CESE (H1), TIC (H2) and CAPAC (H4) has been corroborated (Table 2).

It was demonstrated in the results section that the four possible indirect effects between Globalisation and ADOPT had been confirmed (Table 3), and it was even verified that these were much greater than the direct effects. In view of all the above, and particularly the importance of the indirect effects of the construct, it can be deduced that the relatively low direct influence of GLOBAL on ADOPT could explain why few studies have taken this factor into account, while in this research it turned out to be the most important by adding the indirect effects.

This conclusion is not surprising in the matter that we are dealing with, given that at present, the deverticalisation of large companies through outsourcing tasks that were previously carried out internally is increasingly important, thanks to the application and development of ICT technologies. This new business organisation has given rise to global value chains, a result of the fragmentation of production of a good or service through the participation of firms/plants located in different countries (Palafox, 2017).

The CESE construct is relevant in the technology adoption processes as has been demonstrated by confirming H7 (Table 2). This is consistent with the work of Bayo-Moriones and Lera-López, (2007); Billón *et al.* (2009); Oliveira *et al.* (2014) and Lin and Lin (2008). These consider the market and government institutions to be a significant driving force in the adoption of innovations **(**Chinn and Fairlie, 2007; Gupta *et al.*, 2013).

The validation of H6 is in accordance with the results of Hadjimanolis, A., 1999; Tsai *et al.*, 2010; Billón *et al.*,2009 and Hough *et al.*, 2009; given that the countries with high values in CESE have a considerable impact on the com-

pany's management capacity to adopt ICT. Moreover, the validation of H5 is analogous to that obtained by Laursen *et al.* (2011) and Nieto-Antolín and González-Álvarez, (2011). Hence, these authors consider that scientific institutions provide knowledge and know-how that has been generated internally or acquired externally and which will serve to make technologies available in the market of the country.

Finally, as with the GLOBAL construct, CESE has a weak direct influence on ADOPT, although the indirect influence is important. This helps explain why in other studies, which use similar models to the one in this research but with a sectoral approach, the influence of the CESE construct on ADOPT has been more limited.

The TIC construct has an influence on ADOPT, as H8 has been confirmed. This is consistent with the results of Hollenstein, 2004,Gupta *et al.*,2013 and Tsai *et al.*,2010, which show that the availability of technology in the environment is a prerequisite for ICT adoption to occur; although Tsai *et al.* (2010) adds that the adoption will be limited if it is not reliable or secure.

This construct is the second most important of the model according to the total effects parameter, and it is the one that has the greatest direct effect on the dependent construct (Table 3). The results of this work therefore confirm the important mediating role of the TIC construct on the indirect effects of the model, given that it is a place of obligatory passage in 100% of the indirect effects analysed.

From all of the above, it can be deduced that this construct cannot be absent in a country due to its strategic nature, and it should receive a great deal of attention as its direct influence on ADOPT is decisive; and its role as transmitter of indirect effects is essential.

The CAPAC construct. Companies' capacities to manage ICT have been modelled with a direct relationship with the ADOPT construct (H9). This hypothesis was rejected as it was not significant, which contradicts the conclusions of Bayo-Moriones and Lera-Lópe z (2007), Billón *et al.* (2009) and Oliveira *et al.* (2014). These think that the skill level of employees, financing capacity and business strategy constitute significant variables in ICT innovation adoption.

Furthermore, the confirmation of H10 is consistent with the results of Gertler (2003) as the company's capabilities to adopt ICT would favour the existence of ICT competencies in the country. Moreover, the only indirect relationship between CAPAC and ADOPT has proved to be significant (Table 3).

Therefore, this construct is relevant for the adoption of innovations, but only when it is mediated by the TIC construct. It therefore validates the importance of this factor in the adoption of innovations. Thus, the indirect relationship is only partially consistent with Bayo-Moriones and Lera-López (2007), Billón *et al.* (2009), Oliveira *et al.* (2014) and Gupta *et al.* (2013).

Finally, this research has some limitations which must be presented. The Use of PLS-SEM restricted the causality analysis of the model since its analysis must be unidirectional. Notwithstanding, the impact between explanatory con-

structs is rather bidirectional, for instance, globalization of the countries favors the access to new ICT technologies from abroad, but on the contrary, when ICT technologies are available locally, firms can globalize more easily since ICT technologies are essential for their globalization. Thus, in future research an estimation with bidirectional causality should be carried out.

6. Conclusion

The modelling of the ICT innovation process using PLS-SEM has confirmed the existence of causal relationships between the explanatory constructs, which in turn has made it possible to carry out an analysis of the indirect effects of these constructs on ADOPT. After validating the relationships between constructs and comparing the direct and indirect influence of these on ADOPT, it was seen that the indirect influences are more important than the direct for ICT innovation adoption (0.98 in the direct paths, compared to 1.021 in the indirect, Table 3). Among the direct effects, the TIC construct stands out above the others, while in the indirect effects GLOBAL and CESE stand out.

Therefore our results probed that ICT adoption is explained by the degree of globalization of the countries, the role of public and private institutions in channeling the indirect effects, and level of accessibility to ICT capabilities in the country due to its transmitting role of indirect effects from the other factors.

Thus, the promotion of firm's internationalisation, particularly through FDI outflows, as well as the fostering accessibility to the latest ICT capabilities in the country, are the actions which policymakers should have into account, in order to favour ICT adoption in the firms . This latter element is a strategic construct, as it is the most influential on ADOPT, and also because it is the main channeller of the indirect effects of the factors studied. The development of TIC may be achieved through the globalisation of firms, the efforts of institutions to increase knowledge production, the promotion of legislation on ICT and the establishment of public procurement criteria related to innovation and ICT adoption.

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Annex 1. Variable Definition

Item	Definition	Measurement	Source
ICT use for business-to-business transactions	In your country, to what extent do businesses use ICTs for transactions with other businesses?	1 = not at all 7 = to a great extent	GITR
IoT (LTE) share of total market per country	Share of LTE introduction in the market	0 to 100	OVUM
Country capacity to attract talent	To what extent does your country attract talented people from abroad?	1 = not at all 7 = to a great extent—the country attracts the best and brightest from around the world	GCR
Extent of staff training	In your country, to what extent do companies invest in training and employee development?	1 = not at all 7 = to a great extent	GCR
Ease of access to loans	In your country, how easy is it for businesses to obtain a bank loan?	1 = extremely difficult 7 = extremely easy	GCR
Nature of competitive advantage	On what is the competitive advantage of your country's companies in international markets based?	1 = primarily lowcost labor or natural resources 7 = primarily unique products and processes	GCR
ICT PCT patents, applications/million pop.	Number of applications for information and communication technology–related patents filed under the Patent Cooperation Treaty (PCT) per million population | 2012–2013 average		GITR
Secure Internet servers/million pop.	Secure Internet servers that use encryption technology in Internet transactions.	Secure Internet servers per million population	GITR
Availability of latest technologies	In your country, to what extent are the latest technologies available?	1 = not at all 7 = to a great extent	GCR
Quality of scientific research institutions	In your country, how do you assess the quality of scientific research institutions?	1 = extremely poor, among the worst in the world 7 = extremely good, among the best in the world	GCR

Laws relating to ICTs	How developed are your country's laws relating to the use of ICTs (e.g., e-commerce, digital signatures, consumer protection)?	1 = not developed at all 7 = extremely well developed	GITR
Government procurement of advanced technology products	In your country, to what extent do government purchasing decisions foster innovation?	1 = not at all 7 = to a great extent	GCR
Buyer sophistication	In your country, on what basis do buyers make purchasing decisions?	1 = based solely on the lowest price 7 = based on sophisticated performance attributes	GCR
FDI and technology transfer	To what extent does foreign direct investment (FDI) bring new technology into your country?	1 = not at all 7 = to a great extent	GCR
Outward activity of ICT multinationals	Outward activity of ICT multinationals	Million dollars	World Bank
Foreign market size index	Value of exports of goods and services	normalised on a 1–7 scale	GCR

GCR: Global Competitiveness Report 2016; GITR: Global Information Technology Report, 2016; WBS: World Bank Statistics 2016, Ovum's Telecoms, Media and Entertainment Outlook 2015

Annex 2. Item Loadings / Weights and Significance by Latent Constructs

Construct	Item	Loading	t-statistic	Collinearity with constructs related to (VIFinner model)	
ADOPT	ICT use for business-to-business transactions	0.9178	86.427***	CESE	3.18
				GLOBAL	2.61
	M2M (LTE) share of total market per country	0.8942	41.782***	TIC	3.18
				CAPAC.	3.07
CAPAC	Country capacity to attract talent	0.8676	30.490***	CESE	2.13
	Extent of staff training	0.9237	63.945***	GLOBAL	2.13
	Ease of access to loans	0.7364	15.600***	TIC	2.68
	Nature of competitive advantage	0.8594	31.038***	ICT ADOPT.	3.07
TIC	ICT PCT patents, applications/million pop.	0.9052	59.317***	CESE	2.84
	Secure Internet servers/ million pop.	0.8655	42.511***	GLOBAL	2.43
				ICT ADOPT.	3.18
	Availability of latest technologies	0.9086	69.338***	CAPAC.	2.68
CESE	Quality of scientific research institutions	0.8159	19.849***	GLOBAL	1.00
	Laws relating to ICTs	0.8808	60.492***	ICT ADOPT.	3.18
	Government procurement of advanced technology products	0.7329	14.930***	CAPAC.	2.13
	Buyer sophistication	0.7527	13.714***	TIC	2.84
GLOBAL	FDI and technology transfer	0.7876	22.543***	CESE	1.00
	Outward activity of ICT multinationals	0.8654	23.576***	ICT ADOPT.	2.61
				TIC	2.43
	Foreign market size index	0.8040	20.757***	CAPAC	2.13

The asterisks, *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.
Source: prepared by the authors