What knowledge management approach do entrepreneurial universities need?

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Abstract.

This paper explores how the entrepreneurial outcomes (patents, university spin-offs, research projects and R&D contracts) of universities relate to the availability and use of information and telecommunications (IT) solutions for knowledge management (KM) over the period 2011-2014. We hypothesize that entrepreneurial universities may benefit from a good connection between knowledge infrastructure (IT solutions) and knowledge management processes for KM. We tested this hypothesis by estimating generalized least squares models and negative binomial regression models in a sample of 63 Spanish universities over the period 2011-2014. The results show that using data grouping infrastructure increases several measures of entrepreneurial outcomes of universities. Unexpectedly, institutional tools of collaborative work and data warehouse significantly decrease the number of patents. According to these results we suggest that process-oriented approaches for KM may decrease the entrepreneurial outcomes of universities. The contribution of this analysis is twofold. First, it allows a better empirical understanding of how IT solutions for KM affect the entrepreneurial outcomes of universities. Second, this analysis could guide a new design of IT solutions in order to increase these outcomes.

Keywords: knowledge management, entrepreneurial university, IT solutions, panel data, dynamic simulation, resource-based view.

1. Introduction

Since the Triple Helix model highlighted the importance of partnerships among universities, industry and government for building the knowledge society in a balanced configuration (Etzkowitz and Leydesdorff, 2000), universities are changing from scientific paper producers to knowledge transfer providers. In this context, academics and policy makers have coined the term "entrepreneurial university" (Etzkowitz, 1983; Clark, 1998; Guerrero and Urbano, 2012; Etzkowitz, 2017) to describe universities that perform effectively their "third mission" contributing to the regional economic growth (Clark, 1998). To delimit the university activities involved in this "third mission", the E3M (2010) has grouped them into three dimensions: technology transfer and innovation, continuing education, and social engagement. To date, the literature on entrepreneurial universities has mostly focused on the first dimension of the third mission (Lambert, 2003; Secundo *et al.*, 2017) by analysing the university's capacity to transfer knowledge through contracts with firms, the launch of university spin-offs (USOs), patenting, and licensing activities to generate, use, apply and exploit its knowledge base (Molas-Gallart *et al.*, 2002).

As this third mission has gained acceptance, universities have invested many resources coming from public funds to help the research transfer from academics to society. Particularly, university managers have used Information Technology (IT) solutions to support knowledge management (KM) systems, mainly by facilitating knowledge sharing (Fernández-López *et al.*, 2018). However, due to the lack of a common view of the KM at universities, there are few studies that provide empirical insights of the use of IT solutions in the entrepreneurial activities at university level.

This paper seeks to contribute to fill this gap. Although the literature on KM has generally found a positive effect of IT solutions for KM on firm performance, there is a lack of studies addressing this issue at university level, which is surprising since universities are mainly knowledge-driven organisations. In addition, the few studies focused on universities mostly offer theoretical insights (Asma and Abdellatif, 2016) coming from case studies (Bechina *et al.*, 2009; Tian *et al.*, 2009; Blackman and Kennedy, 2009; Yapa, 2011). Moreover, most of them analyse few universities (Geng *et al.*, 2005; Mahayidin *et al.*, 2007) or only explore the effect of KM practices on scientific production (Fernández-López *et al.*, 2018).

Stimulating the entrepreneurial mission of universities has become a priority of political agendas in recent years. Governments have funded the development of IT solutions for KM, expecting that these solutions increase the entrepreneurial outcomes of universities. However, there is little empirical evidence of this cause-effect relation. Therefore, this study explores the influence of knowledge infrastructure (i.e. IT solutions for knowledge-sharing) and KM processes on the entrepreneurial outcomes in a sample of 63 Spanish universities over the period 2011-2014.

This paper makes some contributions. First, while a large number of studies of KM and performance focus on firms, to date, the literature has paid little attention to study how KM furthers the competitive advantage of universities. Second, unlike other studies, we use as dependent variables a rich set of indicators broadly employed to define an entrepreneurial university. Third, in contrast to previous studies, using panel data methodology and a large sample of universities in the empirical part of the paper allows us to offer robust results. Finally, we based the analysis in Spain because this country can be considered a pioneering case study. In 2009 the Spanish government launched an initiative called "2015 University Strategy" that funded universities basing on their scientific performance. However, the economic crisis shifted the strategy towards universities' self-funding via R&D transfers, so this case study becomes a potential example for other countries in the same situation.

We organized the paper as follows. In Section 2 we review the previous evidence on the contribution of KM on universities' performance and discuss the approach of the paper. In Section 3 we describe the methodology. In Section 4 we present the empirical results of the analysis. In Section 5 we discuss the main results of the paper. Finally, in Section 6 we conclude the analysis and point to the limitations and future research work.

2. Theoretical framework

2.1. University entrepreneurship and KM

In the latest three decades, universities have gained the attention of academics and policy makers as key actors of the economic growth, which has led to a burgeoning set of works on the field. Whereas a significant part of the studies tried to deal with the concept of entrepreneurial university (Etzkowitz, 1983; Clark, 1998; O'Shea *et al.*, 2005; Guerrero *et al.*, 2006; Philpott *et al.*, 2011; Etzkowitz, 2017), another stream of the literature explored why some universities were more successful in running

entrepreneurship activities (i.e. university entrepreneurship) (see Rothaermel *et al.*, 2007). Most of these studies follow an institutional approach and use the resource-based view (RBV) (Penrose, 1958; Wernerfelt, 1984; Barney, 1991; Peteraf, 1993) to understand the determinants of the entrepreneurial activities at universities. From this approach, knowledge is seen as the most significant resource of entrepreneurial universities, which pursue to transform individual and group-level knowledge into successful products, services or decisions through the dynamic interaction between tacit and explicit knowledge (Zahra *et al.*, 2007).

Particularly, the literature on university entrepreneurship has assigned a key role to both the university's interface infrastructures (e.g. Technology Transfer Offices (TTOs), incubators, science parks, entrepreneurship centres, etc.) and the researchers' performance in promoting university entrepreneurship. Thus, the members of interface infrastructures (i.e. the TTO staff) usually accumulate tacit knowledge about the ways of promoting entrepreneurship outcomes (e.g. launching USOs, licensing, patent application, research contracts, etc.) and the TTO members exchange this knowledge through interactions with other TTO's members and researchers, as well as with the industry and the society. Consequently, the entrepreneurial outcomes of a university rely to a great extent on how effective this knowledge exchange is.

In this respect, IT solutions for KM (knowledge infrastructure) can contribute to leverage university entrepreneurship through different ways. Firstly, IT solutions for KM support new practices and applications that increase the efficiency of the knowledge flows (knowledge management processes) among individuals in order to enhance the organisation's performance (Sher and Lee, 2004; Tsui, 2005), also at universities (Fernández-López *et al.*, 2018). Secondly, IT tools employed by universities to facilitate the diffusion of their knowledge and technology act as an alternative channel to offer the research knowledge exploitable by outsiders (i.e. industry, government and society). Finally, to a certain extent, the IT solutions allow to make explicit (i.e. documenting and sharing) a part of knowledge embedded in individuals (Lee and Choi, 2003; Zhang *et al.*, 2019), contributing to the creation of new knowledge and its application (Yahya and Goh, 2002; Han *et al.*, 2010; Zhang and Luo, 2015; Pinoli *et al.*, 2019). This aspect is particularly relevant at universities, where the knowledge necessary to generate innovations and entrepreneurial outcomes is often embedded in researchers and TTO's members,

respectively. Thus, individual's learning depends on the way in which explicit knowledge is structured, used and transmitted (i.e. KM), affecting the employees' contributions to the organisation success (Lam, 1997; Lyytinen and Newman, 2015).

2.2. KM at universities: literature review

In spite of the aforementioned arguments, there is a lack of empirical studies that connect the effect of IT solutions for KM to the entrepreneurial outcomes of the universities. Moreover, the review of the KM literature focused on universities shows two different groups of studies depending on the level of analysis used: at the individual level (those ones focused mostly on researchers) and studies at the university level, which, in turn, are divided into case studies and empirical studies.

Table 1. Summary of results of KM literature focused on researchers (individual level).

Authors (Year)	**Country**	**Sample**	**Main results**
D'Este and Patel (2007)	UK	4,337 university researchers of UK (1995-2003)	University researchers interact with industry through the creation of new physical facilities, consultancy and contract research, joint research, training, meetings and conferences. Incentive policies for knowledge transfer are likely to have a limited impact on encouraging university–industry interactions, unless they take a better account of the individual characteristics of researchers engaged in such interactions.
Rego *et al.* (2009)	Portugal	152 researchers of Portuguese universities	Individual interaction among people is the most relevant factor of the knowledge flow, although technology works as an important facilitator.
Allameh *et al.* (2010)	Iran	430 Isfahan university staff	Organizational culture is related with knowledge capture rather than with knowledge storage and knowledge application.
Aming'a (2013)	Kenya	172 academic and non-academic staff of Kisii University	KM practices positively affect the organizational performance: efficiency and effectiveness productivity, innovation and generation of new knowledge, quality of services delivered, employee morale and improved decision making and problem solving.
Fullwood *et al.* (2013)	UK	230 academics in 11 universities of UK	The role of organizational structure and IT in knowledge sharing with colleagues and external partners for opportunities creation is not clear for academics.
Mohammad and Arul Jose (2016)	Oman	64 academic and non-academic staff	There is a significant relationship between the gatherings of academic and non-academic staff and KM. However, internal procedures and general administration and human resource management applied to KM have no relevance for the knowledge orientation of university.
Omogeafe *et al.* (2014)	Nigeria	389 respondents of Nigerian universities	KM practices are significantly related to innovation, competitive advantage and growth.
Tan and Noor (2013)	Malaysia	421 respondents of 5 research Malaysian universities	Trust and interactive communication between academics positively influence knowledge systems (KS). In contrast, knowledge self-efficacy, the perceived degree of reciprocal benefits on researchers and the perception of the top management support are not relevant factors of KS.

			Organizational incentives are positively related with KM systems. Organizational culture positively influences academic to share their knowledge. KM system infrastructure has no significant relationship with KS members. KM system quality is a significant facilitator of KS practices.
Jamil and Lodhi (2015)	Pakistan	450 employees of Pakistan universities	The dimensions of KM infrastructure (culture and human resources) and processes (acquisition, storage, and application) positively predict university performance.
Masa'deh *et al.* (2017)	Jordan	207 university lecturers	There is a positive relationship between KM processes (knowledge identification, creation, collection, organizing, storage, knowledge and knowledge application) and job and knowledge performance of universities.

The second group of studies, focused on the university level can be, in turn, divided into case studies and quantitative studies (Table 2). The former, mostly referring to Asian countries, show the importance of IT to enable communication and collaboration between researchers and external partners (Numprasertchai and Igel, 2005), and to create a better environment for the KM exchange (Bechina *et al.*, 2009). Nevertheless, the KM resources must be managed in a proper way for achieving the effective governance at university (Yapa, 2011). In contrast, the latter are just a handful of studies that have explored the effect of KM in university activities by using a mix of quantitative techniques.

Thus, the study of Geng *et al.* (2005) show that Chinese universities are more process-oriented, and their KM priorities focus on addressing university-wide information technology (IT) goals. Comparatively, American universities are more performance-oriented, and their KM priorities are based on aligning the needs of end-users with knowledge storage by addressing priorities like institutional research, libraries and information centers. In both countries universities have carried out similar missions and achieved similar goals in KM, even they use different KM tools that respond to different realities.

The results of Mohayidin *et al.* (2007) after analysing a sample of 10 Malaysian universities indicate that info-structure support; infrastructure capacity; info-culture; and knowledge acquisition, generation, storage and dissemination are important factors in shaping the KM initiatives. According to these authors, the socio-technical components supported by the university improve the implementation and application of KM throughout the universities.

In a more recent study, Fernández-López *et al.* (2018), using a sample of 70 Spanish universities, conclude that the KM based on IT influences the university's scientific performance.

Table 2. Summary of results of KM literature based on the university level

Authors (Year)	**Country**	**Sample**	**Main results**
Numprasertchai and Igel (2005)	Thailand	Multiple case study (three R&D units)	The collaboration with industrial partners is the most relevant resource of universities to acquire missing in-house knowledge for creating new knowledge and achieving research goals. Communication, collaboration and storage technologies are relevant factors for communication and collaboration with external partners, but these applications are not sufficient for ensuring the success of research collaboration.
Bechina *et al.* (2009)	Thailand	Case study Bangkok University	The use of appropriate ICT in order to create a more favourable environment for the KM exchange helps to improve the results of universities as knowledge-based learning organizations.
Blackman and Kennedy (2009)	Australia	Case study	Knowledge creation and utilization are relevant factors for the effective governance of this university.
Tian *et al.* (2009)	Japan	Case study Japanese national institute	The main KM obstacles perceived are the lack of technological support for KM, the lack of involvement in creation activities and cultural and organizational dysfunctions.
Yapa (2011)	Sri Lanka	Case study	The lack of management of IT resources for KM can explain the low research results of academics.
Geng *et al.* (2005)	USA-China	28 Chinese universities, 11 American universities	In Chinese universities the four dimensions of KM - priorities, needs, tools and support- are significant and positively related, whereas in American universities the relation between KM priorities and administrative support was the only not significant dimension.
Mohayidin *et al.* (2007)	Malaysia	685 respondents of 10 public and private universities (individual, faculty and university level)	Info-structure support; infrastructure capacity; info-culture; and knowledge acquisition, generation, storage and dissemination are important factors in shaping the KM initiatives. The infrastructure of knowledge was the most relevant factor in shaping the KM initiatives in Malaysian universities.
Fernández-López *et al.* (2018)	Spain	70 universities	The use of applications of data grouping is positively related with university performance. The use of institutional tools of collaborative work is negatively related with the scientific production of universities.

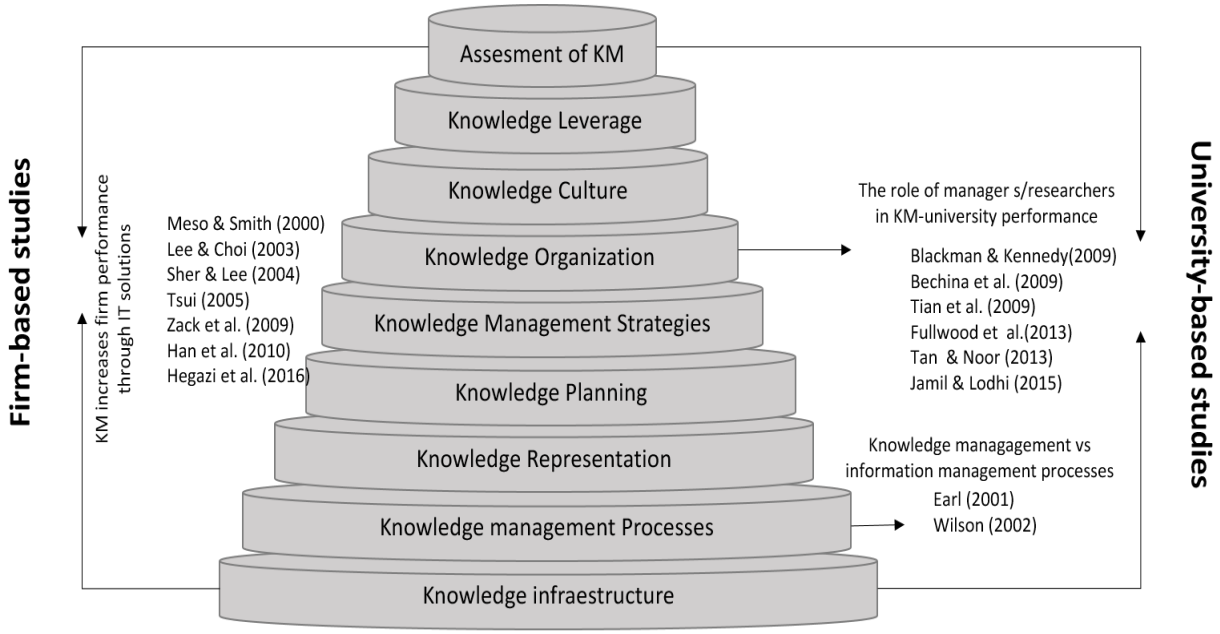
This paper fits into the second group of studies. As Table 2 reports, few studies have explored the effect of KM on the universities' performance at university level using a quantitative approach. Moreover, previous studies (Table 1 and Table 2) have mostly measured the university's performance through its scientific production, instead of using a wider range of entrepreneurial outcomes. Finally, even when the analysis is at individual level (Table 1), it adopts a university managers' perspective; that is, the analysis emphasizes the role of managers to support the positive relation KM-universities performance (Blackman and Kennedy, 2009; Fullwood *et al.*, 2013; Tan and Noor, 2013; Aming'a (2013); Omogeafe

et al., 2014; Jamil and Lodhi, 2015). This approach pays little attention to the importance of the researchers' involvement in KM (Tian *et al.*, 2009, Bechina *et al.*, 2009; Mohammad and Arul Jose, 2016) for supporting their interaction with industry (D'Este and Patel, 2007; Ankrah *et al.*, 2016; Draghici *et al.*, 2015), but it rather focuses on managers' needs of gathering information for effective governance of universities, becoming more process than performance-oriented -or more "technocratic" than "economic" (Earl, 2001).

In this respect, Wilson (2002) has already warned that academics and professionals tend to confuse "knowledge" and "information", and the fact of having good "information management" applications and work routines does not mean "knowledge management". This warning is even more pertinent for KM at entrepreneurial universities, which require a fluid exchange of knowledge between university internal actors (i.e. TTO's staff and researchers) and external actors (Numprasertchai and Igel, 2005; Eun *et al.*, 2006; Mohayidin *et al.*, 2007). In this context, adopting a process-oriented approach for KM might decrease the entrepreneurial outcomes of a university (Geng *et al.*, 2005).

To sum up, this paper explores how the IT solutions for knowledge-sharing (knowledge infrastructure) and decision-making processes (knowledge management processes) available at universities may influence their entrepreneurial outcomes (assessment of knowledge management). In so doing, we draw to a certain extent on the conceptual framework of Entreprise Knowledge Management Model (EKMM), mostly known as the 'knowledge tower', which was proposed by Oztemel and Arslankaya (2009) to identify the hierarchical structure of knowledge at organizations (Figure 1). This perspective is related with the literature review of KM made by Galvis-Lista and Sanchez-Torres (2013) which point that first-generation of KM literature states that knowledge is something that can be captured and stored in repositories of knowledge-based technology, while the second-generation of KM literature considers knowledge as a complex phenomenon related to socio-cultural, political and technological aspects.

Figure 1. Conceptual framework



The knowledge tower (Oztemel and Arslankaya, 2011)

3. Methodology

3.1. The data and sample

We constructed an original dataset from two sources of information; UNIVERSITIC project (http://tic.crue.org/universitic/), and IUNE Observatory (http://www.iune.es/). The UNIVERSITIC project was used to obtain the data referred to the universities' IT solutions for KM (independent variables). It was launched by the CRUE (Conference of Spanish University Rectors) in 2004 and supervised by an IT Committee composed by IT Directors and IT Vice Rectors (CIOs) of all Spanish Universities. The UNIVERSITIC project measures the state of IT at each Spanish university through an annual survey that uses a catalogue of IT indicators (Fernández-Martínez *et al.*, 2015). To the best of our knowledge, it is the only potential source of information about how to use IT solutions for KM. The initial year of the study was 2011 because it is the first year that group all data considered in the analysis. After filtering by the respondent universities with data referred to KM, the sample was formed by 70 Spanish universities.

We completed this dataset with the most common indicators of the performance of entrepreneurial universities such as patents, USOs and contracts (Langford *et al.*, 2006; Shane, 2004; Elia *et al.*, 2017) obtained from the IUNE Observatory. In turn, the IUNE Observatory takes this information from other

sources. Thus, the data about patents was collected from the Spanish Patent and Trademark Office, in particular from INVENES. The USOs information was gathered from the universities' TTOs and the number of projects of EU Framework Program from the Center for Industrial Technological Development (CDTI). We also completed the database with data coming from Statistic National Institute and Ministry of Education of Spain. Given that the data referred to the universities' activity in 2015 were not available in IUNE Observatory, we selected 2011 through 2014 as the period of analysis. To sum up the final dataset was an unbalanced panel consisting of 63 Spanish universities observed between 2011 and 2014.

3.2. Dependent and independent variables

As mentioned, in the empirical literature on university entrepreneurship the most accepted indicators of universities entrepreneurship (Langford *et al.*, 2006) are patents, USOs and contracts. Following this approach, the outcomes of entrepreneurial universities have been approximated by four variables: the number of patents granted at the Spanish Patent and Trademark Office (PAT), the number of USOs created (USOS), the number of research projects obtained within the EU Framework Program (FPP), and the natural logarithm of the amount of R&D contracts and consultancies signed (in thousands of euros) (LNCONT).

Regarding the independent variables, we include the natural logarithm of the budget for centralized IT services (excluding personnel expenses) in euros (LNBUDGETTI) to the analysis for measuring the availability of IT resources at universities. We considered the percentage of the university' researchers that use institutional tools of collaborative work (PTRSHCOLABORA) as a proxy of the level of IT use among researchers. Additionally, four variables referred to the availability of IT solutions were also included in the analysis. All of them were dummies that took the value 1 if the university had documental workflow (BWFLOW), filing applications (BARCHIVODOC), institutional content repositories (BREPOSITORIO), or data warehouse (BDATAWH).

We also included a set of control variables widely used in the empirical literature on university entrepreneurship (Tello *et al.*, 2011; Perkmann *et al.*, 2013; Almeida, 2018). These control variables were the natural logarithm of the number of teachers and researchers (TRS) (LNTRS), the number of first quartile publications (1QPUB), the natural logarithm of the university's total budget in euros

(LNBUDGET) and the natural logarithm of TTOs age (LNTTOAGE).

3.3. Model specification

We used panel data to test the effect of IT solutions of KM on the outcomes of entrepreneurial universities. Unlike cross-sectional analysis, panel data allows to control for the individual heterogeneity that may characterize the behaviour of each university. This heterogeneity is modelled as an individual effect (α_i) with the purpose of control it, avoiding biased results. Accordingly, the basic specification of our model is as follows:

$$UEO_{it} = \beta_1 LNBUDGETTI_{it} + \beta_2 PTRSHCOLABORA_{it} + \beta_3 BWFLOW_{it} + \beta_4 BARCHIVODOC_{it} + \beta_5 BREPOSITORIO_{it} + \beta_6 BDATAWH_{it} + \beta_7 LNTRS_{it} + \beta_8 1QPUB_{it} + \beta_9 LNBUDGET_{it} + \beta_{10} LNTTOAGE_{it} + \alpha_i + \lambda_t + \varepsilon_{it}$$

Where UEO_{it} refers to each of the four dependent variables capturing the universities' entrepreneurship outcomes –namely, patents granted, USOs, number of project within an EU Framework Program, and R&D contracts and consultancies-. As mentioned, α_i is the individual unobserved heterogeneity, 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 the first three dependent variables used in the analysis (PAT, USOS and FPP) have a discrete nature, with only non-negative integer small values and preponderance of zeros, that is, they seem to be count data. In order to estimate the three outcomes, we applied negative binomial regression models under the assumptions of random effects.

Finally, the continuous nature of the fourth dependent variable (LNCONT) allowed us to apply generalized least squares models (GLS) to the analysis. Since time-invariant dummy variables are present, we applied random effects, 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 3 displays the main descriptive statistics of the dependent, independent and control variables considered in the empirical analysis.

Table 3. Descriptive statistics of dependent, independent and control variables

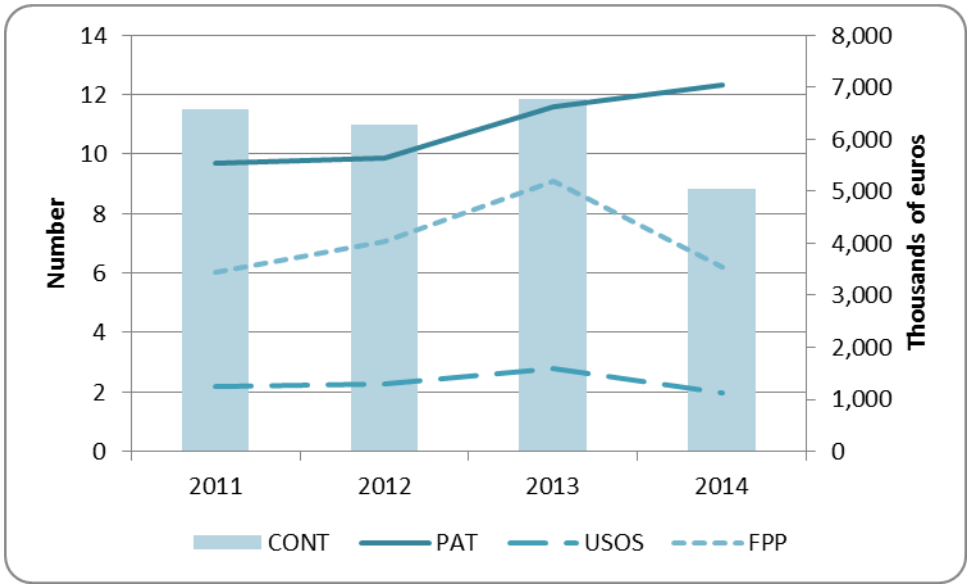
	Variable	Obs	Mean	Std. Dev.	Min	Max
DEPENDENT	PAT	260	11.06	10.84	0	53.00
	USOS	230	2.26	3.54	0	22.00
	FPP	255	6.88	7.91	0	56.00
	CONT[12]	246	5,914.80	7,549.49	1.00	57,878.00
INDEPENDENT	BUDGETTI[12]	189	2,420.45	2,094.70	0	14,100.00
	PTRSHCOLABORA	186	0.81	0.35	0	2.00
	BWFLOW	217	0.37	0.48	0	1.00
	BARCHIVODOC	220	0.61	0.49	0	1.00
	BREPOSITORIO	222	0.75	0.44	0	1.00
	BDATAWH	224	0.68	0.47	0	1.00
CONTROL	TRS[2]	225	1,909.77	1,328.59	123.00	6,206.00
	1QPUB	236	373.01	433.44	0	2,368.00
	BUDGET[12]	195	178,792.10	123,391.80	6,321.80	595,577.00
	TTOAGE[2]	184	20.24	4.44	9.00	28.00

Note: [1] Variables are in thousands of euros. [2] Variables are in absolute values (not in logs).

Concerning the dependent variables proposed as measures of the outcomes of entrepreneurial universities, the annual average number of patents granted is higher than 11 by university. The annual mean number of USOs created by academics is around 2. In average, around 6 projects within the UE Framework Program are obtained by university and by year. In terms of R&D contracts and consultancies, the mean annual amount reached is near to 6 million of euros (Table 3).

In order to deepen in the analysis of the dependent variables, Figure 2 shows the annual evolution of their mean values over the period 2011-2014. The mean number of patents granted in front of the Spanish Patent and Trademark Office increased lightly along all the period studied, while the mean number of USOs created and the projects within an EU Framework Program increased until 2013 and they went down in the next year (2014). The mean values of the amount of thousands of euros obtained with R&D contracts and consultancy showed a decreasing trend.

Figure 2. Evolution of the entrepreneurial outcomes of Spanish universities (2011-2014)



Regarding the independent variables, the annual mean budget for centralized IT services is near to 2.5 million euros. The annual average percentage of researchers that use institutional tools of collaborative work is about 81%. On average, 37% of universities have a documental workflow, 61% have a filing application, 75% have a repository, and 68% have a data warehouse (Table 3).

Concerning the control variables, by university, 1.909 is the average number of TRS, the annual mean number of publications in the first quartile is around 373, the average total university budget is near to 179 million euros and the mean age of TTOs is 20 years (Table 3).

Finally, Table 4 shows the correlation matrix for the continuous variables used in the analysis.

Table 4. Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PAT	(1)	1									
USOS	(2)	0.5569*	1								
FPP	(3)	0.5107*	0.5404*	1							
LNCONT	(4)	0.6345*	0.3978*	0.5895*	1						
LNBUDGETTI	(5)	0.2807*	0.0687	0.2357*	0.4196*	1					
PTRSHCOLABORA	(6)	-0.4065*	-0.2848*	-0.2116*	-0.1736*	-0.0218	1				
LNTRS	(7)	0.5260*	0.3825*	0.5180*	0.7097*	0.5826*	-0.1740*	1			
1QPUB	(8)	0.4700*	0.2853*	0.5787*	0.7014*	0.4634*	-0.1570*	0.7823*	1		
LNBUDGET	(9)	0.5980*	0.4360*	0.5457*	0.8167*	0.5846*	-0.1604*	0.9439*	0.8542*	1	
LNTTOAGE	(10)	0.4723*	0.2243*	0.3309*	0.4888*	0.2830*	-0.2739*	0.4943*	0.6099*	0.5928*	1

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

In view of the correlation matrix data, we noted some possible multicollinearity problems. Then, the variance inflation factor (VIF) was checked for each independent variable and was less than 6, which used to be an acceptable level (Greene, 2012).

4.2. Multivariate analysis

The results of negative binomial models on patents granted (PAT), USOs created (USOS) and projects within an EU Framework Program (FPP) as well as the results of random effects GLS models on amount of R&D contracts and consultancy signed (CONT) are presented in Table 5. In all cases, models include the group of independent variables (LNBUDGETTI, PTRSHCOLABORA, BWFLOW, BARCHIVODOC, BREPOSITORIO and BDATAWH), the group of control variables (LNTRS, 1QPUB, LNBUDGET and LNTTOAGE) and the year's dummy variables (λ_t).

Table 5. Negative binomial and random effects GLS panel regressions

	PAT	USOS	FPP	LNCONT
LNBUDGETTI	-0.021	0.028	-0.056	-0.085*
	(0.075)	(0.139)	(0.061)	(0.034)
PTRSHCOLABORA	-0.513**	-0.378	-0.119	0.114
	(0.197)	(0.400)	(0.236)	(0.204)
BWFLOW	0.03	0.003	0.085	-0.175+
	(0.159)	(0.267)	(0.165)	(0.094)
BARCHIVODOC	-0.202	0.036	0.242	0.330*
	(0.180)	(0.297)	(0.192)	(0.166)
BREPOSITORIO	0.127	0.453+	-0.018	0.084
	(0.144)	(0.238)	(0.167)	(0.145)
BDATAWH	-0.710***	-0.535+	-0.164	-0.521
	(0.161)	(0.292)	(0.205)	(0.320)
LNTRS	0.751+	0.837	0.11	0.594
	(0.436)	(0.758)	(0.503)	(0.576)
1QPUB	-0.282*	-0.216	0.499**	-0.092
	(0.126)	(0.200)	(0.159)	(0.086)
LNBUDGET	0.609	0.468	0.41	1.160*
	(0.377)	(0.653)	(0.439)	(0.475)
LNTTOAGE	0.35	-0.055	-0.227	-0.884+
	(0.515)	(0.821)	(0.524)	(0.469)
CONSTANT	-12.825**	1.692	-7.144	-13.470*
	(4.396)	(485.613)	(5.206)	(5.497)
Years dummy	YES	YES	YES	YES
University-year obs.	117	108	117	112
Unique universities	37	35	38	36
Log likelihood	-347.77	-194.47	-315.90	-
Wald χ^2	105.93***	34.24**	85.36***	303.84***

Notes: This table presents the results for negative binomial models (Models 1 to 3) and for random effects GLS model (Model 4). Robust standard errors are in parentheses.
+ p < 0.10; * p < 0.05; **p < 0.01; *** p < 0.001

The results show that KM based on IT influences the entrepreneurial outcomes of universities. Thus, we found a positive effect in the case of the IT solutions referred to the infrastructure of data storing. Particularly, the availability of filing applications (BARCHIVODOC) and an institutional content repository (BREPOSITORIO) positively influences the number of launched USOs and the amount of funds obtained through R&D contracts and consultancies, respectively.

Nevertheless, we also found negative effects of IT solutions for KM on the entrepreneurial outcomes of universities. Thus, the percentage of researchers using institutional tools of collaborative work (PTRSHCOLABORA) has a strongly significant negative effect when the entrepreneurial outcomes are

measured in terms of the patents granted at the Spanish Patent and Trademark Office. A tentative explanation of this result is that when researchers have the intention of patenting, they do not use institutional tools of collaborative work because the nature of these tools does not guarantee to meet the novelty step requirement in patents. In contrast, the users of these collaborative tools in the university context could be more oriented to other outcomes different from patents (i. e. teaching and training collaborations). Another explanation for this result is that researchers do not use these institutional tools of collaborative work properly, wasting their time and damaging their patenting activity. Similarly, the availability of a data warehouse (BDATAWH) negatively affects the universities patenting activity. It can be explained because the data stored in these tools are not useful for the patenting activity of researchers, and the time required to look for these data and store them by administrative purposes reduces the time of researchers for developing new inventions.

There is also a negative relationship between the budget for centralized IT services and the funds obtained from R&D contracts and consultancies. In this respect, it is noteworthy that that the budgets of the Spanish universities have experienced substantial cuts after the economic downturn started in 2007. In this context of limited total budgets, an increase in the budget for centralized IT services actually means a decrease in the budget spent on other university services. Therefore, the negative effect might be reflecting that other university departments, such as the department of interface infrastructures, have less financial resource to develop their activities, damaging their entrepreneurial outcomes.

It is also noteworthy that whereas de positive effects of IT solutions for KM on the entrepreneurial outcomes of universities are weakly significant, the negative ones are strongly significant. Taken together the aforementioned results, we conclude that the IT solutions for KM in the Spanish universities erode some of their entrepreneurial outcomes, especially when they are measured through patents granted and funds obtained from R&D contracts and consultancies. These results are to some extent consistent with those of Numprasertchai and Igel (2005), Geng *et al.* (2005), Masa'deh *et al.* (2017), and Yapa (2011).

As mentioned, this could be due to the fact that these IT solutions are more process than performance-oriented. Additionally, the KM systems could have been designed for answering mostly the needs of university managers, leaving in the background the needs of the researcher and other internal (i.e. the

TTO's staff) and external (i.e. industry, government and society) actors who are also involved in the entrepreneurial processes of universities.

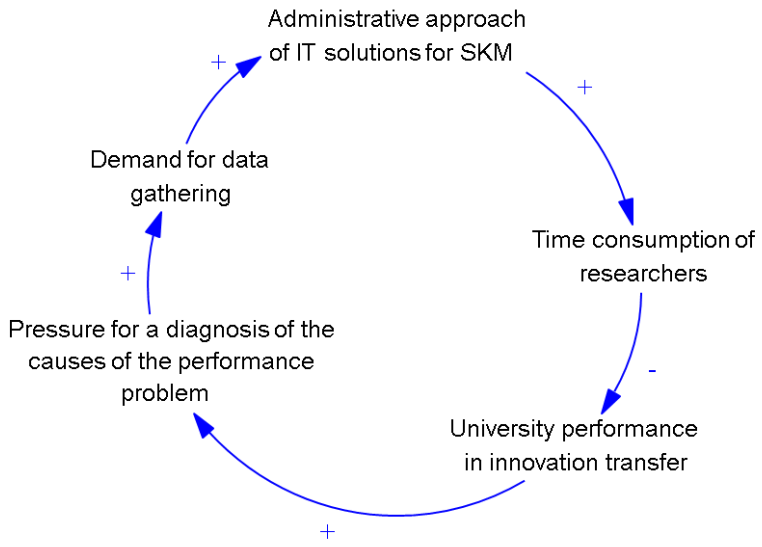
According to the aforementioned conceptual framework of 'knowledge tower' (Figure 1), these results contribute to show how the connection between the knowledge infrastructure (IT solutions) and knowledge management processes can be useful to explain the assessment of KM at universities (entrepreneurial outcomes).

5. Discussion

Despite of governments invest annually a considerable amount of public funds to support university entrepreneurship through the development of IT solutions for KM, the empirical analysis does not show a clear return of this investment in entrepreneurial outcomes.

By investigating the dynamics of the entrepreneurial learning process (Secundo *et al.*, 2017), we used a system dynamics approach (Sterman, 2000) to explain the results through a causal diagram. The process-oriented approach of the KM at universities makes the TTOs' staff continuously demand data to researchers about their research lines, economic justification of projects, explanations of their external agreements, etc. Time spent answering this demand is time that researchers cannot spend innovating, hampering innovation transfer in the long term. The bad position of the university in the innovation ranking increases the pressure of its managers to use the KM system to diagnose the causes of the problem, demanding new data. This reinforces a perverse loop (Figure 3) that maintains the problem of the lack of innovation transfer at universities.

Figure 3. Causal analysis of results



This diagram evidences problems in the role played by the current IT solutions for KM in the entrepreneurial activities of the Spanish universities. As mentioned, a potential explanation lies in the fact that most of these knowledge infrastructure and KM processes are designed at the service of administrative purposes using a process-oriented approach, instead of enabling the knowledge flow among the different stages of the knowledge tower (Oztemel and Arslankaya, 2011), using an approach of the KM system based on the researchers needs for innovation.

6. Conclusions

Over the last three decades, universities have gained the attention of academics and policy makers as a key ingredient for growth prospects of a territory. Indeed, not surprisingly, the literature devoted to the entrepreneurial university and university entrepreneurship is flourishing. Particularly, the literature on the entrepreneurial universities has focused on exploring why some universities are more successful in producing entrepreneurial outcomes. Broadly speaking, most studies have agreed that the support of the university's interface infrastructures (i.e. TTOs), as well as the researchers' performance, exert a positively effect in obtaining entrepreneurial outcomes. Both researchers and personnel of TTOs use them to accumulate tacit knowledge whose exchange helps in creating new knowledge and commercializing it. Then, the way in which explicit knowledge is structured, used and transmitted in a university's KM system may affect its entrepreneurial activities. Particularly, we focus on the role

played by the IT solutions developed for the universities strategy in KM.

This study concludes that the IT solutions for KM available within the universities (knowledge infrastructure) affect the way in which actors involved in entrepreneurial activities store and exchange the knowledge required for generating entrepreneurship (knowledge management processes). Moreover, adopting a process-oriented approach for KM may result in a decrease of the entrepreneurial outcomes of universities (assessment of knowledge). These results are aligned with those of Numprasertchai and Igel (2005), Geng *et al.* (2005), Masa'deh *et al.* (2017), and Yapa (2011).

From our point of view, universities and governments should reflect about the strategic impact the IT solutions at universities, reorienting them to serve as tools for the knowledge sharing and innovation transfer of the researchers and the TTO instead of mere administrative channels. In this respect, previous literature has showed that KM is not just an IT issue. It is necessary to take into account KM priorities and needs, organizational procedures, culture and over all, end-users' involvement (Beesley and Cooper, 2008; Call, 2005; Lang, 2001; Ragab and Arisha, 2013; Tan and Noor, 2013; Zeleny, 2002). We do not know yet if the use of IT solutions will increase the transfer capacity of universities, but what is real by now it is that the process-based approach of these applications goes against of this goal. Future research could enlighten about the effects of the use of IT solutions for knowledge sharing at entrepreneurial universities, if universities managers and government officials agree to design these solutions according to the needs of researchers and firms in order to build the Knowledge, Innovation and Consensus Spaces (Ranga and Etzkowitz, 2013).

Finally, this paper also presents some limitations to be addressed in future research. Some variables reflect the existence of KM systems based on IT tools more than the way in which IT solutions are used in the KM. Future research on this topic might benefit from measuring the specific uses of the IT solutions for KM and the channels through which KM systems based on IT influence universities performance. Moreover, the use of longitudinal datasets could provide new insights about the effect of the IT usage (through the time) on the universities performance. Finally, future work could benefit from extending the analysis to other knowledge-driven institutions.

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