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The relevance of knowledge transfer for universities' efficiency scores: an empirical approximation on the Spanish public higher education system

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Abstract

This paper examines how knowledge transfer (KT) indicators affect analyses on efficiency in the Higher Education sector, taking into account the characteristics of the Higher Education Institutions (HEIs). After revising the concept of third mission as a field for data development and its importance in assessing university performance, we applied various Data Envelopment Analysis (DEA) models with different specifications to 47 Spanish public universities to test whether KT indicators are relevant when evaluating the performance of HEIs in terms of their efficiency and, if so, which indicators are most suitable. Our results suggest that the effect of including KT indicators in the efficiency analyses varies from university to university according to their characteristics. The subject mix taught at the university, the focus according to each mission's relative importance within the total range of activities carried out in each university (mission mix) and the mix of their third mission activities affect the increase of the universities' efficiency scores when KT is taken into account in the analysis. This means that these factors affect the universities' position for the different efficiency scores.

1. Introduction

With the general trend in reducing public funds for universities, analyses on efficiency in the Higher Education (HE) sector have become a priority in most industrialised countries. The pursuit of efficiency is highly desirable when dealing with the increasing number of students in HE and engaging in research for the current race for performance and reputation, where funds are increasingly allocated according to results (Van Vught 2008). Additionally, there is an increasing demand by society for transparency and accountability in institutions receiving public funds (value for money).

The development of the knowledge economy led to the role of universities being reviewed, placing their third mission under the scrutiny (Bueno & Casani 2007), as well as increasingly recognising the benefits of collaboration between Higher Education Institutions (HEIs) and the wider society (Davey 2011). The third mission is the university's 'relationship with the non-academic outside world: industry, public authorities and society' (Schoen et al. 2007, p.127) and involves collaboration 'between institutions of higher education and their larger communities (local, regional/state, national, global) for the mutually beneficial exchange of knowledge and resources' (Driscoll 2008, p.39) for the benefit of the economy and society (Molas-Gallart et al. 2002). In this light, third mission activities are seen to extend beyond the aspects traditionally considered in knowledge transfer (KT) and include developing lifelong learning and public service initiatives. Nonetheless, the available indicators are still balanced towards KT, and empirical studies usually focus on this aspect. Indeed, this paper is inserted in this stream because of the lack of available data on continuing education and university outreach relating to our study, which concerns the Spanish HE system.

Conceptually, the third mission reflects the broader role taken on by universities over the last few decades. It, therefore, seems logical, and necessary from an institutional point of view, to include the new tasks that universities must carry out when evaluating their productivity and efficiency, a fact that can lead to a better understanding of the differences in their performance. From this perspective, we are interested in studying how the third mission can affect the efficiency indicators used to assess universities, although we are obliged, because of the previously mentioned lack of available data, to restrict our analysis to a narrow set of third mission activities. Having therefore explained our background, our main research questions are: *How do Spanish HEIs perform in terms of efficiency when KT indicators are included or excluded in empirical analyses? How are the changes in their efficiency measures distributed?* To answer these questions, we analysed the differences in efficiency performance for Spanish universities under different model specifications. We first calculated the efficiency scores through a technique called DEA (Data Envelopment Analysis) in a more traditional way i.e. considering teaching and research outputs, and then we compared them with models that also propose KT variables as outputs. We feel that this research question is relevant because the role of the third mission (or at least the KT) in the assessment of university efficiency is still not understood in depth. In so doing, we were forced to address an additional research question: *Which are the most suitable indicators that can be used as proxies for KT engagement within Spanish universities, looking at the specific context of technical efficiency?* To address this question, we carried out several DEA analyses that made use of different KT proxies.

This analysis concentrates on the Spanish HE system, which is one of the largest in the European Union. According to ETER data (*European Tertiary Education Register*), HE in Spain is one of the six systems in Europe with more than one million students, representing almost 10 per cent of all HE students in the EU27 (for the academic year 2012-13). It is a decentralised system and regional governments are responsible for policies on education, under the coordination of central government. The third mission became a legal duty for

Spanish universities with the introduction of the Fundamental Law of Universities (Ley Orgánica de Universidades - LOU) in 2001, amended in 2007 (LOMLOU). According to this act, the service provided to society by Spanish universities in both the public and private sector include the 'dissemination, valorisation and knowledge transfer at the service of culture, quality of life and economic development'; as well as the 'dissemination of knowledge and culture through university outreach and life-long learning' (see Article 1, LOU & LOMLOU). Encouraging the development of the universities' third mission in Spain, particularly in terms of the KT dimension, was one of the aims set in the original law and its subsequent amendment.

Alongside legal support for third mission initiatives, in the early part of this century, the Spanish HE system received increasing public funds for KT and innovation, with new structures for its development being established and existing structures reinforced. However, the evidence in terms of the efficiency achieved by these structures is inconclusive, and results vary significantly from one university to another (Berbegal-Mirabent, Lafuente & Solé 2013). Moreover, as a consequence of the financial crisis, Spanish public expenditure in this field has dropped since 2009 and, although universities have been partially able to cover this by making changes to their own internal budget, there is an ensuing negative impact on their KT production level, which varies from KT output to KT output.

The analysis presented in this paper is innovative in two respects. Firstly, while there are numerous studies that examine KT, in terms of its definition, measurement, assessment and management, none of them focus on the contribution that KT brings to a university's overall efficiency or on its heterogeneity, which varies in function of the characteristics of each university. Secondly, there is still little discussion about which are the suitable indicators to be used as proxies for the KT output in the specific context of technical efficiency analysis. Our empirical analysis tests how various combinations of KT proxies affect the results, and whether using a KT composite indicator is appropriate.

The paper is organised as follows: in Section 2, we reviewed the concept of the third mission as a field for data development, describing the different trends in Data Envelopment Analysis (DEA) literature dealing with KT. Section 3 describes the data and methodology, and Section 4 contains the results of our empirical work. We then set out our discussion in Section 5, drawing some concluding remarks.

2. Literature and hypotheses

2.1 University missions: broadening the role of universities through the third mission

Nowadays, the socio-economic role of universities is broader than it was two decades ago: ‘HE is not only expected to deliver excellent education and research’, its first and second missions, but ‘it also has to deliver knowledge in ways, volumes and forms that are relevant to the productive process and to shaping the knowledge society’ (Jongbloed, Enders & Salerno 2008, p.306), which is its third mission. Universities that embraced the three missions were then defined as ‘entrepreneurial’ universities (Etzkowitz 1997) and more recently as ‘new flagship’ universities (Douglas 2016). With the expansion of their duties, universities are given a new identity, which entails a great challenge for the sector (Czarniawska and Wolff 1998; Huisman et al. 2002; Stensaker and Benner 2013; Stensaker 2015).

From a policy perspective, interest in the universities’ third mission (their social and economic role) has increased over the last 20 years. Although the topic has been widely studied, researchers have yet to agree on whether the third mission is a mission in itself, with a set of functions that are distinct from teaching and research (see, for example, Vorley & Nelles 2008) or whether it is an extension of the first two (E3M 2012b). This is because the ‘traditional’ missions overlap the third mission. All three share resources, such as human resources, funding and facilities, and some outputs from the first two missions become inputs for the third, e.g. knowledge generated through research (Schoen et al. 2007). In fact, this overlap of missions is a thorny issue to deal with (E3M 2010), because it may hinder third mission activities from being identified and, therefore, the impact and performance of the third mission from being measured. With this paper, our intention is to contribute to this debate and shed light on the role of the third mission in the assessment of university efficiency.

As has been acknowledged in several studies, the different institutional and historical characteristics of universities, particularly their subject specialisation (Thursby & Kemp 2002), in combination with differences in their socio-economic context, lead to universities having a greater or lesser leaning towards teaching and/or research, and to different levels of third mission engagement, which means that their strategies are specialised by type of mission and/or they implement different mixes of third mission activities (D’Este & Patel 2007; Laredo 2007; Schoen et al. 2007; Wright et al. 2008; Hewitt-Dundas 2012; Rossi 2014; or Mora et al. 2015). In this sense, we can define the concept of ‘mission mix’ as the relative weight that each institution assigns to each of teaching, research and the third mission. Some studies, such as that carried out by Schubert (2014), have classified universities according to their mission mix.

One aspect that is widely recognised as a source of heterogeneity among universities is their subject mix or ‘repartition of activities of a HEI between its subject domains’ (Lepori, Probst Schilter & Baschung 2010, p. 77) because it implies conferring different characteristics to the organisation of education, research (Clark 1996) and the third mission (Thursby & Kemp 2002). Different fields of knowledge provide different opportunities and resources, with social sciences being related more to the potential development of the teaching mission, whereas business studies and technology provide more opportunities for raising private funds and technical and natural sciences are seemingly better at raising third-party funds for research (Lepori, Probst Schilter & Baschung 2010, p.76). In other words, the subject mix influences the universities' strategies, in the sense that it has a strong impact on the type of interaction between HEIs and their communities. This is one of the key factors in defining the type, scope, reach and targets of each university's mission. The subject mix is likely not only to affect the mix of activities within each mission, including the mix of third mission activities, but also how each university mission weighs on the entire set of university activities (the 'mission mix' defined above).

2.2 Third mission as a new field of data development

Numerous studies have examined how the third mission is defined, measured, assessed and managed. Different suggestions emerge from research concerned with defining a theoretical framework and system of indicators for the third mission, see for instance the projects by Molas-Gallart (2002), Schoen et al. (2007) and E3M (2010), demonstrating that there is no consensus on this topic within the scientific community (Piva & Rossi-Lamastra 2013). Because of the overlap between the various missions, it is tricky to circumscribe the activities that fall under the umbrella of the third mission. This apart, the afore-mentioned projects are in agreement on (i) the difficulty of gathering the metrics proposed; and (ii) defining a third mission concept that goes beyond KT, which usually takes the form of classifying third mission activities into technology transfer and innovation (such as those related to research), continuing education (related to teaching) and social engagement (related to involvement in social and cultural life) – see E3M (2012b). In this vein, analysts are looking closely at how to develop new sets of indicators that can be applied to these complex and multi-faceted activities. This process is similar to the one that took place in the past for teaching and research, which involved additional indicators for teaching outputs that went beyond purely graduation marks, for instance student drop-out rates, student satisfaction and employability, and additional measures for research results, for example, bibliometric measures, research contracts and success in attracting international grants.

Most HE policies encouraging the development of the third mission focus on activities that are most likely to bring in extra funds to HEIs. This fact, together with the difficulty in producing indicators on implicit, informal and long-term activities, means that it is much easier to obtain reliable data on KT and innovation than on continuing education or community outreach. Even for research projects, where the aim was to define a set of indicators for the third mission, more indicators were proposed for KT than for the other two dimensions – see Table 1, where the most balanced set of indicators concerning third mission operations is found in the E3M project. These KT indicators relate to (i) the inclusion of KT in the university's mission and strategy, e.g. through a KT institutional action plan, (ii) human resources dedicated to KT, (iii) intellectual property (IP), (iv) agreements on IP, (v) spin-offs and start-ups, (vi) research collaboration, (vii) conferences and networking, (viii) university-industry staff and (ix) student mobility and university-industry shared facilities. Each project, however, proposed different indicators for the various KT operations (see Annex I) (and those with better implementation possibilities and/or availability were selected for the SPRU and E3M projects). Moreover, different indicators come into play that may be used for distinct purposes, e.g. to analyse the processes and management practices backing the KT activities (Schoen et al., 2007), to define the third mission funding scheme (Molas-Gallart et al., 2002) or to rank universities according to their third mission performance (Montesinos et al., 2008).

Thus, KT is the dimension that has been studied the most and for which data are more readily available. Even so, several authors still claim that the range of reliable metrics for the universities' KT is generally narrow (Rossi 2014). Accordingly, they are still not understood in depth (Berbegal-Mirabent, Lafuente & Solé 2013), although the channels used to transfer knowledge to society have been widely studied (Hall, Link & Scott 2003; Perkmann & Walsh 2007).

Table 1. Third mission indicators proposed by E3M, SPRU and OEU projects.

	E3M indicators		*SPRU indicators*		*OEU indicators***
	Proposed	*Selected*	*Proposed*	*Selected*	
*Technology transfer and innovation**	30	19	53	23	55 aprox.
Continuing Education	28	17	6	5	0
Social Engagement	36	11	8	6	16 aprox.
TOTAL	94	47	67	34	71 aprox.

Source: authors' elaboration based on Molas-Gallart *et al.* (2002, pp.67–79), Schoen *et al.* (2007, pp.125–168), and E3M (2012a).

* Note: a high share of the technology transfer and innovation indicators are related to commercialisation activities and advisory work: 15 (or 9 finally selected) indicators for the case of E3M, 39 (or 13 finally selected) indicators for the case of SPRU and 34 indicators approximately for the case of the OEU project (see Annex I).

** Note: the number of measures for the OEU system of indicators is approximated because each third mission activity was to be measured in absolute terms and in shares and, when possible, by various scales, e.g. geographic location (regional share, national share) or fields of knowledge.

To summarise, while the heterogeneity of third-mission activities is a well-established methodological concept, the associated measurement system is still inadequate and undeveloped. As a consequence, the empirical analysis in this paper is limited to KT, with a discussion on the potential implications for the other areas of third mission.

2.3 Bringing knowledge transfer into efficiency studies

Education is one of the fields where efficiency analyses, particularly DEA, are applied the most and, in recent years, DEA has been used specifically to analyse HE (Liu et al. 2013). A review of the different ways this methodology has been used in HE can be found in Johnes (2006), while Berbegal-Mirabent & Solé-Parellada (2012) reviewed the various proxies for inputs and outputs used in empirical DEA studies. Additionally, Worthington (2001) and De Witte & López-Torres (2015) reviewed the various efficiency methodologies, including DEA, used in analyses within the field of education.

In the literature on efficiency of HEIs, it is generally agreed that inputs, such as financial resources, consumables, human capital and facilities, are used to produce three types of output: teaching, research and third mission products (Johnes 2004). In particular, the review of literature on efficiency, which examines DEA and other methods such as Stochastic Frontier Analysis (SFA), brought up two different approaches to the third mission. The first approach includes studies on KT efficiency, restricting the analysis to KT activities. According to this approach, the inputs are primarily related to human capital, i.e. academic staff, administrative staff and Technology Transfer Office (TTO) staff; and to the financial resources involved in the KT process. The outputs mostly relate to the number of patents, spin-offs, licenses, R&D and consultancy contracts, as well as the income from licensing and R&D contracts. Given that the the inputs are used jointly in teaching, research and third mission activities, the main limitation of these papers consists in the difficulty in determining which share of each input is used for KT activities only. The second approach (Table 2) is to assess the universities' efficiency considering all missions in the analysis: teaching, research and the third mission (specifically, KT). In this case, the production process is approximated through the inputs and outputs commonly used in the literature for teaching and research and the authors simply added an output KT measure to the model specification. However, in none of these papers has the specific impact of KT activities on efficiency scores been assessed, i.e. how the efficiency scores change or not when including or excluding the KT indicators. This means that these studies do not contribute to the debate on the role of the third mission in the efficiency results and its heterogeneity in relation to the HEIs' different features, or to that on the suitability of the KT indicators employed. In these publications, the third mission indicators used by the authors were intellectual property and patents, spin-offs, income from intellectual property and the private funding and income from other services. Once again, the third mission proxies are in the main related to KT, with the other dimensions of the third mission activity of universities being disregarded.

Table 2. Efficiency analyses of HEIs accounting for the three missions of universities.

Reference	*Third mission inputs*	*Third mission outputs*	*Country*
Yang et al. (2014)	-	- Aggregate of number of patents (applied and granted), new varieties of plants and animals, software copyrights, new medicine, standards and similar activities.	China
Berbegal-Mirabent, Lafuente & Solé (2013)	- R&D income	- Spin offs created	Spain
Thanassoulis et al. (2011)	-	- Income from other services rendered	United Kingdom
Johnes, Johnes & Thanassoulis (2008)	-	- Income from other services rendered	United Kingdom

Source: authors' elaboration.

Given the theoretical framework depicted above, our hypothesis is the following. The effect of including KT within the analysis on university's efficiency performance is different according to the type of university, in the sense that any change in efficiency measures experienced by the universities when considering KT is closely related to their 'mission mix' and 'subject mix'. In Spain, this tendency affects in particular the universities with a relatively stronger leaning towards KT activities, as well as those concentrating in the technical and scientific fields.

3. Methodology, empirical approach and data

3.1 Data

We constructed a new integrated database containing data on teaching, research and KT activities in 47 (out of 50) Spanish public universities[1] for the most recent academic year available, 2013-14. Three public universities were excluded from the sample because of their special characteristics: Universidad Internacional Menéndez Pelayo (UIMP) and Universidad

[1] A list of the universities included in the analysis and their acronyms is available in Table 4.

Internacional de Andalucía (UNIA) do not have academic staff but provide postgraduate courses through outsourced academics and Universidad Nacional de Educación a Distancia (UNED) provides education through distance learning.

In this study, we used the most up-to-date information on the Spanish university system available from two new data sources. We obtained student and academic staff numbers from the new Integrated University Information System (*Sistema Integrado de Información Universitaria* - SIIU), a platform newly formed by the Spanish Ministry of Education to collect, process and analyse data on the Spanish HE system. Information on the production of research and KT was provided by the *IUNE Observatory*. This observatory gathers data from various Spanish administrative sources and builds its own bibliometric indicators from the Web of Science (ISI).

3.2 Methodology

We applied the DEA method (Farrell 1957; Charnes, Cooper & Rhodes 1978), which is the deterministic non-parametric frontier methodology most commonly used to measure the relative efficiency of Decision Making Units (DMUs), which in this analysis are the universities. Examples of DEA analyses in Spain on universities come from Duch (2006), Agasisti & Perez-Esparrells (2010) and Gómez-Sancho & Mancebón-Torrubia (2012). In this paper, we have presented the results of an output-oriented DEA model, because our assumption is that universities have greater control over their output than their input, which, in turn, is more likely to be influenced by the decisions taken by their external stakeholders (Duch 2006; Agasisti & Perez-Esparrells 2010). We have shown the inverse of the output-oriented efficiency scores, which means that, for efficient universities, the efficiency score is equal to one (output cannot be increased without increasing input) while inefficient universities score below one. Given the high differences in terms of size among the universities included in our sample, we applied a DEA analysis for variable returns to scale (VRS), since this takes into account these differences in size, so each DMU (university) is compared to other DMUs of a similar size. DEA works as a linear programming problem, where weights are endogenously assigned to each input and output in such a way as to place the universities (DMUs) in the best possible light when their efficiency is approximated. We considered these weights to be proxies for the universities' strategic profiles. In this perspective, the weights approximated the 'implicit strategy' of the universities and we did not check whether each university defined its own set of priorities, but instead inferred their strategic profile by analysing the DEA weightings.

3.3 Selection of inputs and outputs

In selecting the indicators to approximate the production process within Spanish universities, we followed the same approach used in the studies included in Table 2. Therefore, alongside the inputs and outputs commonly used in the literature for teaching and research, we have added the output variables for measuring the universities' KT performance. In this case, unlike the approach followed in previous studies, we did not simply add a single KT indicator to evaluate the efficiency of the HE system, but we tested various combinations of KT proxies in order to assess their impact on the efficiency analysis (see section 3.4). This is a substantial improvement on previous literature in the field, since our results were not restricted to having chosen a single KT indicator and we were able to check the robustness of results from differing specifications, which included a number of potential viewpoints on the KT activities taking place within the universities.

With regards to the inputs, we employed two different proxies for the human capital within the universities. These are (i) the number of bachelor and master students and (ii) the total number of Full Time Equivalent (FTE) academic staff; both of these have been widely used in the DEA literature (see, for example, Fandel 2007; Rayeni & Saljooghi 2010; Kuah & Wong 2011; Duh et al. 2014; and Johnes 2014).

With regards to the outputs, we used the number of students graduating in that year as a proxy for the teaching output, also used extensively (the most recent publications include Kuah & Wong 2011; Thanassoulis et al. 2011; Wolszczak-Derlacz & Parteka 2011; and Duh et al. 2014). We used the number of publications as a proxy for the research output (e.g. Lee 2011; and Duh et al. 2014, among the most recent studies).

To measure the KT outputs, we used three different proxies (where not all of them are used in all the models and the combinations used can vary), as well as a composite indicator combining all three, to test the robustness of our results against different indicators. Table 2 summarises the proxies for the KT output used in the few efficiency studies for universities where all three missions are considered.

The first KT indicator is the number of intellectual or industrial property (IIP) agreements, gathering non-disclosure agreements concerning IIP. These include licences on national patents, confidentiality agreements to protect know-how, material transfer agreements, agreements on utility models and on biological materials, plant varieties and microorganisms registered, and agreements on digital content (i.e. computer programs, databases and web pages) that have been recorded in some way (including internal records) and registered trademarks. This indicator does not simply approximate KT through the number of inventions generated and the legal rights conferred through IIP to inventors for potential commercialisation, but directly assesses whether there is a market for the new knowledge generated. In this way, we avoided misleading information concerning IIP rights in the case of Spanish universities, where patents are considered an academic asset and are often applied for even when there is no transfer of knowledge envisaged. However, in this case, it was not possible to identify which of the non-disclosure agreements included in our indicator had been signed with non-academic partners. Additionally, our indicator did not provide any information about the economic value of the inventions.

Looking at the studies that highlight the importance of financial resources in KT (Landry, Amara & Ouimet 2007; Zortea-Johnston, Darroch & Matear 2012), the second KT indicator consists of the income that the university is able to attract through its scientific work. This indicator combines the income from R&D and consultancy contracts, from minor technical services provided, IIP and company-sponsored professorships. Our indicator also provides information about demand for the knowledge produced in universities and its socio-economic value and commercial success. This indicator is likely to fluctuate in the short-term when there are a small number of contracts or agreements that generate most of the income, and it is probably underestimated because universities can also potentially provide advisory services (for example to policy-makers) that are not paid for but obviously could be quantified. Additionally, income performance is subject to market conditions (e.g. the socio-economic development of the university environment) or public policy trends (e.g. national research programmes that are unrelated to university initiatives). In addition, this indicator does not provide information on the sums involved in the various contracts and agreements, which may be a proxy of their ability to generate substantial new knowledge, i.e. the quality of these contracts and agreements. In our case, it was not possible to identify the share of KT income coming from non-academic sources.

Finally, the third KT proxy is the number of university spin-offs established in the last five years. 'Spin-offs have an important role in the transfer of frontier knowledge from university to economy and society, being among the agents that transform cutting-edge knowledge into services, processes or products relevant to companies' (Mustar et al. 2006; Mustar, Wright & Clarysse 2008). Moreover, the process to create a spin-off is very complex, with several structures within the university being involved (Berbegal-Mirabent, Lafuente &

Solé 2013) for the purpose of marketing a broad set of university capabilities. Consequently, we considered this to be a good proxy for the KT output of universities. Given that the number of spin-offs varies substantially year by year, we only took into account the spin-offs from the last five years, to build a less volatile indicator. Since data concerning the number of start-ups is still unreliable in the case of Spain, this value was not considered. Our indicator does not take into account the size or commercial success of the spin-offs. The spin-offs' cash-in for equity, turnover, profit or staff may depend on market factors which are beyond the control of universities, while spin-off survival rates are difficult to identify because of changes in ownership over time.

To interpret our data and subsequent results correctly, it is worth noting that, since university TTOs are the original data source, the indicators concerning KT activity are likely to underestimate the universities' performance, because inventions, research and consultancy contracts are not always communicated to the university (see Markman, Gianiodis & Phan 2007; Siegel & Phan 2004; Siegel, Veugelers & Wright 2007; Thursby, Jensen & Thursby 2001 for patents and Di Gregorio & Shane 2003 for spin-offs). Finally, none of the proposed indicators approximate the social value of the university's inventions and research.

Most of these strengths and weaknesses were already stated fifteen years ago by Mollas-Gallart et al. (2002) for similar indicators. However, the discussion concerning the suitability of KT (and third mission) indicators is still very much alive (see section 2.2) and, although the indicators selected for our study still have a number of the shortcomings, as we have stated, they are useful for exploring certain important aspects in KT. In this study, we tested whether they can be used as proxies for KT engagement within Spanish universities in the context of technical efficiency.

Finally, we carried out an additional DEA analysis using a further proxy for the KT, in the form of a composite indicator for the number of IIP agreements, KT income and number of spin-offs. The KT composite indicator was constructed through Principal Component Analysis (PCA). PCA is the most widespread method used in the DEA literature for building composite indicators. The Principal Components are calculated as uncorrelated linear combinations of the original data and are ranked by their variances in descending order. Following the common practice when combining PCA and DEA methods, our composite indicator was the first component of the PCA analysis, that is, the one with the greatest variance, which gather together 59.94 per cent of the information on KT production contained in the raw data. This component is highly correlated with all three original variables (0.706 for IIP agreements, 0.859 for KT income and 0.749 for spin-offs). It is therefore a proxy of the 'size' of the KT output from universities. In order to avoid negative and zero values, we added a constant to the original value of the component for each university, so that all values are non-negative (Adler & Golany 2001). This affine transformation of data did not lead to changes in the results for the VRS DEA variant (Ali & Seiford 1990; Pastor 1996).

3.4 Exploring the effects of considering knowledge transfer on efficiency scores

We performed nine DEA analyses with different input and output specifications (see Table 3), and both accounting and not accounting for the KT indicators. We initially ran a baseline model (*bs* hereafter), which is a DEA analysis without KT proxies. The results of this baseline analysis were then compared with the results from other DEA models with one KT proxy (DEA specifications bs_aip, bs_i and bs_s), two KT indicators (DEA specifications bs_aip_i, bs_aip_s and bs_i_s), the three KT indicators (bs_aip_i_s) and the KT composite indicator (bs_c).

Table 3. Input and output specifications of the DEA analysis performed.

DEA models		*Inputs*	*Outputs*
1. Baseline model (bs)		1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications
Baseline model + Knowledge Transfer	*2. Agreements on IIP (bs_aip)*	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications **3. Agreements on IIP**
	3. Income (bs_i)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications **3. KT income**
	4. Spin-offs (bs_s)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications **3. Spin-offs**
	5. Agreements on IIP + Income (bs_aip_i)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications **3. Agreements on IIP** 4. **KT Income**
	6. Agreements on IIP + Spin-offs (bs_aip_s)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications **3. Agreements on IIP** 4. **Spin-offs**
	7. Income + Spin-offs (bs_i_s)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications 3. **KT Income** 4. **Spin-offs**
	8. Agreements on IIP + Income + Spin-offs (bs_aip_i_s)	1. Enrolled students 2. Academic staff (FTE)	3. Graduates 4. Publications 5. **Agreements on IIP** 6. **KT Income** 7. **Spin-offs**
	9. Composite indicator (bs_c)	1. Enrolled students 2. Academic staff (FTE)	1. Graduates 2. Publications 3. **Composite indicator of KT**

Source: author's elaboration.

We also investigated whether there were different efficiency patterns by mission mix and subject mix, checking for heterogeneity after including KT in the calculations. Regarding the mission mix, we followed the university classification procedure proposed by de la Torre, Casani & Perez-Esparrells (2015). Their classification for public and private universities in Spain is based on 36 variables for absolute and relative teaching, research and KT production. Applying a multivariate analysis to the output indicators, the authors identified five groups of homogeneous universities: (i) those with a leaning towards teaching, labelled teaching-oriented universities; (ii) those with a relatively stronger leaning towards research (research-

Table 4. Description of typologies of universities based on clusters.

	University	*Abbreviation*	*University hospital*
Cluster 1 KT oriented universities	1. Universidad del País Vasco / Euskal Herriko Unibertsitatea	EHU	Yes
	2. Universidad de Málaga	UMA	Yes
	3. Universidad de Zaragoza	UNIZAR	Yes
	4. Universitat Politécnica de Catalunya	UPC	No
	5. Universidad Politécnica de Madrid	UPM	No
	6. Universidad Politécnica de Valencia	UPV	No
	7. Universidad de Sevilla	US	Yes
	8. Universidad de Salamanca	USAL	Yes
	9. Universidad de Santiago de Compostela	USC	Yes
Cluster 2 Not differentiated universities	1. Universidad de Alicante	UA	Yes
	2. Universidad de Alcalá	UAH	Yes
	3. Universidad de Almería	UAL	No
	4. Universidad de Burgos	UBU	Yes
	5. Universidad Carlos III de Madrid	UC3M	Yes
	6. Universidad de Cádiz	UCA	Yes
	7. Universidad de Castilla-La Mancha	UCLM	Yes
	8. Universidad de Córdoba	UCO	Yes
	9. Universidad de A Coruña	UDC	No
	10. Universitat de Girona	UDG	Yes
	11. Universitat de Lleida	UDL	Yes
	12. Universidad de Huelva	UHU	No
	13. Universitat de les Illes Balears	UIB	Yes
	14. Universidad de Jaén	UJAEN	No
	15. Universidad Jaume I de Castellón	UJI	No
	16. Universidad de La Laguna	ULL	Yes
	17. Universidad de Las Palmas de Gran Canaria	ULPGC	Yes
	18. Universidad de Murcia	UM	Yes
	19. Universidad Miguel Hernández de Elche	UMH	No
	20. Universidad Pública de Navarra	UNAVARRA	No
	21. Universidad de Extremadura	UNEX	Yes
	22. Universidad de León	UNILEON	No
	23. Universidad de Oviedo	UNIOVI	Yes
	24. Universidad de La Rioja	UNIRIOJA	No
	25. Universidad Politécnica de Cartagena	UPCT	No
	26. Universidad Pablo de Olavide	UPO	No
	27. Universidad Rey Juan Carlos	URJC	Yes
	28. Universitat Rovira i Virgili	URV	Yes
	29. Universidad de Valladolid	UVA	Yes
	30. Universidad de Vigo	UVIGO	No
Cluster 3 Research oriented universities	1. Universitat Autònoma de Barcelona	UAB	Yes
	2. Universidad Autónoma de Madrid	UAM	Yes
	3. Universitat de Barcelona	UB	Yes
	4. Universidad Complutense de Madrid	UCM	Yes
	5. Universidad de Granada	UGR	Yes
	6. Universidad de Cantabria	UNICAN	Yes
	7. Universitat Pompeu Fabra	UPF	Yes
	8. Universitat de València (Estudi General)	UV	Yes

Source: author’s elaboration.

oriented); (iii) those advancing KT (KT-oriented); (iv) those with no special emphasis on any mission; and (v) the outliers. We replicated their analysis for the 47 public universities in our sample and then analysed the relationship between our resulting groups and the efficiency scores of our DEA analyses.

We identified three homogeneous groups of Spanish universities (Table 4). These are (i) 'KT-oriented': technical and scientific universities known as polytechnics or medium sized/large universities with a relative strong emphasis on KT and technical fields; (ii) 'not differentiated': medium sized/small universities with no relatively strong orientation towards research or KT; (iii) 'research- oriented': mostly large universities with a relatively stronger emphasis on science and medicine. It should be noted that teaching does not seem to be an element of diversification for public universities in Spain.

With regards to the subject mix, we also looked at whether the universities had a medical school, because this entails a distinct set of activities and the KT involved may not be measured correctly through the selected proxies.

4. Results

4.1 Main results: efficiency scores for various DEA specifications (with and without knowledge transfer indicators)

We have presented the results of the nine DEA specifications for the academic year 2013-14 in Table 5. The statistics show that, for the baseline model, the average efficiency of the Spanish HE system is 0.770, showing some degree of heterogeneity. These results are not in line with those of previous studies (Duch 2006; Johnes & Salas-Velasco 2007; Agasisti & Perez-Esparrells 2010; Berbegal-Mirabent, Lafuente & Solé 2013), which showed rather high homogeneous efficiency results for the Spanish HE system (average efficiency over 0.9). The higher heterogeneity in technical efficiency for 2014 may be a consequence of universities with different production structures (mission mix and subject mix) reacting differently, and being more or less resilient, to the recent cutbacks in public funding to universities.

Table 5. Descriptive statistics on the efficiency scores by DEA specification.

	Min	*Q1*	*Median*	*Mean*	*Q3*	*Max*	*SD*	*Increase of the mean efficiency*	*N. of efficient univs.*	*% of efficient univs.*	*% of univs. that become efficient*
bs	**0.472**	**0.648**	**0.778**	**0.770**	**0.862**	**1**	**0.143**	**-**	**7**	**14.89%**	**-**
bs_aip	0.472	0.667	0.802	0.799	0.930	1	0.148	3.73%	9	19.15%	4.26%
*bs_i**	0.472	0.669	0.840	0.818	0.972	1	0.151	6.20%	10	21.28%	6.38%
*bs_s***	0.472	0.723	0.838	0.836	1	1	0.136	8.56%	13	27.66%	12.77%
*bs_aip_i***	0.472	0.672	0.886	0.838	1	1	0.156	8.87%	13	27.66%	12.77%
*bs_aip_s****	0.472	0.723	0.861	0.852	1	1	0.138	10.72%	16	34.04%	19.15%
*bs_i_s****	0.472	0.729	0.913	0.860	1	1	0.141	11.69%	16	34.04%	19.15%
*bs_aip_i_s****	0.472	0.729	0.924	0.871	1	1	0.143	13.17%	20	42.55%	27.66%
*bs_c***	0.472	0.685	0.897	0.843	1	1	0.153	9.53%	15	31.91%	17.02%

Note: statistical significance of the mean difference between the DEA models accounting for KT and the baseline model: * > 80%; ** > 95%; *** > 99%.
Source: author's elaboration.

Given that the maximum efficiency score is 1 and that the average efficiency is 0.770, the potential increase of efficiency scores when we account for KT is somewhat limited. However, when we account for KT, depending on the various variables and combinations thereof, between two and thirteen universities of the 36 inefficient universities in the baseline model become efficient[2], while the system efficiency increases by an average of 14.90 per cent. The model where number of IIP agreements (bs_aip) was used as the KT proxy gives the lowest increase in efficiency, with only two universities becoming efficient. This is also the only model where the mean efficiency is not significantly different from that of the baseline model. The highest increase in general efficiency was recorded for the models that include the number of spin-offs.

For the model where the KT composite indicator was used, the increase in efficiency is halfway between the increase found in models using one KT proxy (*b3aip, bs_i* and *bs_s*) and those using two KT proxies (*b3aipi, bs_aip_s* and *bs_i_s*). In this case, the effect of including additional variables to the DEA specifications is reduced and reflects university KT

[2] Table 7 shows the universities which are efficient in the baseline model (first column) and those that become efficient when applying each of the DEA models that take KT into account.

activity more closely than the models that only use a single KT proxy. Finally, as expected, the highest increase takes place in the model that includes all three KT proxies (*bs_aip_i_s*) simultaneously, which shows the statistical effect of adding variables in a DEA analysis.

Table 6. Correlations between the DEA specifications.

Pearson correlation

	bs	*bs_aip*	*bs_i*	*bs_s*	*bs_aip_i*	*bs_aip_s*	*bs_i_s*	*bs_aip_i_s*	*bs_c*
bs	1	**0.947**	**0.833**	**0.785**	**0.797**	**0.771**	**0.751**	**0.739**	**0.780**
bs_aip		1	**0.851**	**0.808**	0.881	0.859	0.807	0.830	0.878
bs_i			1	**0.821**	0.973	0.850	0.912	0.911	0.921
bs_s				1	0.830	0.963	0.943	0.914	0.902
bs_aip_i					1	0.891	0.923	0.946	0.963
bs_aip_s						1	0.951	0.959	0.947
bs_i_s							1	0.987	0.952
bs_aip_i_s								1	0.967
bs_c									1

Spearman correlation

	bs	*bs_aip*	*bs_i*	*bs_s*	*bs_aip_i*	*bs_aip_s*	*bs_i_s*	*bs_aip_i_s*	*bs_c*
bs	1	**0.946**	**0.792**	**0.756**	**0.753**	**0.743**	**0.713**	**0.700**	**0.729**
bs_aip		1	**0.823**	**0.794**	0.845	0.839	0.767	0.805	0.836
bs_i			1	**0.820**	0.970	0.821	0.898	0.891	0.892
bs_s				1	0.787	0.967	0.948	0.913	0.908
bs_aip_i					1	0.835	0.866	0.907	0.912
bs_aip_s						1	0.926	0.951	0.931
bs_i_s							1	0.967	0.937
bs_aip_i_s								1	0.943
bs_c									1

Note: all correlations are significant at 99%.
Source: author's elaboration.

Table 6 contains the Pearson and Spearman correlations for the efficiency scores between the nine DEA specifications. The correlations between all the DEA specifications are generally high; the lowest correlations being those between the baseline model and the DEA specifications that use the 'spin-offs' proxy, while the highest correlations are between the models that share a KT proxy. Additionally, the correlation between the baseline model and the DEA specification that uses the IIP agreements as a proxy is very high (0.947), and what small difference there is between the two models is not significant (see Table 5). From these results, it is clear that the proxy number of IIP agreements does not bring the bulk of KT activity of Spanish universities into play, i.e. this indicator does not approximate KT activity of Spanish universities in our technical efficiency analysis, whereas KT income and spin-offs do make such an approximation.

The high correlations between the models that include one KT proxy suggest that the increases in efficiency are not a consequence of a new indicator being introduced, but rather that these models account for a substantial part of university activity that is not considered in the baseline model. As expected, the correlations between the model with the KT composite indicator and the models with the other KT proxy combinations are also high.

4.2 Heterogeneity: how efficiency scores vary across Spanish universities

While the universities that are efficient in the baseline model retain their efficient status across all DEA specifications, those that were seemingly inefficient but are upgraded to efficient when KT is accounted for alter in relation to the KT proxy included in the DEA specification. Table 7 shows which are the efficient universities in the baseline model (first column) as well as the universities that become efficient in each of the DEA specifications where KT is taken into account. This table reveals a certain degree of overlap between the universities that become efficient in each DEA specification, because universities become efficient for every DEA model containing a particular KT proxy, e.g. a university that becomes efficient when accounting only for the spin-offs established in the last five years (bs_s) also becomes efficient in the other DEA models having this KT proxy (bs_aip_s, bs_i_s and bs_aip_i_s).

To examine the heterogeneity of the effect of the different KT proxies on universities, we took into account both the specialisation of universities by mission and their subject mix. Accordingly, in Tables 7 and 8, the results are organised according to the clusters of universities previously described (see Section 3.4) and according to the presence of at least one university hospital. In this way, we analysed the relationship between the impact of KT on university efficiency and their mission mix and subject mix.

Table 7. Efficient universities in the baseline model (bs) and universities that become efficient when accounting for the third mission by DEA specification and cluster.

	bs	*bs_i*	*bs_s*	*bs_aip_i*	*bs_aip_s*	*bs_i_s*	*bs_aip_i_s*	*bs_c*
Cluster 1		-	EHU*	-	EHU*	EHU*	EHU*	-
		-	-	UPC	-	-	UPC	-
		UPM	UPM	UPM	UPM	UPM	UPM	UPM
		-	-	UPV	UPV	-	UPV	UPV
		-	USAL*	-	USAL*	USAL*	USAL*	USAL*
Cluster 2	UNILEON	UAH*	-	UAH*	-	UAH*	UAH*	UAH*
	UNIRIOJA	-	-	-	UBU*	-	UBU*	-
		-	UMH	-	UMH	UMH	UMH	UMH
		-	UPCT	-	UPCT	UPCT	UPCT	UPCT
		-	-	-	-	URV*	URV*	-
Cluster 3	UAB*	-	UGR*	-	UGR*	UGR*	UGR*	UGR*
	UAM*	UNICAN*	-	UNICAN*	-	UNICAN*	UNICAN*	UNICAN*
	UB*	-	-	UV*	UV*	-	UV*	-
	UCM*	-	-	-	-	-	-	-
	UPF*	-	-	-	-	-	-	-

Source: author's elaboration.
Note 1: * universities with at least one university hospital.
Note 2: see acronyms in Table 4. Results for the bs_aip model are not included.

Table 8. Average and variation rate of the efficiency scores by DEA specification for the whole sample, by cluster and by universities with and without university hospital (U.H.).

			bs	*bs_i*		*bs_s*		*bs_aip_i*		*bs_aip_s*		*bs_i_s*		*bs_aip_i_s*		*bs_c*	
		N.	*Mean*	*Mean*	*Δ%*	*Mean*	*Δ%*	*Mean*	*Δ%*	*Mean*	*Δ%*	Mean	*Δ%*	Mean	*Δ%*	Mean	*Δ%*
Total		47	0.770	0.818	6.20	0.836	8.56	0.838	8.88	0.852	10.72	0.860	11.69	0.871	13.17	0.843	9.53
Cluster	*1*	9	0.755	**0.873**	**15.69**	**0.868**	**15.09**	**0.906**	**20.06**	**0.917**	**21.48**	**0.919**	**21.74**	**0.948**	**25.60**	**0.917**	**21.45**
	2	30	0.724	0.758	4.64	0.786	8.60	0.775	7.04	0.794	9.70	0.806	11.31	0.814	12.43	0.780	7.73
	3	8	0.959	0.980	2.21	0.985	2.67	0.999	4.18	0.998	4.09	0.996	3.85	1	4.28	0.998	4.09
No U.H.		15	0.723	**0.800**	**10.54**	**0.848**	**17.17**	**0.826**	**14.22**	**0.871**	**20.38**	**0.874**	**20.82**	**0.886**	**22.49**	**0.847**	**17.05**
Yes U.H.		32	0.792	0.826	4.34	0.830	4.87	0.844	6.59	0.844	6.58	0.853	7.77	0.864	9.18	0.841	6.31

Source: authors' elaboration.
Note 1: the variation of the efficiency scores is calculated as (B/A) – 1, where A = efficiency score of the baseline model and B = efficiency score of the corresponding DEA specification accounting for third mission. Mean differences across clusters are significant for all DEA specifications at 99%. Results for the bs_aip model are not included.
Note 2: Cluster 1 gathers the KT oriented universities; Cluster 2 includes those universities without a relatively strong orientation toward research or KT; and Cluster 3 comprises the research oriented universities.

We have found some interesting patterns between the clusters and the efficiency gains when accounting for KT in Tables 7 and 8. By focusing on the analysis of efficiency scores by cluster, no university in the group with a strong emphasis on KT (Group 1) is efficient according to the baseline model, while most of the universities considered to be efficient are large research universities.

Additionally, from Tables 7 and 8, it is clear that Group 1 contains the greatest number of universities that become efficient, and has greater increases in the average efficiency score. On the contrary, few 'research-oriented' universities (Group 3) become efficient when accounting for KT. The lowest efficiency increases are recorded in this group because most of these universities are already efficient in the baseline model.

The average increase in efficiency is also higher among universities without a university hospital, suggesting that a different set of proxies may be needed for future research into KT activities in medical schools. These results are in line with prior studies on the efficiency of medical schools, where it was concluded that the KT variables used were not appropriate in this case (e.g. Thursby & Kemp 2002; Powers 2003; and Anderson, Daim & Lavoie 2007).

Given the DEA measurement properties, the increases in efficiency for the DEA models that involve KT cannot be attributed unambiguously to having previously neglected KT, because efficiency scores tend to increase with the dimensionality of the production possibility set (PPS). However, results show that the distribution of these increases is dependent on the distinct characteristics of the various universities, and the size (and correlation) of these increases indicate that the inclusion of KT plays a fundamental role in approximating the university activity more effectively and in explaining the dissimilarities among universities' performance.

4.3 Output weights: the strategic profile of Spanish universities

Table 9 contains the variation of the weights assigned using the DEA method for the two outputs included in all DEA specifications, e.g. the number of graduating students and number of publications. The variation in these weights provides information on the type of increase to the efficiency measures when accounting for the KT output in universities, because they indicate the weight of each mission in the final efficiency score. In this way, it is possible to see which are the outputs allocated more importance in the model in determining the efficiency score – indirectly, we can interpret this as a proxy for the intention of each unit to value one output dimension over another.

Table 9. Average variation of the weights (absolute value) of the teaching and research output of universities by DEA specification for the whole sample, by cluster and by universities with and without university hospital (U.H.).

Teaching output: number of graduates (weights)

		N	***Δ bs_i***	***Δ bs_s***	***Δ bs_aip_i***	***Δ bs_aip_s***	***Δ bs_i_s***	***Δ bs_aip_i_s***	***Δ bs_c***
Total		47	-0.117**	-0.119***	-0.139***	-0.145***	-0.163***	-0.174***	-0.112***
Cluster	*1*	9	**-0.248**	**-0.191**	**-0.297**	**-0.302**	**-0.349**	**-0.368**	**-0,237**
	2	30	-0.088	-0.096	-0.107	-0.103	-0.131	-0.142	-0,103
	3	8	-0.080	-0.122	-0.085	-0.127	-0.070	-0.075	-0,005
No U.H.		15	**-0.175**	**-0.185**	**-0.203**	**-0.236**	**-0.256**	**-0.261**	**-0.194**
Yes U.H.		32	-0.090	-0.088	-0.109	-0.103	-0.119	-0.133	-0.074

Research output: number of publications (weights)

		N	*Δ bs_i*	*Δ bs_s*	***Δ bs_aip_i***	*Δ bs_aip_s*	***Δ bs_i_s***	***Δ bs_aip_i_s***	***Δ bs_c***
Total		47	-0.041	-0.010	-0.081**	-0.040	-0.066**	-0.083**	-0.088**
Cluster	*1*	9	-0.071	-0.031	-0.065	-0.053	-0.067	-0.062	-0,104
	2	30	-0.031	-0.017	-0.062	-0.039	-0.047	-0.062	-0,066
	3	8	-0.045	0.039	**-0.173**	-0.027	**-0.134**	**-0.185**	**-0,154**
No U.H.		15	-0.030	-0.032	-0.068	-0.049	-0.053	-0.056	**-0.117**
Yes U.H.		32	-0.046	0.001	**-0.087**	-0.035	**-0.072**	**-0.095**	-0.075

Source: authors' elaboration.

Note 1: the variation of the efficiency scores is calculated as the row difference between the weight of the corresponding DEA specification accounting for third mission and the weight of the baseline model.

Statistical significance of the mean difference between the DEA models accounting for KT and the baseline model: * > 80%; ** > 95%; *** > 99%. Results for the bs_aip model are not included.

Note 2: Cluster 1 gathers the KT oriented universities; Cluster 2 includes those universities without a relatively strong orientation toward research or KT; and Cluster 3 comprises the research oriented universities.

Table 9 shows an especially strong increase in the weights for the number of graduating students when not accounting for KT. Teaching in Spanish public universities is not relevant for differentiating between them according to our cluster analysis. However, when not accounting for KT activities in the efficiency analyses, KT seems more relevant than it actually is (by showing higher weights), proposing a misleading picture of the implicit strategies of universities.

The mean differences between the weights of the baseline model and the KT specifications are always significant in the case of graduating students, but in the case of publications, the mean differences are only significant for a few models: *bs_aip_i*, *bs_i_s*, *bs_aip_i_s* and *bs_c*. Again, the group of 'KT-oriented' universities (Group 1) and the group of universities with no university hospital show the greatest variations in the weights for graduating students. Considering the weights assigned to research output, 'research-oriented' universities (Group 3) and the universities with at least one university hospital show a greater average reduction in their publication weights, in models where there is a significant variation with respect to the baseline model.

[Table 9] around here

5. Discussion and concluding remarks

In this paper, we made a comparison between one DEA analysis where the third mission (specifically, KT) was not taken into account and several additional DEA analyses where KT was included, using various combinations of KT proxies. Our main aim was to analyse the differences in efficiency between Spanish universities under different model specifications, as this would provide a better understanding of the role of the third mission in the HEIs' complexity. From the macro perspective, our results show that the estimates for technical efficiency in the Spanish HE system change when KT indicators are included, instead of the analysis being limited simply to teaching and research in universities. Additionally, the findings presented here confirm our initial hypothesis: the effect of including KT is different according to the type of university because the increase in efficiency measures experienced by universities when including KT in the efficiency analysis is related to the subjects taught at the universities (subject mix) and the focus on the relative importance given to each mission within the universities' total activity (mission mix), but also to their mix of third mission activities. This means that these factors affect the universities' position for the different efficiency scores.

These results confirm the importance of KT in the efficiency results, and its heterogeneity according to the characteristics of the HEIs. This provides evidence about the greater accuracy of efficiency analyses that consider the third mission (or at least the KT). This greater accuracy is the consequence of the fact that the university production process is approximated better when the third mission is included (or at least when KT is considered). This, in turn, leads to the relative efficiency of Spanish universities being measured more accurately, because the amount of KT activity taking place in Spanish universities varies substantially (and depends not only on their mission mix but also on their mix of third mission activities). Specific universities with specific profiles would be affected negatively if KT was not taken into account and, therefore, the resulting distribution of the relative performance of the universities would be misleading.

In particular, universities with a strong technical profile or a relative stronger focus on KT would be penalised the most if KT is not taken into account. The same pattern occurs when, as a result of including KT in the DEA models, there is a reduction in the weights assigned to the teaching and research outputs. These weights are specially biased for the number of graduating students when KT is not taken into account. These results corroborate the conclusions reached by Garcia-Aracil & Palomares-Montero (2012), who showed a negative relationship between teaching and KT activities, but a positive relationship between research and KT amongst Spanish public universities. This effect may be a consequence of the indicator used to approximate the research output of universities in both studies, which does not differentiate between scientific papers on the basis of quality.

Our study contributes to the debate on the KT indicators that should be considered in efficiency analyses to approximate the production process of universities and their performance more accurately. With regards to the KT proxies used in this analysis, our results suggest that the number of IIP agreements does not approximate the KT activity of Spanish universities in analyses on their technical efficiency. On the contrary, KT income and spin-offs can be used to approximate their KT activity. These results not only advance knowledge on the characteristics of KT in Spain, they also imply that the suitability of the various indicators proposed in the extant literature (e.g. Molas-Gallart 2002; Schoen et al. 2007; or E3M 2010) does not only depend on the objectives of the analysis, but also on the nature of the KT by country/region.

In addition, the distribution of the efficiency gains implies that the composite indicator approximates the KT activity of Spanish universities better than the alternative models with a single KT proxy. Additionally, using the KT composite indicator provides the benefit of keeping the DEA specification as simple as possible, minimising the statistical effects of including additional variables in the DEA analyses. These results support the benefits of employing composite indicators in DEA analyses cited by Adler and Golany (2001).

However, due to the lack of indicators on continuing education and social engagement, it was not possible for us to assess the efficiency of universities with third mission mixes advancing these two dimensions, a fact that we consider to be the main limitation of this study. At the same time, this is also an area for potential improvement in future research. This, in turn, is particularly relevant in Europe where most HEIs are generalist. As additional indicators for uncovered third mission dimensions become available, new studies will shed more light on the differences in efficiency across universities. A preliminary example for the UK (Rossi 2014) is already available, but it does not show the problems of omitting these variables. The theoretical framework developed in this paper is an already usable contribution in that sense.

We join the researchers demanding that the administrative datasets should include among their objectives an extensive and reliable characterisation of the third mission (e.g. Rossi 2014). A governmental request to universities for comprehensive data on the third mission for evidence-based policy-making and the production of comprehensive administrative datasets is a strong incentive to extend the scope of universities when measuring their activity and will encourage the debate among practitioners about the critical indicators to use for their third mission activity. Different mixes of third mission activities should entail different indicators (e.g. medical schools, technical universities or schools for humanities). A wider array of KT variables that collect this dimension accurately will allow comparisons to be made between universities across regions and countries, to reflect the new trends in HEIs for the XXI century.

All Spanish public universities were founded with the same missions[3] and similar objectives (Casani et al. 2014), and there was no drive for differentiation, except in the case of the particular subject mix offered in technical universities (*politécnicos*). However, over the years, differences have emerged between universities and, nowadays, some have a more marked leaning towards research or to innovation and entrepreneurship. Our results make it clear that the Spanish HE education system is heterogeneous, not only in terms of size and fields of scientific specialisation, as commonly recognised by the Spanish university community and stakeholders, but also in terms of institutional strategy and production mix. These results contradict the general conceptions surrounding the Spanish HE system, advancing the understanding in this field. Hence, such a differentiation should be adequately considered. Any public policy or funding model that does not take these differences into consideration would reward or penalise different types of universities. Formula-based

[3] Spanish regulation assigns teaching, research and third mission duties to all Spanish universities through the University Reform Law (*Ley Orgánica de Reforma Universitaria* – LRU, 1983), Fundamental Law of Universities (*Ley Orgánica de Universidades* – LOU, 2001) and amendments *(*LOMLOU, 2007).

funding models and performance-based research funding systems are likely to lead to ill effects if based on misleading incentives (Hicks 2012) and could even discourage the development of particular activities if they are not considered (e.g. entrepreneurial initiatives). The comparison of our results with previous efficiency studies of the Spanish HE system (Duch 2006; Johnes & Salas-Velasco 2007; Agasisti & Perez-Esparrells 2010; Berbegal-Mirabent, Lafuente & Solé 2013) already reveals current lower efficiency levels. These effects would be stronger in more differentiated systems.

Given the particular characteristics of technical and scientific universities in Italy (*politecnici*) and in France (*grande écoles*)¸ the above recommendations are applicable in particular to the Italian and French HE systems, where lessons can be learnt from the biases that occur in efficiency assessments when KT activities are not taken into account. In addition, countries or governments that opt for the differentiation of their university systems unequivocally will target the universities better and therefore achieve greater efficiency within the whole system.

Our analysis has also managerial implications. Given that we have studied the relationship between the efficiency results and the mission mix of universities, our analysis broadens the concept of measuring efficiency and we have provided useful evidence that may encourage strategic thinking among university managers, helping them to identify their peer universities and the areas of activity that would improve their universities' relative efficiency, including with regards to the third mission.

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Annex I. Third mission indicators related to its technology transfer and innovation (TTI) dimension. E3M, OEU and SPRU projects.

	E3M	*SPRU*	*OEU*
Mission and strategy	TTI included in HEI policy/strategy*		
	Existence of TTI institutional action plan*		
Structure		No. of licensing, admin professionals and risk managers involved in commercialisation activities	No. of permanent staff in transfer offices
			No. of research staff concerned by these main 3rd mission focus
		Expenditure on the licensing, admin professionals and risk managers involved in commercialisation activities	
			No. and amount of private funding
Patents		No. of inventions disclosed and/or no. of researchers disclosing inventions	
	No. of Non-Disclosure Agreements (NDA) with non-academic partners	No. of confidentiality/nondisclosure/material transfer agreements	
		Indicators on other forms of IPR (copyright, trademarks…)	Joint IPRs by university professors and firm employees (by fields)
			Co-invention between faculty members and industrial researchers/employees
		No. of patent applications*	No. of national patent applications by university
		Patent applications as a % of inventions disclosed	
		No. of patent awarded*	No. of patents produced by the university (by fields)
		Patents awarded as a % of patent applications	
			No. of active patents owned by the university (by fields)
Licences		No. of licences granted (including option agreements)*	No. of licences
		No. of technology licenses and/or option agreements having generated a high, predetermined level of income	
		Patents awarded as a % of patent applications	
			Share of regional, national, international actors in licences
	No. of licences, options and assignments (active & executed, exclusive & non-exclusive) to start-ups/spin-off & existing companies*		
	Total earned royalty income (ERI) + licencing income or Revenue and profit Alternative indicator: Total budget coming from commercialisation revenue*	Royalty income (including option fees)*	University revenues from licensing of patents, copyright, (total amount, ratio to total funding and ratio to non-core funding)

		Median value of royalties (including option fees)*	
		No. & value of products brought to market and based on technology licensed from the university	
		Value of exports of products based on technology licensed from the university	
		Cost of litigation over infringement of university IPR	
Spin-offs and start-ups			No. of new firms
	No. of start-ups & spin-offs*	No. of spin-offs created in the last 5 years*	
	No. of start-ups & spin-offs which include HEI employee as a founder		No. and % of spin-off firms funded by universities and/or faculty members
	No. of start-ups & spin-offs that are founded by graduates before or just after their		
		Spin-offs survival rates	
		No. of current employees in spin-offs created in the last 5 years*	No. of permanent staff involved
			Existence of support staff funded by university
		Turnover/profits from spin-off and commercial arms*	
		Development funds and loan facilities provided by universities to support start-ups*	
		No. of business plans funded by university financial sources	
		No. of start-up projects funded by university financial sources	
		Value of contributions (both in cash and in-kind) provided by non-academic collaborators to above projects*	No. and amount of co-investment with large firms in spin-off
			Strategic alliances with venture capital
		Equity realisation ("cash-in for equity")	
		Value of university equity holdings in spin-off companies and commercial arms	
		No. of academic staff holding equity in start-up and/or spin-off companies	
			Incentives for creation, funds for seed capital
			No. of incubators
Research collaborati on			Types of collaboration: joint teams, multi-annual conventions, non-financial inputs
	No. of creative commons and social innovation projects that HEI employee are involved*		
	No. of HEI employees involved in creative		

	commons and social innovation projects		
	No. of R&D sponsored agreements, contracts and collaborative projects with non-academic partners*	No. of contract research deals (excluding follow-on deals) signed by universities with non-academic organisations*	No. of contracts with industry
	No. of consultancy contracts*		
		No. of contract research deals carried out through commercial arms	
		No. of contract research deals carried out by academic individuals without using university-related administrative channels	
	% of HEI budget from income of R&D sponsored contracts and collaborative projects with non-academic partners*	Value of contract research carried out by the university*	Amount of contracts with industry
		Value of contract research deals carried out through commercial arms	
		Value of contract research deals carried out by academic individuals without using university-related administrative channels	
		Income from advisory work	
	% of total research income related to R&D and Consultancy income		
		Average or median length and/or size of research contract deals	Duration of contracts with industry
		No. of non-academic organisations collaborating in research projects funded through Research Councils, charities and foundations, European Commission Framework Programme, and other grants*	
		No. of different non-academic organisations who have signed contract research deals with the university	
			Share of regional, national, international actors in contract research (large and SME)
			Level of concentration (sectorial and/or on a few partners)
			No. of partners who regularly acquire university research
			No. of companies, R&D laboratories and mission-oriented laboratories located on the university premises
		Distribution of research contract deals among firms, industrial associations, NGOs, government agencies and other organisations	No. of collaborations with large firms
			No. of contracts with private economic actors (large and SME)
			Volume of contracts with large firms

			Volume of contracts with private economic actors (large and SME)
			No., volume, ratio, duration of contracts by various public bodies
			No. and volume of contracts with local and public bodies
			Share of regional, national, international actors in contract research
Conferences and networking	No. of organised conferences and workshops which have non-academic organisations' participating and/or sponsoring		
	No. of staff participating in conferences, workshops and fairs which have non-academic organisations		
	No. of academic staff giving lectures or talks to non-academic organisations and non-academic partners giving lectures or talks at HEIs	No. of times that academics have participated in professional, non-academic conferences (in which the majority of participants were not academics)*	
		No. of invitations to speak at non-academic conferences (excluding project presentations to funders)*	
	No. of staff participating in business-oriented social networking sites		
Staff mobility	No. of HEI employees with temporary positions outside of academia*	No. of faculty member taking a temporary position in non-academic organisations*	No. of staff moved from university to new firms
	No. of non-academic employees with temporary positions at HEIs*	No. of employees from non-academic organisations taking temporary teaching and/or research positions in universities*	
		No. of employees from non-academic organisations who have moved to academic jobs in university as a result of collaborations with the university	
		No. of faculty who have moved to permanent employment in non-academic organisations as a result of previous collaboration between both organisations	
	No. of double appointments		
	No. of academic staff participating in professional bodies, networks, organizations and boards*	No. of invitations to attend meetings of advisory committee of non-academic organisations*	No. of staff member participating in norms/standards/regulation committees
	No. of external organizations or individuals participating at advisory, steering, validation, review boards to HEIs, institutes, centres or taught programmes*		
Life-long	No. of non-academic individuals attending CPD		

learning	courses		
	No. of companies participating in CPD courses*		
Facilities	No. of created (co-funded) or shared laboratories and buildings*		
	No. of staff (non-academia & academia) with the access to co-funded or shared R&D facilities or equipment	Total No. of days spent by external (non-academic) visitors using laboratories and testing facilities without payment*	Access to special equipment of firm/university with or without assistance of owner's organisations
		Income derived from leasing/letting/hiring of S&T university facilities (laboratories and testing facilities)*	
			List of original/unique facilities and/or services located on the university premises.
			No. of external users for these facilities or services Territorial embedding
Research outcomes	No. of joint publications with non-academic authors*	No. of refereed publications authored with non-academics*	Co-authorship between faculty members & industrial researchers
		No. of non-peer-reviewed publications (excluding books and book chapters)	
	No. of prestigious innovation prizes awarded by business and public sector associations or funding agencies (national and international)*		
			No. of research results cited in patent applications by faculties/field of sciences (only for patent rich universities)
Students' mobility	No. of HEI fairs organized for employers		
		No. of students in sandwich courses and attending internships organised by the university*	
		No. of faculty who have moved to permanent employment in non-academic organisations as a result of previous collaboration between both organisations	
	No. of postgraduate theses or projects with non-academic co-supervisors*		Joint supervision of PhD theses by university and firm members or members of other external bodies (by fields)
			No. of PhDs and Post Docs involved in new firms
	% of postgraduate students and postdoctoral researchers directly funded or co-funded by public and private businesses*	No. of postgraduate students directly sponsored by industry*	No.& % of PhD students supported by industry (by fields)

Source: authors' elaboration based on Molas-Gallart et al. (2002, pp.67–79), Schoen et al. (2007, pp.125 –168), E3M (2012a) and Hazelkorn (2012, p.856).

* Finally selected indicator.