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Universities' Performance in Knowledge Transfer: An Analysis of the Ibero-American Region Over the Golden Decade

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Abstract. Universities play a crucial role in the systems of innovation by transferring the results of R&D activities to society and industry. This contribution is even more important in the Ibero-American countries given that the other critical 'player' (i.e., the industry) exercises a less active role in the development of innovation compared to the OECD countries. The aim of this paper is to analyze the knowledge transfer activities of the Ibero-American Higher Education Systems over the period 2000-2010. Using that database by Barro (2015), this study provides an accurate diagnosis of the Ibero-American universities' performance in knowledge transfer, suggesting a number of practical implications for university decision-makers.

Keywords. Ibero-America, Technology transfer, University, Patenting, R&D activities, R&D resources.

1 Introduction

Universities play a critical role in the ecosystem of innovation (Etzkowitz and Leydesdorff, 2000). Thus, their mission is no longer limited to research and education, instead they have included a 'third' dimension, namely to contribute to the economic growth of their regions (Branscomb et al., 1999; Ertkowitz et al., 2000). In doing so, universities have fostered their processes of knowledge transfer.

In the specific context of Ibero-America, universities gain even further relevance in the ecosystems of innovation, as the other agents -mainly firms or the private industry- play a secondary role compared to regions with a similar level of development. This fact makes extremely necessary to study the contribution of Higher Education Institutions (HEIs) in knowledge transfer. To date, there are few studies that have investigated this issue (Santelices, 2010; De Moya-Anegón, 2012; Cruz, 2014). In addition, most of them have tended to focus on one aspect of the technology transfer process or in a few universities rather than adopting a broader approach which includes more emphasis on outputs of technology transfer as well as more HEIs.

The goal of this paper is to analyze the knowledge transfer activities of the Ibero-American Higher Education Systems (HES's) during the first decade of the 21st century from an input-output approach. In doing so, a recent study by Barro (2015) provides us with an original and longitudinal database which gathers information in

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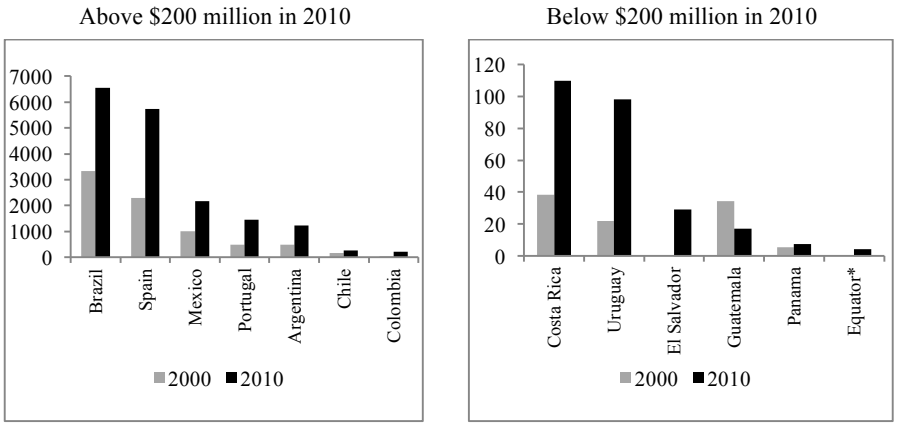
this issue unpublished to the date. Using that database, this study provides an accurate diagnosis of the Ibero-American universities' performance in knowledge transfer, which allows us to suggest a number of practical implications. Although there has been more available information for those countries that make up the higher education systems of the Ibero-American region, namely Argentina, Brazil, Mexico, Portugal and Spain, the paper analyses a range of countries wider than in the previous studies by Santelices (2010) or by Cruz (2014).

Following this introduction, the next section describes the human and financial resource endowment allocated to academic R&D. The third section presents the main outputs from the knowledge transfer activities measured in terms of publications, and patenting activity. Finally, we present the main conclusions, as well as a set of recommendations that can be drawn from the previous findings.

2 Gaining muscle mass: financial and human R&D resources

2.1 Financial R&D resources

During the decade 2000-2010, the financial R&D resources of Ibero-American HES's have risen markedly in absolute terms. Almost all the region's countries, except Guatemala, have considerably increased the expenditure on university R&D. In fact, this amount has doubled in most countries and even multiplied by three in Portugal and Costa Rica, and by four in Colombia and Uruguay (Fig. 1). However, we must note that in Spain and Portugal, for which we have data also for 2011 and 2012, this indicator is falling as a consequence of the severe crisis their economies have suffered since 2008.

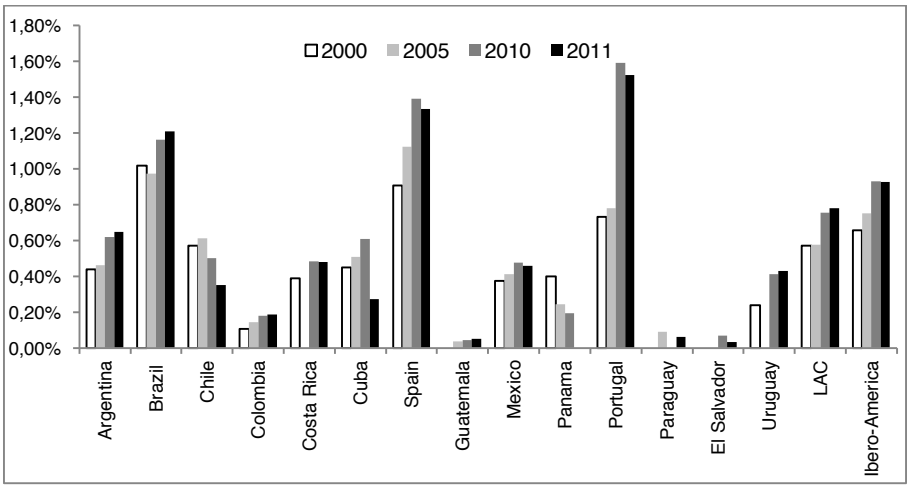


Notes: Countries are ordered according to R&D expenditure at current prices and purchasing power parities (PPPs) in 2010. * 2008. Source: Barro (2015)

Fig. 1. R&D expenditure at current prices and PPPs performed by the HES in some countries of the region (2000-2010).

This impressive growth is mainly due to two overall trends: 1) a relatively strong GDP growth over the 'golden decade', especially in Latin American and Caribbean

(LAC), which has been rising at a 5% for several years (OECD, 2014), and 2) an increasing intensity of R&D investment, since the ratio of R&D expenditure to GDP has been growing even faster than their economies (Van Noorden, 2014) (Fig. 2). In spite of both trends, the LAC's spending on R&D still underperforms slightly relative to its 5–6% share of world population and GDP, since it accounted for 3.2% of total R&D expenditure in 2011 (RICYT, 2013).



Source: Barro (2015)
Fig. 2. Ratio of R&D expenditure to GDP in some countries of the region (2000-2011).

In addition, the government is the main source of R&D financing (around 50%) in the Ibero-American countries, whereas about 40% of R&D expenditures are financed by industry. Both figures has remained largely the same since 1997 (Crespi et al., 2010; Santelices, 2010), with the exceptions of Chile and Portugal, where industry has increased its share in R&D financing. Conversely, in OECD countries the business' share in R&D financing represented around 59% in 2010 (OECD, 2015).

These patterns make the universities' R&D activities strongly dependent on the economic development of the region's countries, rather than on a deliberate policy to involve government, industry and universities on R&D.

2.2 Human R&D resources

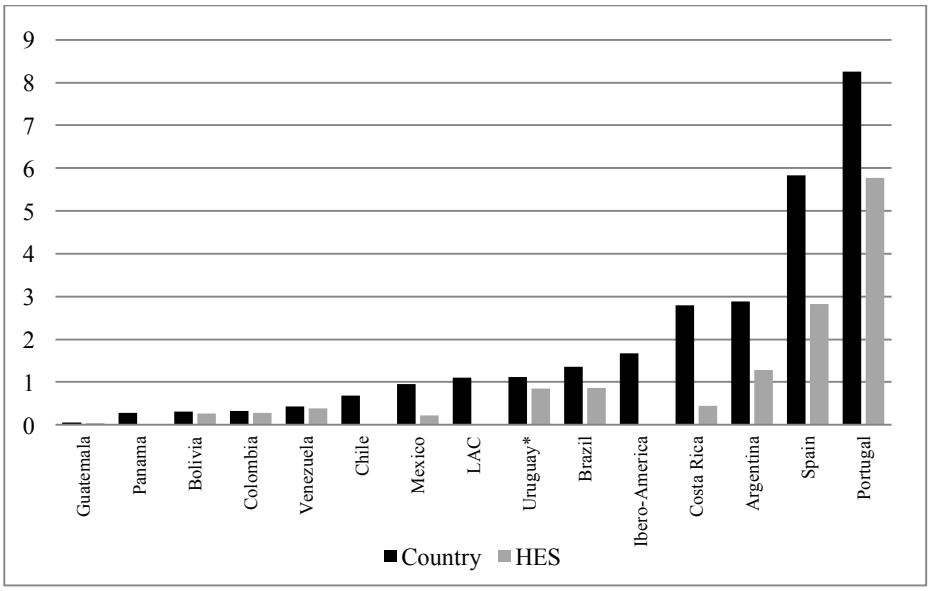
Similarly, the number of researchers in full-time equivalent (FTE) in the region's universities experienced significant growth rates. This indicator has multiplied by two in Argentina, Brazil, Colombia and Costa Rica and by three in Portugal and Venezuela, whereas this growth has been more moderate in the rest of countries. Overall, researchers (FTE) in the HES's account around 60% of the countries' researchers (FTE). This pattern significantly differs from OECD countries where the business sector absorbs more than 50 percent of researchers (Crespi et al., 2010).

However, the data show a shortage of R&D support staff for those HES's where information is available. In this context, researchers are usually forced to accept the huge bureaucratic workload of running R&D activities, undermining the overall

system's efficiency.

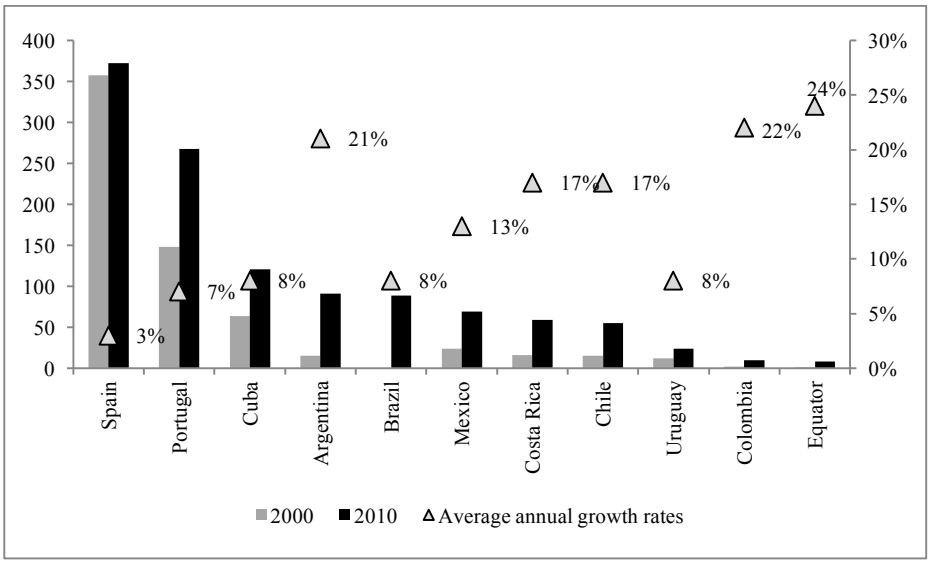
Growth in the number of researchers has also been accompanied by an improvement in their quality. The region's countries have implemented different strategies to attract high-skilled human capital, from the repatriation of scientist working abroad (Mexico), to the design of academic careers with more stability and scholarships for researchers (Brazil or Argentina).

Nevertheless, there are huge differences among the region's countries. These differences become more obvious when considering the researchers (FTE) per 1,000 labor force (Fig. 3). While the number of the country's researchers (FTE) per 1,000 labor force was similar to those of the OECD countries only in Portugal (over 7.5 in 2009) (FORFÁS, 2011), most of LAC countries were struggling to bring this indicator closer to 1 over the decade. Moreover, in 2010 only Argentina, Spain and Portugal had more than 1 researcher (FTE) in the HES per 1,000 labor force.



Notes: Countries are ordered according to total researchers per 1,000 labor force. * 2011
Source: Basic data from Barro (2015)
Fig. 3. Number of researchers (FTE) per 1,000 labor force in some countries of the region (2010).

The same trends are also observed for the PhD graduates. While the number of PhD graduates has shot up significantly over the decade 2000-2010, with annual growth rates beyond 2 digits for a set of countries (Fig. 4), when considering the number of PhD graduates to the labor force, the gap between countries becomes more evident. Thus, in 2010 most of the countries were still under 100 PhD graduates per million of labor force, and even less than 10 PhD graduates in Colombia and Ecuador.

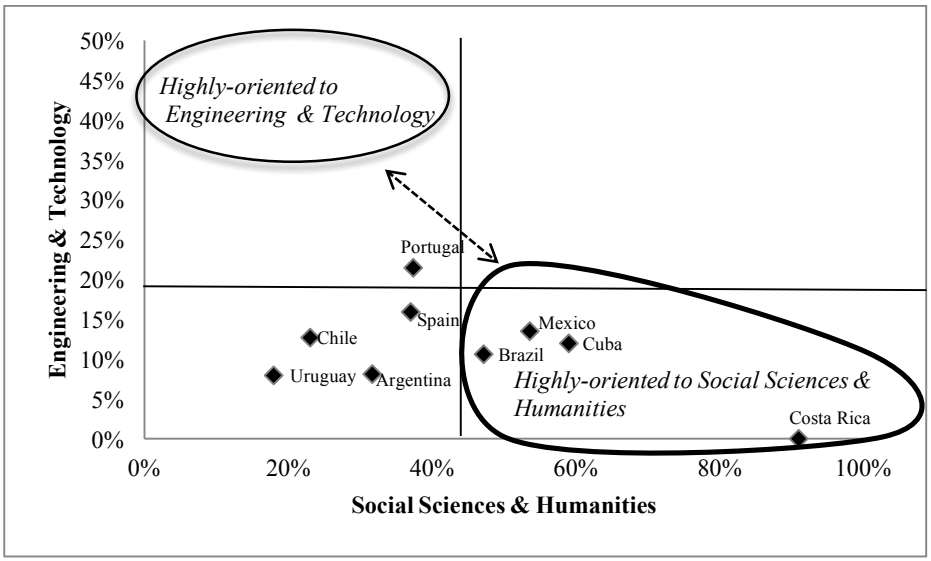


Source: Barro (2015).

Fig. 4. PhD graduates per million of labor force in some countries of the region (2000-2010).

In any case, in the past decade all HES's have driven reforms aimed at fostering the growth of advanced human capital, since it acts as facilitators for a subsequent development of R&D results. Whereas the larger HES's have strongly promoted training PhD students through national programs, the smaller HES's (i.e., Bolivia, Guatemala, Honduras, Nicaragua. Paraguay or El Salvador, among others) continue the policy of sending PhD students abroad or training them through co-operation programs with foreign universities, mainly Spanish universities.

The number of PhD graduates in Humanities and Social Sciences, both fields of knowledge less related to applied research, represents very high percentages of the total number of PhD graduates (Fig. 5). The complete opposite can be appreciated in the field of Engineering and Technology, where it is easier to use applied research in commercial products. Thus, with the exception of Portugal, where the number of PhD graduates in this area represented 21% of the total PhD graduates in 2010, they are around 15% or less in the rest of the countries for which data are available. These figures show that the region's university research still suffer from a low specialization in 'horizontal' scientific areas, i.e., with a transversal impact in various industries, such as Engineering, Sciences related to materials and Computer Technology and Interdisciplinary research. It is essential to acquire scientific abilities in these 'horizontal' sciences, as they generate spillovers on other scientific areas (BID, 2010).



Source: Basic data from Barro (2015)

Fig. 5. Percentage of PhD graduates in Social Sciences & Humanities and in Engineering & Technology in some countries of the region (2010).

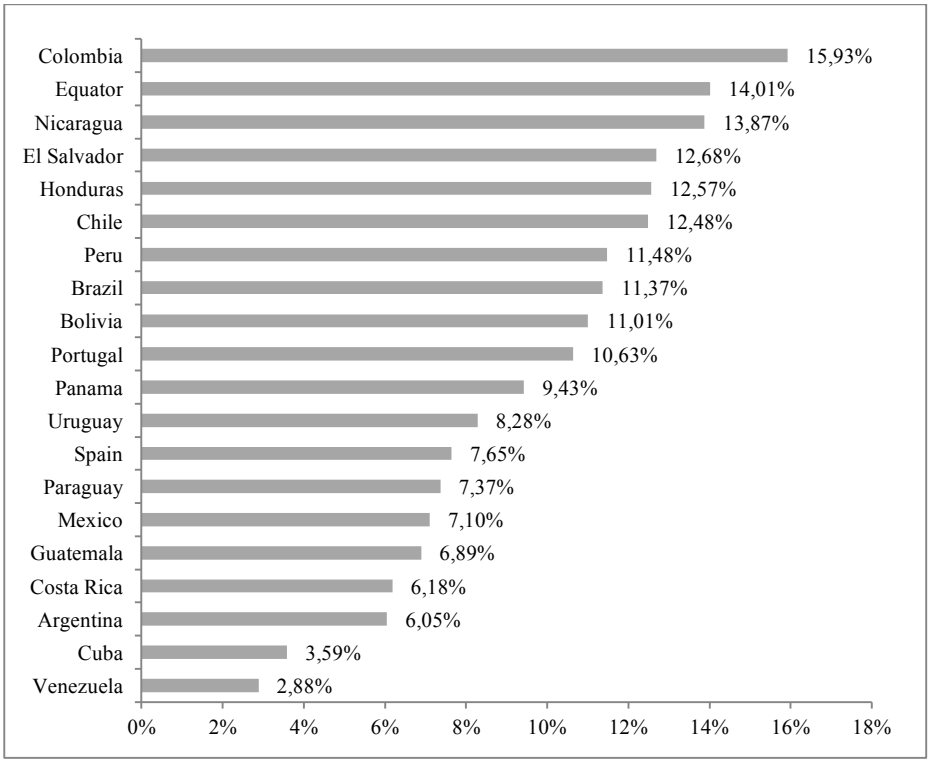
Finally, the HES's of Brazil and Spain represent nearly 70% of the total expenditure on R&D performed by the HES's of the region, as well as 62% of the researchers (FTE) and 72% of the PhD graduates. When adding Mexico, Portugal and Argentina these percentages exceed 90% for the three indicators and these figures have been reasonably stable throughout the decade 2000-2010. These differences are not only between countries, but within countries as well. Thus, in most of the HES's analyzed, especially in LAC, R&D resources tend to concentrate in a few universities, leaving a residual role on R&D the rest of them. Furthermore, this distribution usually follows a centralizing trend around large cities (in Argentina, Brazil or Chile), as well as public universities, because private HEIs, with a few exceptions, still focus their offer on teaching (in Mexico).

3 Falling behind in power: publications and patenting

3.1 Publication activity

The publication activity of the region's universities has experienced two opposing trends over the decade. On one hand, there is an outstanding growth in the number of publications in the Science Citation Index (SCI). Thus, countries such as Spain and Mexico have doubled their number of publications, while Chile and Portugal have tripled theirs. In fact, the average annual growth rates registered throughout the decade are over 6% for the HES's shown in Fig. 6, except Cuba and Venezuela. On the other hand, there has been a fall in the number of citations. Both trends have also been highlighted by Van Noorden (2014) for the national science systems of South

America.



Source: Basic data from Barro (2015)

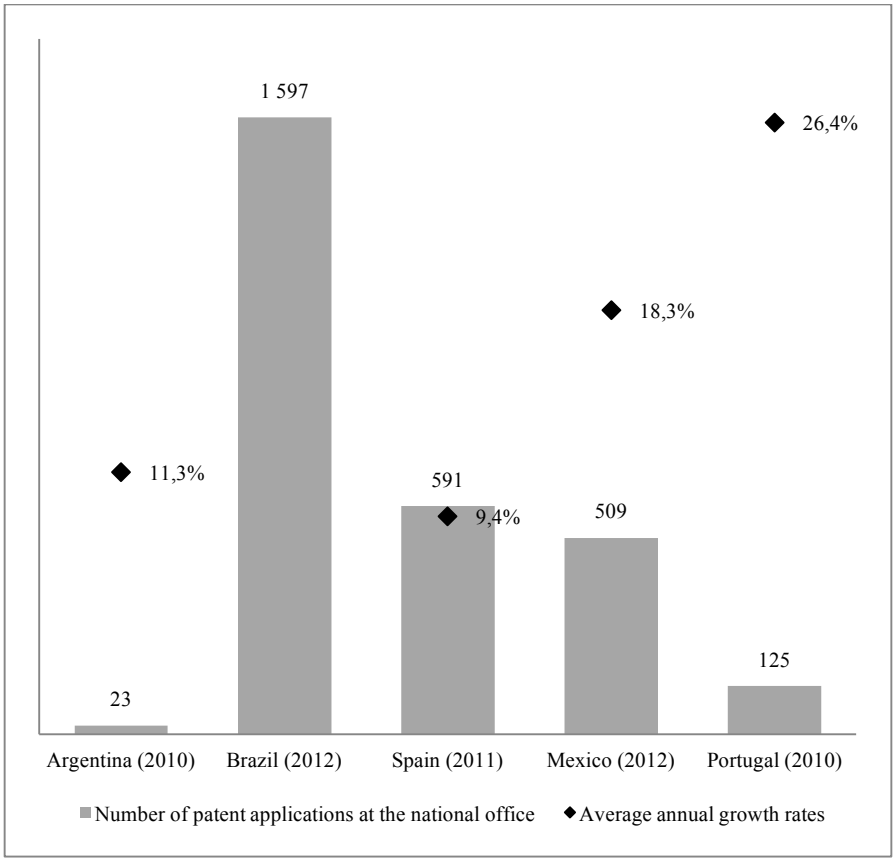
Fig. 6. Average annual growth rates of the HES' publications in *SCI* in some countries of the region (2000-2010).

The universities' publication activity has also been characterized by a low percentage of international collaborative publications, While in Colombia, Chile and Portugal, it represents 50-60% of all their publications in the SCI, it is around 35 to 42% in the rest of the countries. This percentage tends to be negatively related to the size of national science system, i.e., universities in the region's less developed countries are more likely to collaborate beyond the region, which increases the number of citations (Santelices, 2010; Van Noorden, 2014).

Again, the biggest HES's in the region (Spain, Brazil, Mexico, Portugal and Chile) concentrate 90% of the region's publications in SCI. However, in the publication activity the 'size effect' has been partly offset by the researchers' efficiency. Thus, when considering the number of publication per million inhabitants, Chile, whose HES is smaller than those of Argentina, Brazil or Mexico, occupies the third place with almost 500 publications per million inhabitants in 2010. These figures are only surpassed by Spain and Portugal, with nearly 900 publications in the SCI per million inhabitants. The rest of the HES's are far behind (under 180).

3.2 Patenting activity

Considerable effort has been devoted in the HES's for which data are available to applying for patents at the national office, since they display average annual growth rates over the 9% in this indicator during the period 2000-2010 (Fig. 7). However, there are huge differences among the HES's. While the number of patent applications annually filed by the Brazilian HES has been around 1,500 in the past few years, in Spain and Mexico, it has been of over 500 and in Portugal over 100. Argentina is far behind with around 30 patents in 2010. In any case, these figures are eclipsed by nearly 15,000 new patent applications filed by only 70 of the higher education institutions integrating the *Association of University Technology Managers* (USA) in 2013, which represents 41 new patent applications a day (AUTM, 2014).



Source: Basic data from Barro (2015)

Fig. 7. Number of the HES' patent applications at the national office and average annual growth rates of this indicator over the period 2000-2010 in some countries of the region.

The Brazilian HES has filed more Patent Cooperation Treaty (PCT) applications than those at the national office (2,084 in 2012). In contrast, in Spain the number of filed PCT applications represents around 40% of those filed at the national level. In both

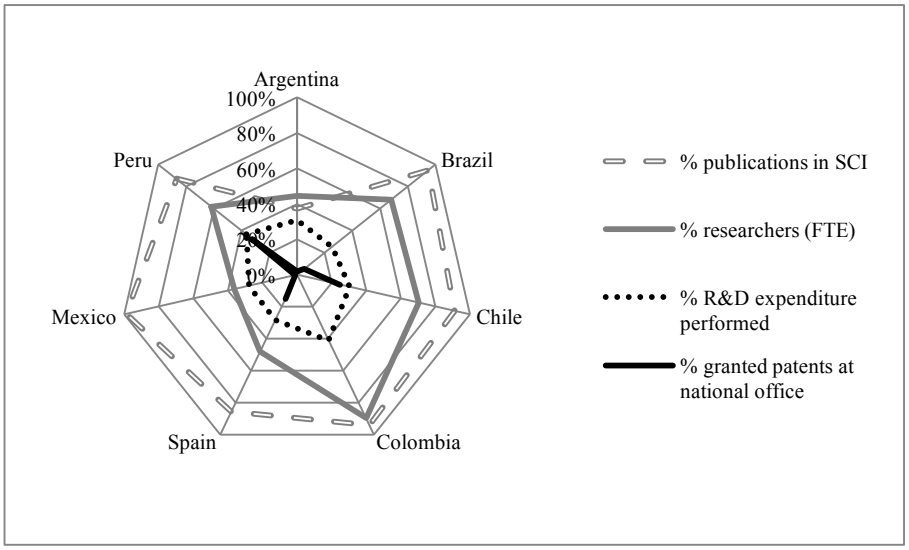
countries, these percentages have barely changed in the last decade. Meanwhile, the Portuguese HES shows an important growth, partly due to the fact that its starting point was very low, so in 2010 the number of filed PCT applications represents around 30% of those filed at a national level.

The 'success rates', approximated as the ratios of patents granted to patents applications or patent applications five years earlier, have also shown significant differences. While Portugal shows success rates over 50%, in Argentina, Brazil and Mexico there has been a slight fall, as in Argentina and Brazil granted patents are around 10-13% of patent applications and 30% in Mexico. Spain has also experienced a fall, however its HES has the highest 'success rate' (with over 60% of patent applications granted).

De Moya-Anegón (2012) also presents a detailed analysis of patents granted by the *United States Patent and Trademark Office* (UPSTO) to Ibero-American applicants for the period 2003-2009. Out of the 900 Ibero-American applicants, 6% are universities (54 institutions in total) which own 171 patents. Thus, the HES's have a relevant presence in the patents granted by the USPTO.

3.3. Where is the universities' focus on R&D activities?

When considering the HES's shares in the R&D resources and results of the countries, it becomes obvious that the university research activities are focused on publication rather than on patenting. Thus, the universities' shares in the publications in SCI exceed 80% in most of the region's countries, over performing in relation to their R&D resources. Conversely, the HES′s patenting activity underperforms, in some cases dramatically, in relation to R&D resources (Fig. 8).



Source: Basic data from Barro (2015)

Fig. 8. Percentage of the HES's to the national science system (2010) in some countries of the region.

This low level of patenting activity is a common feature of the region's economies, which are mainly based on natural resources, dependent on imported technology, and formed primarily by SMEs with hardly any inclination towards innovation (Lederman et al., 2014). This overall context does not help patenting activity. Nonetheless, universities share a responsibility in low patenting performance, since they barely maintain relationships with industry and academic careers mainly focused on publications.

However pessimistic the situation might seem based on the previous data, there are two bright spots concerning university patenting activity. First of all, in all countries for which data are available, patents granted to HES's at a national level have increased over the decade. Secondly, the percentage of HES's patenting activity at a national level could be underestimating the university patenting output. On one hand, patents developed by academic researchers are sometimes owned by private companies. This is the case of Spain, where only 29% of all European patent applications from university researchers belong to universities, as opposed to 69% belonging to private companies (Fundación CYD, 2013). On the other hand, when the patents granted to universities are compared to patents granted to residents, the percentage of HES's patents increases up to 11% in Brazil, 60% in Chile, 25% in Colombia or 40% in Mexico.

Finally, in the particular case of LAC, the publication and the patenting activities are usually concentrated in a few HEIs with more R&D resources available, showing dramatic differences among universities within the same country. In order to minimize the effects of this 'Matthew effect' (Merton, 1968), national policies aiming at decentralizing the geographical concentration of research have been developed (that is the case of Argentina, for instance), but until now results have not been significant.

4 Conclusions and policy implications

The HES's of the region present huge differences in their dimension and results, which together with a systematic lack of information, make it enormously difficult to draw conclusions that could summarize the knowledge transfer activities in Ibero-American universities. Thus, we find that the Portuguese and Spanish HES's are close to those of developed countries. In turn, within LAC there is a need to detach Brazil, Argentina, Mexico or Chile from the rest of the countries, because, depending on the indicator analyzed, their HES's gather around 90% of all activity in LAC.

Apart from the differences in size, the Ibero-American HES's are crucial agents within the national science system, due to the importance of their share both in R&D resources and results. Regarding resources, in 2010 they performed around 30% of the R&D expenditure and concentrated over 50% of the researchers (FTE), being responsible for qualifying PhD graduates. Both figures have barely changed in the last 15 years. In addition, for some of the region's countries, the HES's concentrate a high part of the infrastructure and facilities their governments allocate to R&D activities (Barro and Fernández, 2015).

Regarding results, the HES's of the region produce around 80% of all publications in

the SCI and, despite the limited amount of patents granted, when considering patents granted to residents at national offices they play a significant role.

The importance of HES's in the region's R&D makes it so urgent to promote a good number of improvement actions in order to bridge the gap with other regions.

Over the period 2000-2010 the financial R&D resources of Ibero-American HES's have proven to be extremely linked to the economy of the countries, putting universities' R&D activities seriously at risk in the coming years, since most of the region's countries are likely to experience only a moderate economic growth in the near future (Brazil, Chile, Mexico, Portugal or Spain, among others). Under this climate of macroeconomic volatility, greater efforts are needed to ensure a minimum level of financial R&D resources which enable universities to develop quality R&D and transfer their results to industry and society.

Despite the improvement both in the quantity and quality of researchers, there is not enough 'researcher density' yet to apply an intensive program of technological development in HES's and consolidate research group. Similarly, a lack of R&D support staff has been detected. Management to achieve a critical mass of R&D human resources involves clear scientific careers, with incentives attached not only to publications but also to other knowledge transfer activities, which guarantee stability for researchers who reach clearly defined goals. Regarding R&D support staff, once the administrative and technical workload attached to R&D processes was clear, the HES's need to professionalize these tasks by training support staff and, if necessary, by hiring personnel with specialized profiles.

PhD graduates in the fields of Social Sciences and Humanities outnumber those in the Experimental Sciences and Engineering. Overall, LAC does not offer many programs on emerging subjects (for instance, Genomics, Nanotechnology, Advanced Computer Science, among others). The challenge is to train PhD tutors and encourage them, together with the PhD students, to engage in emerging areas and more 'horizontal' subjects, whose results are more easily transferable to industry.

Over the decade, although the number of publications in the SCI has increased, their quality, measured as the number of citations, has dropped. The international collaborative publications represent a percentage of around 50-60% for most HES's, and it is negatively related to the size of the HES. These figures would also explain why there is less interest in the research carried. Continued efforts are needed to foster the quality of research, which usually involves publication outputs with a high impact. The challenge is also to encourage the collaboration with prestigious researchers at a national and international level and fund headhunting programs while retaining the staff.

There are many reasons explaining the low number of patents granted in the region. Obviously, changing some of them exceeds the universities' missions. However, there are several courses of action which can be taken by universities. Thus, researchers ought to be encouraged to explore which research results could be patented. Incentives could include sharing royalties with the researcher and recognizing the results patented or protected in any other way. Besides, researchers need to be supported by the Technology Transfer Offices (TTOs). Thus, it is necessary an expert team able to deal with the time-consuming and expensive process of patenting and the

commercialization of R&D results. When unavailable, HES's ought to engage with public or private agents with experience in this field. There is also a need to go beyond patent grants and exploit them economically. In this sense, prior to filing a patent application, the expert team must estimate its economic value in order to prioritize applications most likely to be successfully exploited. Finally, when possible, HES's need to compel legal changes so as to make the patenting process easier, because, in general, the national regulation frameworks in the region's countries tend to be fairly restrictive.

Lastly, with the exception of the Spanish and Portuguese HES's, R&D activities tend to concentrate around a few LAC universities, namely public universities located in the larger cities of LAC. To break this circle, several actions are possible, however we advise against the demagogic approach of dividing resources without considering scientific and strategic criteria. On one hand, differences between universities must be considered in order to encourage them to specialize in knowledge fields related to strategic national industries and somehow close to the university. On the other hand, the co-operation among universities must be enforced, especially between those with a long background in knowledge transfer processes and those with a less experience in these tasks. This is possible if they promote expert mobility and share best practices and experiences, among other options.

One of the difficulties we encountered when elaborating this study was the lack of information on many of the knowledge transfer processes at universities, which made it difficult to design policies geared towards improving the efficiency of HEIs. It is recommended that further work be undertaken in gathering enough reliable information. Further research needs to be done to establish standardized indicators for each HES. These indicators could be based on those used by institutions with recognized background experience in the field (AUTM or OTRI Network, among others).

The findings of this study have proved to show a number of important implications for future practice. Unless governments and university authorities adopt some of the previous recommendations, improving the economic value creation from university R&D activities will not be attained in the Ibero-American region.

5 Acknowledgements

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