The effect of strategic knowledge management on the universities' performance: an empirical approach

Sara Fernández-López, David Rodeiro-Pazos, Nuria Calvo and María Jesús Rodríguez-Gulías

Abstract

Purpose – *The purpose of this paper is to explore the relationship between the availability and use of IT solutions for strategic knowledge management (SKM) and the universities' performance, measured in terms of scientific production.*

Design/methodology/approach – *Drawing on the resource-based view (RBV) and the knowledge-based theory, the authors develop a conceptual framework for exploring the effect of SKM based on IT on the organisation's performance that they empirically test by applying panel data methodology to a sample of 70 Spanish universities over the period 2011-2014.*

Findings – *The authors confirm that the SKM based on IT influences the university's performance. This effect is positive in the case of the IT solutions referred to the infrastructure of data grouping and more evident when the university's performance is measured by indicators more directly related to scientific quality. Contrary to expected, the percentage of training and research staff that uses institutional tools of collaborative work is negatively related with the universities' capacity of publication.*

Practical implications – *The authors followed the system dynamics approach to identify a causal diagram and a flow sequence that lets them group universities in three different profiles in the knowledge management (KM) flow diagram.*

Originality/value – *First, the authors develop a conceptual framework for exploring the effect of SKM based on IT on the organisation's performance that could be applicable to analyse the case of other knowledge-driven organisations. Second, in contrast with the large number of studies dealing with SKM and performance focused on firms, the authors analyse universities. Third, the authors' empirical approach used the panel data methodology with a large sample of universities over the period 2011-2014.*

Keywords *Resource-based view, Panel data, University performance, Dynamic simulation, IT solutions, Strategic knowledge management*

Paper type *Research paper*

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1. Introduction

n 1958, Penrose defined, for the first time, a firm as a pool of knowledge and its supply of services as the result of the experience and knowledge of its employees (Penrose, 1958). After this definition, many authors have studied the relation between knowledge management (KM) and firm's performance, as well as the way in which KM involves all actors (government, academia, industry and civil society) that take part in the acquisition and transfer of knowledge inside and outside of organisations (Carayannis and Campbell, 2006, 2009, 2011; Miller *et al.*, 2011). The knowledge-based theory of the firm (Grant, 1996) also recognises knowledge as the most significant resource of a firm, and its relevance as input factor to the achievement of organisational goals (Kalling, 2003; Marr *et al.*, 2004).

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In the literature on KM, most researchers have studied the value of knowledge in organisations from two perspectives: the value of the "knowledge employee" and the value of the "learning organisation". From the first perspective, researchers have found evidences of that the increase of the productivity obtained by "knowledge employees" is a relevant factor of the firms' competitive behaviour (Andersson *et al.*, 2005; Calvo, 2011; Warren and Kourdi, 2003). From the second perspective, the main research outcomes show that "learning organisations" use their capacity to learn better and faster than competitors as source of sustainable competitive advantage (Senge, 1990) and innovation (Ferreira *et al.*, 2015).

Stemming from previous approaches, a KM system can be regarded as the way of joining the individual knowledge of employees, especially strategic knowledge, in a learning organisation. Given that the explicit knowledge could be documented and shared to encourage individuals' learning (Andriani, 2001; Grant, 1996), the way in which it is stored, used and transmitted (i.e. strategic knowledge management or SKM) may contribute to the success of the organisation (Lam, 1997). Thus, some researchers have found evidence that supports the relationship between KM practices and organisational performance (Del Rey-Chamorro *et al.*, 2003; Zack *et al.*, 2009, O¨Dell *et al.*, 2003). In this context, the advent of information technology (IT) has allowed developing IT solutions that work as SKM systems. These IT solutions for SKM are aimed at facilitating knowledge-sharing, or in other words, enabling explicit knowledge to flow within a "learning organisation" of "knowledge employees".

Although the effect of the KM practices on the organisational performance is the way to understand the strategic value of knowledge, most of the researchers have focused on big companies, forgetting the application of this perspective to the analysis of universities as knowledge-driven organisations. In addition, the few studies focused in universities mainly offer theoretical insights (Asma and Abdellatif, 2016) coming from case studies. Although these cases highlight the importance of the KM dimensions (Singh and Sharma, 2011), the collaboration networks (Ronda-Pupo and Guerras-Martin, 2016; Tan, 2016; Fari and Ocholla, 2015), the impact of IT-based KM intervention (Ranjan *et al.*, 2012; Branco *et al.*, 2015) or the use of data mining (Hegazi *et al.*, 2016), it is difficult to extrapolate through these outcomes the cause-effect relations existing between IT solutions for SKM and universities' performance in a specific country. Furthermore, these studies analyse a reduced group of universities (Branco *et al.*, 2015; Fari and Ocholla, 2015; Singh and Sharma, 2011; Ranjan *et al.*, 2012) or only deal with a single component of SKM (Hegazi *et al.*, 2016; Fari and Ocholla, 2015; Ronda-Pupo and Guerras-Martin, 2016; Tan, 2016) which limits the understanding of the relation, SKM-universities' performance.

This study aims to fill this gap in the literature by exploring the relationship between the availability and use of IT solutions for SKM and the universities' performance. In so doing, we first develop a conceptual framework for analysing the effect of SKM based on IT on the organisation's performance and then we empirically test by using a sample of 70 Spanish universities over the period 2011-2014. This choice becomes particularly relevant for several main raisons. First, universities spend a huge amount of funds on IT solutions for SKM, which only makes sense if these IT solutions contribute to the universities' success. Second, KM is necessary than ever before for universities to recognise the value of their intangible assets (Ramachandran and Chong, 2010) to survive in an extremely competitive environment that is putting a lot of pressure on them. Third, Spain represents an interesting study case. Because of Spanish recession and public cuts in R&D budget, the university system has suffered in the last decade a reduction of their funds availability. At the same time, higher education reforms have introduced competitive and performance-based research funding aiming to boost domestic competition by offering economic incentives to universities. In this sense, in 2009 the Spanish government launched a policy initiative

called “2015 University Strategy”. Other countries in Europe such as Portugal and Italy have experienced the same situation.

This study makes several contributions to the research on the relationship between SKM and organisation’s performance. First, drawing on the resource-based view (RBV) and the knowledge-based theory, we develop a conceptual framework for exploring the effect of SKM based on IT on the organisation’s performance by focusing on the mediating role that IT solutions play between the organisational design and human capital acquisition. Second, a large number of studies dealing with SKM and performance have been focused on firms. However, SKM is an important source of competitive advantage for any organisation, such as universities, governmental agencies or Non-Governmental Organizations (NGOs), among others. Analysing this issue in the case of universities by using a validated conceptual framework can open the way for future research. Third, in comparison to results obtained by the few studies on SKM in universities, which are mainly descriptive or study cases, our empirical approach of using panel data methodology and a sample of 70 universities over the period 2011-2014 seems to yield more robust results. Finally, on the basis of the results, we propose some policies to improve the SKM in the universities.

We structure the analysis as follows. In Section 2, we introduce the proposal of a conceptual framework for analysing the effect of IT solutions for SKM on the organisation’s performance. In Section 3, the methodology is described. Section 4 presents the empirical results. Section 5 draws the main conclusions and points to the limitations and to future research work. The paper ends with a discussion of the scientific and policy implications in Section 6.

2. Theoretical framework

As we mentioned in the Introduction section, in the theoretical part of this paper, we first develop a conceptual framework for exploring the effect of SKM based on IT on the organisation’s performance (Subsection 2.1). Then, we review the few studies that have empirically analysed the relationship between SKM and performance in universities to validate whether the proposed conceptual framework is also applicable to this kind of organisations (Subsection 2.2).

2.1 A conceptual framework for analysing the effect of SKM based on IT on the organisation’s performance

We followed the approach of the RBV of the firm, promoted by Penrose (1958) and later expanded by others (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993), to understand how companies can increase their performance through KM (Meso and Smith, 2000) and become learning organisations. More specifically, the knowledge-based theory of the firm (Grant, 1996), which can be considered an extension of RBV (Nonaka and Takeuchi, 1995), recognises knowledge as the most significant resource of a firm, as it is valuable to the enhancement of business excellence, and at the same time, the knowledge acquisition is an organisational capability scarce and difficult to imitate by the market. Under this approach, knowledge conversion is understood as a dynamic interaction between tacit and explicit knowledge (Zahra *et al.*, 2007), where individual and group-level knowledge is transformed into products, services or decisions aimed at increasing the firm’s success.

From both perspectives – the RBV and the knowledge-based view of the firm – at the organisational level, knowledge is embedded and carried through policies, culture, routines, documents, systems, and mainly individuals. In fact, although KM has drawn from a wide range of established disciplines since its appearance as an emerging science (Ologbo and Nor, 2015), intellectual capital has been one of the most highlighted (Beesley and Cooper, 2008), up to the point that a large body of traditional literature on KM considers that only individuals can learn (Grant, 1996; Andriani, 2001). Similarly, Han *et al.* (2010)

conclude that some kind of the organisations' knowledge, especially the strategic knowledge, is embedded in individuals themselves. In contrast, Yahya and Goh (2002) point out that knowledge such as strategic knowledge can be documented and shared, acting as an input for new knowledge.

In this context, the way in which explicit knowledge is structured, used and transmitted (i.e. SKM) encourages individuals' learning and may contribute to the success of the organisation (Lam, 1997). In this respect, the maturity and the use of IT developments facilitate new practices and applications that enable knowledge to flow efficiently among individuals to enhance the organisation's performance (Sher and Lee, 2004; Tsui, 2005). At the organisational level, individuals need IT solutions that work as KM systems and enhance knowledge-sharing (Nonaka and Takeuchi, 1995). Under the lens of the RBV, IT solutions for SKM are strategic assets for the firm (Meso and Smith, 2000), because a well-developed IT solution allows integrating explicit knowledge in the organisation's flow (Lee and Choi, 2003), contributing to the creation and utilisation of knowledge (Han *et al.*, 2010). In addition, this knowledge has to be measured as any asset in the firm (Bontis, 2001).

According to this perspective, the integration between human capital and a KM system implies four mechanisms:

1. rules and directives, that involve plans, policies, procedures, standardised information and communication systems;
2. sequencing, where individuals integrate their knowledge in a time-patterned sequence;
3. organisational routines that support patterns of interactions between individuals; and
4. group-solving and decision-making that improve the competitive behaviour of the organisation.

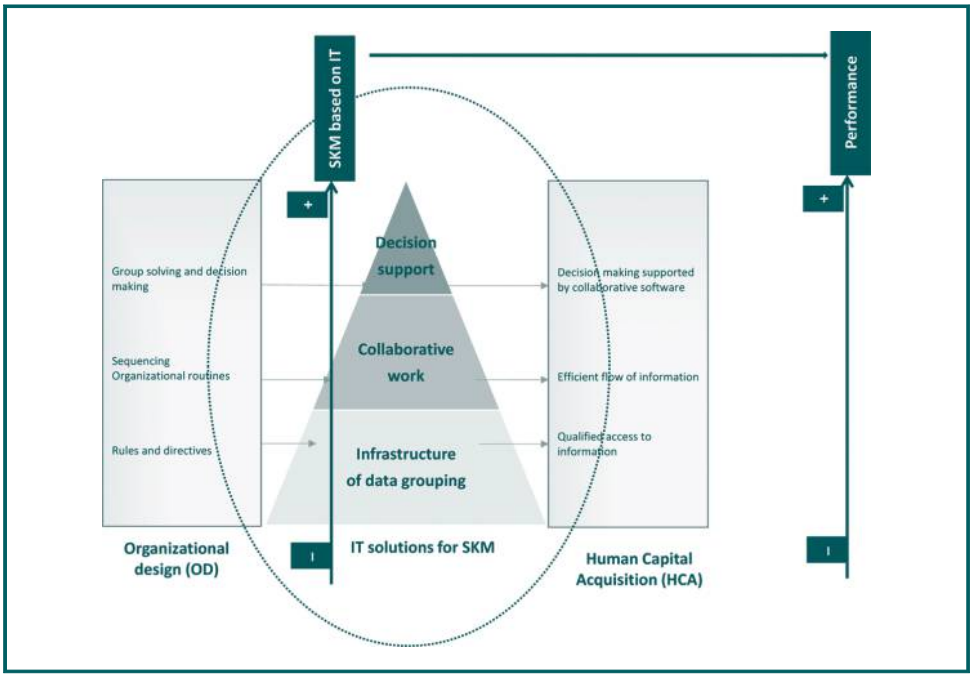
In this paper, we argue that the way in which these four mechanisms of the organisational design (OD) affect the human capital acquisition (HCA) is mediated by the IT solutions for SKM available within the organisation, as well as how these IT solutions are used by individuals for knowledge-sharing and decision-making processes (Figure 1). In this sense, it is expected that the performance increases as an organisation gains efficiency in the SKM based on IT.

We focus on IT solutions because of its role as the facilitator of the rapid collection, storage and exchange of data, supporting the SKM and affecting organisational performance (Lee and Choi, 2003; Zack *et al.*, 2009; Hegazi *et al.*, 2016). More specifically, after identifying three levels of IT solutions for SKM, we propose a pyramid-shaped model of SKM based on IT. In the first level of the model, we position the IT solutions related to the infrastructure of data grouping, as they determine the IT resources available within the organisation to collect and store information, which in turn can be considered a "necessary condition" for SKM. In the second level, we place the IT solutions of collaborative work, or, in other words, tools for knowledge-sharing. Finally in the third level, we position the IT solutions for decision support. It is noteworthy that the first level is referred to the SKM based on the IT resources "available" in the organisation, whereas the second and third levels tell us about the way in which individuals "use" these IT solutions for SKM. It is expected that as the organisation moves up in the "pyramid" model, it gains efficiency in the SKM and, in turn, increases its performance. From this approach, the KM system that supports the competitive advantage of an organisation requires a good adjustment among the organisational design (OD), the IT solutions for KM and the process of HCA.

2.2 Literature review: SKM and university's performance

With the rise in KM literature, there has been a burgeoning set of work on KM in firms. In the field of intellectual capital and KM, the above-mentioned study by Bontis (2001) offers

Figure 1 Conceptual framework for analysing the effect of SKM based on IT on the organisation's performance: a proposal



probably the most comprehensive review of the measurement models of KM. Particularly, the author reviews the assumptions of the most important measurement models of intellectual capital – Scandia model (Bontis, 1996; Huseman and Goodman, 1999), Intellectual Capital Index (Roos *et al.*, 1997), Technology Broker (Brooking, 1996; Intangible Asset Monitor (Sveiby, 1997), market value added and economic value added (Bontis, 1999) and Citation-weighted Patents (Bontis, 1996) – regarding their scope, method, variables and level of analysis. In so doing, Bontis (2001) integrates to a great extent the theoretical framework that we have used as basis to propose the conceptual framework for analysing the effect of SKM based on IT on the organisation's performance.

In contrast, only a bunch of researchers has focused the analysis of the relationship between KM and performance in universities (Table I), which is surprising given that these organisations not only spend a significant share of their budget on KM based on IT solutions, but also the environment is putting a lot of pressure on them to perform better (for example, the leading international rankings). After reviewing this scarce literature, we can conclude that it is difficult to find not only a common conceptual framework that integrates the three aspects established in the previous section – OD, HCA and IT solutions for SKM – but also measurement variables that relate all of them.

Regarding the conceptual framework, Bechina *et al.* (2009) suggest that encouraging the use of IT applications is a key factor for the knowledge capitalisation and university's productivity. Following this approach, Tian *et al.* (2009) conclude that researchers consider knowledge as the main input of the scientific creation, followed by the moderating effect of IT infrastructure to support knowledge repositories. These authors also show that the lack of researchers' IT skills limits their efficient personal KM. Both studies support the linkage between OD and IT solutions for SKM.

The need of considering OD in the analysis is also reinforced in the studies by Blackman and Kennedy (2009), Tan and Noor (2013) and Fullwood *et al.* (2013).

Table I Research framework of the empirical studies on SKM and university's performance: a summary

Author	*Scope*	*Method*	*Dependent variable*	*Independent variables*	*Level of analysis*
Bechina *et al.* (2009)	Bangkok University (BU)	Case study of the knowledge management practices at BU	KM outcomes for higher education	Technical requirements Socio-organisational requirements	OD* HCA** IT solutions for SKM***
Tian *et al.* (2009)	Japan Advanced Institute of Science and Technology	Case study of the knowledge management practices	Scientific knowledge creation	Data Information Knowledge	OD* IT solutions for SKM***
Blackman and Kennedy (2009)	Australian University	Case study of the knowledge management practices	University success (technocratic, economic, behavioural and integrative schools)	Focus Aim Unit Principal IT contribution Philosophy	OD*
Tan and Noor (2013)	Malaysian universities (421 academics of five research universities)	PLS path modelling	Research collaboration	Trust Knowledge self-efficacy Reciprocal benefits Top management support Organisational rewards Organisational culture KM system infrastructure KM quality Openness in communication F2F communication Knowledge-sharing	OD*
Fullwood *et al.* (2013)	UK academics (230 academics in 11 universities)	Questionnaire-based survey	Profiles of attitudes and intentions towards knowledge-sharing of academics	Attitudes of academics to: Intention to share knowledge Expected rewards and associations Expected contribution Normative beliefs on knowledge sharing Attitudes towards knowledge sharing	OD*

(*continued*)

Table I

Author	*Scope*	*Method*	*Dependent variable*	*Independent variables*	*Level of analysis*
Jamil and Lodhi (2015)	Pakistani universities (450 academics)	Hierarchical multiple regression	University performance (publications, employee commitment and industry linkages)	Autonomy Affiliation to institution Affiliation to discipline Leadership Structure Technology platform KM infrastructure: Culture Human resource KM Processes: Acquisition Storage Application Technology	OD* HCA** IT solutions for SKM***

Notes: *OD: Organisational design; **HCA: Human capital acquisition; ***Information Technology solutions for Strategic Knowledge Management; F2F communication: face-to-face communication

Blackman and Kennedy (2009) find linkages between the incentive systems of university and the success of the KM practices; Tan and Noor (2013) reinforce the role of the top management support and organisational rewards; while Fullwood *et al.* (2013) suggest that universities engaged in KM initiatives could improve the ways in which knowledge is created, shared and disseminated.

Finally, in a study involving 450 employees from Pakistani universities, Jamil and Lodhi (2015) find that KM process and KM infrastructure (human resources and culture) are significant predictors of the universities' performance, supporting the hypothesis that IT moderates the relationship between KM practices and universities' performance.

Regarding the variables used in the empirical studies, after comparing the review by Bontis (2001) and the studies in Table I, we conclude that there are substantial differences between the KM measurement variables used in the traditional models of KM and those used to measure the KM outputs at universities. Only the variable referred to citation-weighted patents (Bontis, 1996), also considered by Hall *et al.* (2005) as evidence of technological output and information flow, has also been used in the academia as an indicator of performance, but basically in the case of big universities with a relevant behaviour in technology transfer. Instead of traditional variables of the market value of KM practices, authors use scientific production, employee commitment and industry linkages as main indicators for universities.

The literature review leads us to conclude that the proposed conceptual framework including OD, HCA and IT solutions for SKM is also applicable to analysing the relationship between SKM and performance in the universities. In contrast, the traditional measurement indicators of KM used in the studies focused on firms do not serve for universities.

To sum up, under the lens of the RBV and the knowledge-based theory of the firm, knowledge is regarded as a strategic resource that provides organisations with a competitive advantage, enhancing its performance. Because knowledge such as explicit knowledge can be documented and shared through IT solutions, it could be used by individuals to create new knowledge ("creating by learning") and contribute to the organisations' success. In this paper, we explore the relationship between SKM and performance in the Spanish universities by analysing the mediating role of the IT solutions for SKM. This relationship would provide evidences of the role of SKM based on IT as an enabler of the learning organisations.

3. Methodology

3.1 The data and sample

We constructed an original data set by collecting data from two sources of information: the data referred to the universities' IT solutions for SKM (independent variables) were obtained from the UNIVERSITIC project (http://tic.crue.org/universitic/), whereas the data referred to the universities' performance (dependent variables) were collected from the IUNE Observatory (www.iune.es/).

More specifically, the UNIVERSITIC project is aimed at measuring the state of IT at each Spanish university and comparing it with the rest of its counterparts (IT benchmarking). To the best of our knowledge, it is the only potential source of information about the Spanish universities' SKM based on IT. The UNIVERSITIC project was launched by the CRUE (Conference of Spanish University Rectors) in 2004 and supervised by the IT Committee of CRUE, composed by IT Directors and IT Vice Rectors Chief Information Officers (CIOs) of all Spanish Universities, among other members.

The UNIVERSITIC project yields three main "products": a catalogue of IT indicators, an annual survey whose results are published in a report of the same name and a knowledge-base, which contains the values from the annual survey (Fernández Martínez *et al.*, 2015).

The three products are directly linked. The annual survey is based on the indicators included in the catalogue and, in turn, the universities' values for these indicators are saved in the knowledge-base, as the annual UNIVERSITIC reports present only the aggregated results for all universities.

We collected the data referred to the universities' SKM based on IT from the knowledge-base. Although the UNIVERSITIC project started in 2004, some of the indicators that we used as variables were introduced in the catalogue in its last revision of 2011. Therefore, the initial year for our sample is 2011.

In addition, even though UNIVERSITIC project has achieved a high level of participation (more than 60 of the 73 Spanish universities) after more than a decade of surveys, the respondent universities are not always the same. As a result, after filtering by the respondent universities with data referred to SKM indicators, we obtained a sample of 70 Spanish universities.

Then we completed our data set with the information about universities' performance by using some of the indicators of scientific activity selected by the IUNE Observatory. In turn, the IUNE Observatory takes this information from the Web of Science platform (Science Citation Index, Social Science Citation Index and Arts & Humanities Citation Index) by searching the record with at least one Spanish address in the "address" field. Also data from Statistic National Institute and Ministry of Education of Spain is used by IUNE Observatory. Given that the data referred to the universities' scientific activity in 2015 are not available in IUNE Observatory, we consequently chose our period of analysis as 2011-2014.

To sum up, the final data set is an unbalanced panel consisting of 70 Spanish universities observed between 2011 and 2014.

3.2 Dependent and independent variables

As we observed in the empirical literature, there are substantial differences in the dependent variables used as KM outputs at universities, being the most common indicators related to scientific production (Bechina *et al.*, 2009; Tian *et al.*, 2009; Jamil and Lodhi, 2015). Following this approach, the universities' performance (U-PERFORM) has been approximated by three variables: the number of defended doctoral theses (THESIS_TRS), the number of publications (TOTPUB_TRS) and the number of publications in the first quartile (1QPUB_TRS), all of them divided by the total number of the university' researchers (TRS).

The independent variables (Table II) have been grouped in three categories according to the three levels established in the proposed pyramid-shaped model of SKM based on IT.

The first group of variables, corresponding to the first level of the model, is referred to the IT solutions related to the infrastructure of data grouping. It includes a set of dummies that take the value 1 if the university has an application of documentary file (BARCHIVODOC), an institutional content repository (BREPOSITORIO) or a data warehouse (BDATAWH). These variables tell us about the IT resources available within the organisation to collect and store information and knowledge. In addition, we have also included in this group the natural logarithm of the budget (euros) for centralised IT services excluding personnel expenses (LNPRESUTI), as it can be considered as an indicator of the IT resources available for KM.

The second group of independent variables, corresponding to the second level of the pyramid-shaped model, is related to the IT solutions for knowledge-sharing. Then, we include in this group the percentage of the university's researchers that use institutional tools of collaborative work (PTRSHCOLABORA) and the natural logarithm of the number of interoperability services offered by the university (LNNSIOFRECE).

Table II Definition of dependent and independent variables

Groups of variables	*Variable*	*Measures*
Dependent	THESIS_TRS	Number of defended doctoral thesis by researcher
	TOTPUB_TRS	Number of total publications by researcher
	1QPUB_TRS	Number of first quartile publications by researcher
Independent		
G.1: Infrastructure of data grouping	LNPRESUTI	Natural logarithm of the budget for centralised IT services, excluding personnel expenses (euros)
	BARCHIVODOC	1 if the university had an application of documentary file
	BREPOSITORIO	1 if the university had an institutional content repository
	BDATAWH	1 if the university had a data warehouse
G.2: Collaborative work	PTRSHCOLABORA	Percentage of TRS that uses institutional tools of collaborative work
	LNNSIOFRECE	Natural logarithm of the number of interoperability services offered by the university
G.3: Decision support	BCMANDO	1 if the Board of Directors had a dashboard with indicators drawn from the data warehouse

Finally, the third group, corresponding to the third level of model, refers to the IT solutions for decision support. It contains only one variable (BCMANDO); that is, a dummy that takes the value 1 if the University Board of Directors had a dashboard with indicators drawn from the data warehouse and 0 otherwise.

3.3 Model specification

To test the effect of SKM based on IT on the universities' performance, we used the panel data methodology. We started on the basis that each university has its own individual behaviour and, consequently, the universities are heterogeneous. Using panel data allows us to control for this individual heterogeneity, contrasting with cross-sectional analysis. To control for this heterogeneity and to avoid biased results, we modelled it as an individual effect (α_i). Consequently, the basic specification of our model is as follows:

$$\text{U-PERFORM}_{it} = (\beta_1 \text{lnpresuti}_{it} + \beta_2 \text{barchivodoc}_i + \beta_3 \text{brepositorio}_i + \beta_4 \text{bdatawh}_i) + (\beta_5 \text{ptrsihcolabora}_{it} + \beta_6 \text{lnnsiofrece}_{it}) + (\beta_7 \text{bcmando}_i) + \alpha_i + \lambda_t + \varepsilon_{it}$$

Where U-PERFORM_{it} is the dependent variable, which has been measured in three complementary ways: defended doctoral theses by researcher (THESIS_TRS), number of publications by researcher (TOTPUB_TRS) and number of publications in the first quartile defended (1QPUB-TRS). As we mentioned, α_i is the individual unobserved heterogeneity or the individual effect. Meanwhile, λ_t is a set of dummy variables for years that incorporate the time-specific effect common to all universities, and ε_{it} is the random disturbance.

Given that several independent variables in our analysis (BARCHIVODOC, BREPOSITORIO, BDATAWH and BCMANDO) are time-invariant dummy variables, we used random effects generalised least squares (GLS) models, where the estimator assumes that the individual effects (α_i) are independent (uncorrelated) from the explanatory variables (x_{it}).

4. Results

4.1 Descriptive analysis

Table III shows the main descriptive statistics of the dependent and independent variables studied in the empirical analysis.

Regarding the university's performance, the annual average number of defended doctoral theses is higher than 7.5 per 100 researchers. The annual mean number of publications and publications in the first quartile per 100 researchers are around 44 and 17, respectively (Table III). With the purpose of analysing closely the dependent variables, Figure 2 exhibits the evolution of their mean values by year over the period 2011-2014. The mean values of all the dependent variables showed an increasing trend during the analysed period.

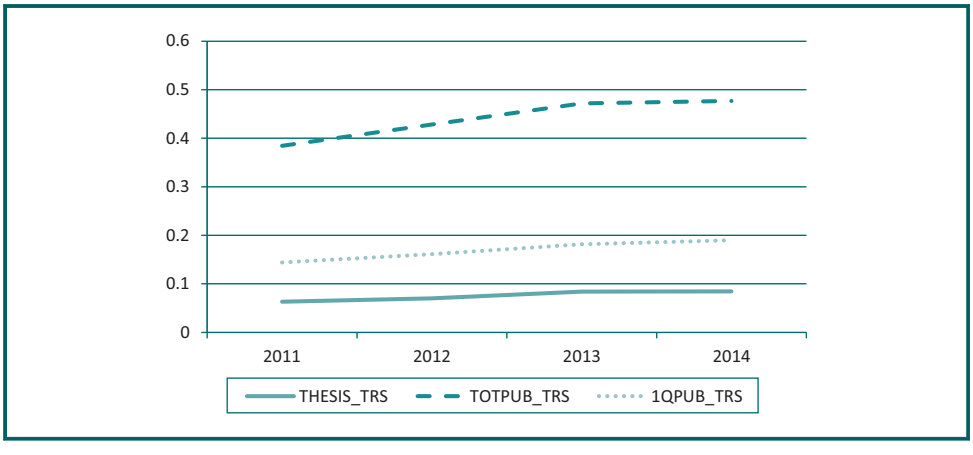
Concerning the IT solutions related to the infrastructure of data grouping (first level of model of SKM based on IT), the annual average budget for centralised IT services is about 2mn euros. On average 59 per cent of the universities have an application of documentary file, 72 per cent of the universities have an institutional content repository and 66 per cent of the universities have a data warehouse (Table III).

Table III Descriptive statistics of dependent and independent variables

Variable	*Obs.*	*Mean*	*SD*	*Minimum*	*Maximum*
Dependent					
THESIS_TRS	263	0.0753	0.0474	0.0000	0.2538
TOTPUB_TRS	267	0.4401	0.3256	0.0053	1.7124
1QPUB_TRS	254	0.1692	0.1323	0.0000	0.6328
Independent					
NPRESUTI[a]	202	2,287,336	2,090,084	0	14,100,000
BARCHIVODOC	241	0.5934	0.4922	0	1
BREPOSITORIO	243	0.7202	0.4498	0	1
BDATAWH	245	0.6612	0.4743	0	1
PTRSHCOLABORA	202	0.7861	0.3413	0	1
NSIOFRECE[a]	194	1.4716	2.9156	0	30
BCMANDO	242	0.3512	0.4783	0	1

Note: [a]Variables are in absolute values

Figure 2 Evolution of the Spanish universities' scientific production (2011-2014)



For the IT solutions which referred to collaborative work (second level of model), the annual average percentage of researchers that uses institutional tools of collaborative work is close to 79 per cent and the number of interoperability services offered by the university is, on average, higher than 1.4 (Table III). Taken together, both indicators suggest a significant number of potential academics prone to knowledge-sharing.

With regard to the IT solutions for decision support (third level of model), Table III shows that, on average, about 35 per cent of University Board of Directors has a dashboard with indicators drawn from the data warehouse.

Finally, Table IV shows the correlation matrix for the dependent and independent continuous variables.

4.2 Multivariate analysis

The results of random effects GLS models on defended doctoral theses, total publications and publications in the first quartile (by researchers) are presented in Tables V to VII, respectively. In all cases, Model 1 includes the first group of independent variables (LNPRESUTI, BARCHIVODOC, BREPOSITORIO and BDATAWH) and the year's dummies variables (λ_t). Then, Model 2 adds the second group of independent variables (PTRSHCOLABORA and LNNSIOFRECE). Finally, Model 3 adds the last independent variable (BCMANDO). In so doing, we want to explore whether the university's performance is affected as the institution uses more and more advanced IT solutions for SKM, or in other

Table IV Correlation matrix

Variables		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
THESIS_TRS	(1)	1					
TOTPUB_TRS	(2)	0.8391*	1				
1QPUB_TRS	(3)	0.8104*	0.9803*	1			
LNNPRESUTI	(4)	0.4000*	0.4067*	0.3684*	1		
PTRSHCOLABORA	(5)	0.0499	−0.0311	−0.0286	−0.0440	1	
LNNSIOFRECE	(6)	0.3033*	0.0604	0.0322	0.1218	0.0936	1

Notes: Table shows the Pearson correlation coefficients for the continuous dependent and independent variables considered in the empirical analysis; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table V Random effects GLS panel regressions on theses by researcher

Variables	*Model 1*	*Model 2*	*Model 3*
LNPRESUTI	0.003 (0.003)	0.014** (0.005)	0.015** (0.005)
BARCHIVODOC	0.012* (0.006)	0.007 (0.010)	0.008 (0.010)
BREPOSITORIO	−0.001 (0.005)	0.007 (0.006)	0.006 (0.006)
BDATAWH	−0.001 (0.006)	0.000 (0.004)	0.000 (0.003)
PTRSHCOLABORA		−0.016 (0.013)	−0.017 (0.013)
LNNSIOFRECE		0.008 (0.006)	0.008 (0.006)
BCMANDO			−0.005 (0.008)
2012	0.006* (0.003)	0.002 (0.004)	0.002 (0.004)
2013	0.019*** (0.003)	0.016** (0.005)	0.017** (0.005)
2014	0.022*** (0.004)	0.022*** (0.005)	0.022*** (0.005)
_cons	0.017 (0.043)	−0.137**** (0.076)	−0.145**** (0.080)
University – year obs.	186	71	71
Unique universities	55	26	26
Wald χ^2	97.54***	85.78***	118.48***

Notes: This table presents the results for random effects GLS models on number of thesis defended by TRS (THESIS_TRS). Robust standard errors are in parentheses; ****$p < 0.10$; ***$p < 0.001$; **$p < 0.01$; **$p < 0.001$

words, as the institution moves up in the pyramid model of SKM based on IT solutions (Figure 1).

First, the evidence confirms that the SKM based on IT influences the university's performance. This effect is positive in the case of the IT solutions referred to the infrastructure of data grouping. These findings are consistent with those by Bechina *et al.* (2009), Fullwood *et al.* (2013) and Jamil and Lodhi (2015). Moreover, the positive role played by the IT solutions available to store knowledge is more evident when the university's performance is measured by indicators more directly related to scientific quality. Thus, the availability of both an application of documentary file (BARCHIVODOC) and an institutional content repository (BREPOSITORIO) influences the number of publications in the first quartile, whereas only the IT budget for centralised services (LNPRESUTI) matters in the case of the defended doctoral theses. The latter is generally accepted as a lesser accurate indicator of universities' scientific quality than the former.

Table VI Random effects GLS panel regressions on publications by researcher

Variables	*Model 1*	*Model 2*	*Model 3*
LNPRESUTI	−0.003 (0.009)	0.050**** (0.027)	0.049**** (0.027)
BARCHIVODOC	0.036 (0.023)	0.062 (0.044)	0.061 (0.044)
BREPOSITORIO	0.000 (0.016)	0.054* (0.022)	0.054* (0.023)
BDATAWH	0.001 (0.035)	0.007 (0.012)	0.007 (0.011)
PTRSHCOLABORA		−0.092* (0.044)	−0.087 (0.053)
LNNSIOFRECE		−0.008 (0.015)	−0.008 (0.015)
BCMANDO			0.006 (0.025)
2012	0.034*** (0.010)	0.022 (0.014)	0.022 (0.015)
2013	0.078*** (0.012)	0.078*** (0.021)	0.078*** (0.022)
2014	0.092*** (0.013)	0.092*** (0.020)	0.091*** (0.021)
_cons	0.436** (0.133)	−0.295 (0.388)	−0.293 (0.388)
University-year obs.	190	71	71
Unique universities	56	26	26
Wald c^2	91.62***	333.75***	317.95***

Notes: This table presents the results for random effects GLS models on total publications by TRS (TOTPUB_TRS). Robust standard errors are in parentheses ****$p < 0.10$; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table VII Random effects GLS panel regressions on publications in the first quartile by researcher

Variables	*Model 1*	*Model 2*	*Model 3*
LNPRESUTI	−0.005**** (0.003)	0.009 (0.012)	0.009 (0.013)
BARCHIVODOC	0.016 (0.010)	0.035* (0.018)	0.036* (0.017)
BREPOSITORIO	0.001 (0.008)	0.029* (0.014)	0.029* (0.014)
BDATAWH	0.000 (0.016)	0.004 (0.007)	0.004 (0.007)
PTRSHCOLABORA		−0.054* (0.023)	−0.056* (0.026)
LNNSIOFRECE		−0.001 (0.006)	−0.002 (0.006)
BCMANDO			−0.003 (0.014)
2012	.017** (0.006)	0.015* (0.007)	0.015* (0.007)
2013	0.037*** (0.006)	0.035*** (0.008)	0.035*** (0.008)
2014	0.051*** (0.007)	0.050*** (0.009)	0.051*** (0.010)
_cons	0.212*** (0.043)	0.016 (0.179)	0.022 (0.182)
University-year obs.	177	69	69
Unique universities	53	25	25
Wald χ^2	110.15***	130.13***	137.72***

Notes: This table presents the results for random effects GLS models on first quartile publications by TRS (1QPUB_TRS). Robust standard errors are in parentheses; ****$p < 0.10$; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$;

Second, contrary to expected, the university's performance does not increase as the institution gains efficiency in the use of IT solutions for SKM, or in graphical terms, as the institution moves up in the pyramid model of SKM based on IT. Thus, the percentage of researchers that use institutional tools of collaborative work (PTRSHCOLABORA) has a strongly significant negative effect when the university's performance is measured in terms of the publications in the first quartile and a weakly significant one when it is measured by the total publications. To some extent, this is a counter-intuitive result, as the number of publications in the first quartile tends to show a high share of both international and interdisciplinary collaboration in which tools for knowledge-sharing are getting more and more necessary. In this context, the researchers engaged in co-authorship tend to use non-institutional resources (for example, Dropbox or Google Docs). In contrast, the users of institutional tools of collaborative work could be more oriented to other outcomes different from publications (projects, training collaborations), reducing the universities' capacity of publishing. Another plausible alternative explanation for this counter-intuitive result is that researchers have not been trained for using these institutional tools of collaborative work properly, wasting their time and damaging their publishing activity.

Finally, the availability of a dashboard with indicators drawn from the data warehouse (BCMANDO) has no effect on the universities' performance measured in terms of both the defended doctoral theses and publications. This result could be partially explained because the dashboard tends to be used by the University Board of Directors in making decisions (i.e. funding, hiring human resources or career offerings) other than those concerning scientific production. In addition, as the dashboard obtains the data from the data warehouse (BDATAWH), the non-effect of the dashboard helps in explaining the non-effect of the data warehouse on the universities' performance.

5. Conclusions

Over the last two decades, a stream of the KM literature began devoting attention to the effect of SKM on firm's performance. Particularly, the massive use of IT tools has provided researchers with a valuable opportunity to test whether the SKM based on IT solutions may influence firm's success. While the bulk of empirical analyses focuses on the big companies, this approach often neglects other knowledge-driven organisations such as universities. In this paper, we address this question by exploring the relationship between the availability and use of IT solutions for SKM and the universities¨ performance.

Drawing on the RBV and the knowledge-based view of the firm, we argue that the way in which the explicit knowledge is stored, used and transmitted through the IT for SKM conditions the HCA ("learning organisation" approach), affecting, in turn, the universities' performance. More specifically, as a university gained efficiency in the SKM based on IT, its performance would increase.

In carrying out the analysis, we first developed a conceptual framework for analysing the mediating role of IT solutions for SKM in the organisation's performance that, then, we empirically tested by using a sample of 70 Spanish universities over the period 2011-2014. The results show that the SKM based on IT affects the universities' performance in the case of the IT solutions referred to the infrastructure of data grouping. This effect is positive and more evident and much more directly related to scientific quality, and is the indicator used to approximate the universities' performance (i.e. publications in the first quartile). Thus, the IT budget for centralised services only matters in the case of the defended doctoral theses. Therefore, even more important than funding is the question of how IT solutions are used for SKM.

Surprisingly, we also find that the universities' performance decreases as the percentage of researchers that use institutional tools of collaborative work increases. This counter-intuitive result has been partially explained by the "institutional" nature of the IT tools as the

researchers engaged in co-authorship tend to use non-institutional resources when they collaborate. In contrast, the users of institutional tools for knowledge-sharing could be more oriented to other outcomes such as projects, training collaborations and less aimed at publishing. Another alternative explanation is that researchers have not been trained for using these institutional tools of collaborative work properly. Given the cost and the time needed to learn how to use them, universities should assess the potential impact of these IT solutions for SKM.

Finally, the results show that the availability of a dashboard with indicators drawn from the data warehouse has no effect on the universities' performance. This lack of effect may be attributed to the fact that the dashboard tends to be used by the university governing boards in making decisions such as funding, hiring human resources or career offerings whose performance is not reflected in the dependent variables included in the empirical analysis. In this sense, as the universities' funds get more and more linked to scientific production, the availability of a dashboard, and even of the data warehouse, will gain importance.

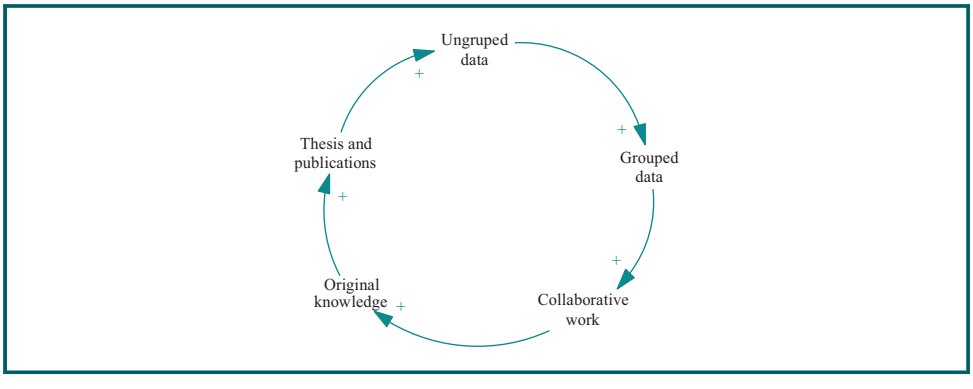
This paper also presents some limitations that could open the way for further research. In particular, some variables that approximated the SKM based on IT tools capture the availability of IT resources instead of the way in which resources are used. Future research on this topic may benefit from collecting information about the specific uses of the IT solutions for SKM. In so doing, the channels through which SKM based on IT influences the universities' performance could be deeply explored. Moreover, using a data set with a longer longitudinal nature would allow researchers to test whether the IT usage (if it changes over the time) impacts on the universities' performance. Finally, the applicability of the proposed conceptual framework for analysing the relationship between SKM and performance to other knowledge-driven institutions provides researchers with a valuable opportunity to carry on analysing this issue in other sectors.

6. Scientific and policy implications

We, based on the previous results, propose, from a system dynamics perspective (Forrester, 1961; Sterman, 1984, 1987, 2000), a flow diagram that shows the sequence of generation of original knowledge at universities, a key factor of their performance.

According to this approach (Figure 3), universities collect multiple data from different sources (previous theses, publications), which form a stock of ungrouped data individually used by researchers. If the university has IT tools for data grouping such as a documentary

Figure 3 Reinforcing loop of KM at universities



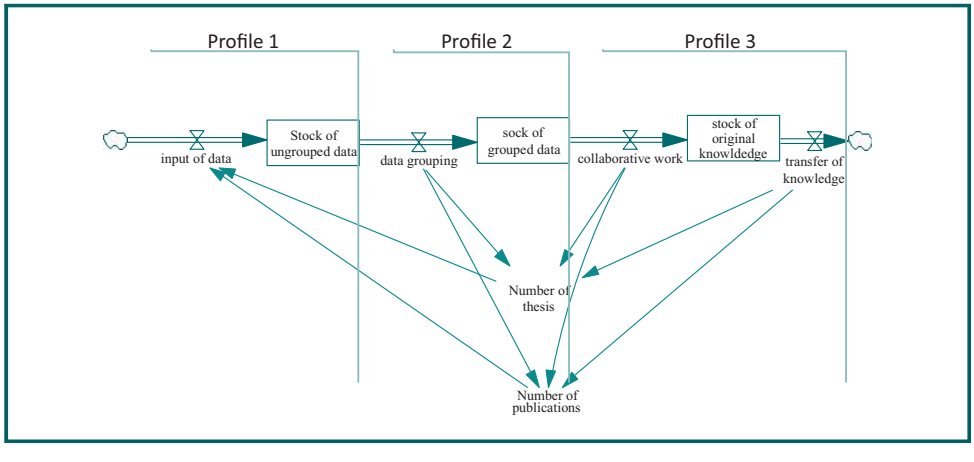
archive and a content repository, the continuous flow of data will be grouped according to different criteria. Additionally, if the university counts with IT solutions for collaborative work and researchers who have been trained to use them for knowledge-sharing, it is likely that the data will result in a higher stock of original knowledge than in other institutions. The original knowledge at universities is used to present doctoral theses and scientific publications, and these outcomes will revert in new data input for universities, creating a reinforcing loop.

Even without considering the moderating effect of budget, universities can be grouped in three profiles according to the sequence of the KM flow diagram (Figure 4). The universities of Profile 1 maintain IT solutions for SKM with low impact in their performance. Their IT tools allow the individual access to data, but do nothing for grouping information. The universities of Profile 2 have IT solutions for SKM that group data according to different criteria useful for researchers. Finally, the universities of Profile 3 have IT solutions for SKM that use the grouped data for the collaborative work, enabling the accumulation of original knowledge and the knowledge transfer. The impact of these profiles will be differential in the generation of theses and scientific production, main indicators of the universities' performance.

Therefore, the accumulative effect of the KM practices of universities through their investment in IT solutions let them increase their capacity to transfer the original knowledge generated from the data- grouping used in a collaborative way. Universities of Profiles 1 and 2 can also get some performance, but do not get advantage of the integration between data and collaborative work through a more adequate OD. However, in our opinion, universities of Profile 3 will only get more publications if they not only train researchers how to use IT tools for collaborative work properly, but also they have incentive systems to revert the collaborative work in the transference of original knowledge. In the practice, as we evidenced in the results, the work of researchers with collaborative IT tools damages the universities' capacity of publishing.

What is the use of IT solutions for SKM that we want to incentive at universities? This is the question that universities' managers should answer in the future, through the balance of pros and cons of these applications. New research should be addressed to answer this question in the future, using not only data of the IT availability but also data of the specific uses of the IT solutions for SKM. We also suggest linking the analysis of the researchers' motivation to collaborate with the real use of collaborative software for this purpose.

Figure 4 Profiles of universities in the KM flow



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