Intellectual capital and university performance in emerging countries

Evidence from Colombian public universities

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Abstract

Purpose – The purpose of this paper is to explore the relationship between intellectual capital (IC) and performance of public universities in emerging countries in order to identify patterns and provide recommendations that may turn the universities' IC into development opportunities, in terms of research, innovation, and education.

Design/methodology/approach – The analysis targeted the whole population of the public universities in the Republic of Colombia. A cluster analysis, based on five performance variables, has been conducted. Then, the IC of the universities pertaining to the three resulting clusters has been compared. Subsequently, for each performance variable, the IC of above-average and below-average universities has been benchmarked.

Findings – The results of this study show how different aspects of IC are associated with University performance. Among the many, the authors found that universities should achieve a critical mass to obtain outstanding research and innovation results. The findings also identify the particular importance of both students and scholars' international mobility programs for most of the performance variables.

Social implications – This study provides a baseline for the assessment of the impact on society of the IC available in the universities of emerging countries. The application may serve as a guide in the choice of public policies, dedicated to the strengthening of the universities' IC in order to improve their performance.

Originality/value – This paper proposes an innovative model to analyze the relationship between IC and university performance in emerging countries. The model identifies the association between the IC accrued in the universities and their capability of transferring it to the society under the form of science, innovation, and education.

Keywords Universities, Emerging countries, Intellectual capital, Education, Republic of Colombia, University performance

Paper type Research paper

Introduction

In the era of "knowledge-based economy," knowledge-intensive subjects such as universities are central to the economic development (OECD, 1996). Several authors have reported the important contribution of universities to the innovation systems of countries (Sánchez and Elena, 2006; Brătianu, 2009; Lu, 2012; Dumay *et al.*, 2015; Secundo *et al.*, 2016), and to their economic development (Drucker, 1994; Etzkowitz and Leydesdorff, 2000).

The investigations on the economics of emerging countries showed that to higher levels of education correspond higher economic growth, and that the governments' interventions could enhance their economies by leveraging knowledge and skills (Glewwe, 2002; Drucker, 2012).

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Therefore, the governments of developing countries should nurture their national intellectual capital (IC) (Aubert and Reiffers, 2003) through policies aimed to remodel the structure of primary, secondary, and tertiary education (Weber, 2011).

Recently, universities in many countries have undergone an analytical process of internal organization in order to enhance their IC. Similarly to other productive organizations, universities are now also required to become increasingly competitive and must valorize their capital. The role of IC in universities is critical, as universities are the focus of intangible activities: professors are repositories of knowledge and transmit it to students (Ortega, 2013; Sánchez, 2008; Silvestri and Veltri, 2011; Stewart, 1997; Vidrascu, 2016). Universities themselves are "loci" of knowledge as any kind of activity inside them is strictly related to develop and transmit knowledge (Fazlagic, 2005; Leitner, 2004). Nonetheless, in this competitive era, the role of universities should not be restricted to knowledge dissemination, but also to its valorization (Campos, 2003; Feng *et al.*, 2012; Lu, 2012; Ramírez Córcoles and Santos Peñalver, 2013; Secundo *et al.*, 2016). To this aim, the contemporary university needs to assess its own IC. The capability of disclosing the universities' IC can be tackled, among the several other methods, by trying to assess the universities' performance. University performance has a multidimensional nature and its assessment requires the research of appropriate indicators and of methods for representing and measuring the components of the performance itself.

This requirement is even more compelling in the emerging countries, the economy of which is mostly based on tangible assets and neglects the intangible ones (Maditinos *et al.*, 2011). In consequence of the relevant asymmetry of knowledge distribution in favor of the developed countries (Seleim *et al.*, 2004; Abeysekera, 2007), the emerging countries, which are still unable to take advantage of R&D and IC as drivers of growth and development, should utilize the wide spectrum of non-saturated IC activities by increasing human capital endowment and university performance (Kianto, 2007; Ståhle and Bounfour, 2008).

In the light of what has been observed so far, it seems necessary to dispose off a method for evaluating production, accumulation, and transfer of universities' IC in order to assess their contribution to the economic development of countries, as solicited from many sides (McGillivray, 1991; Tezanos and Sumner, 2013).

The analysis of the literature shows tha, while several papers have dealt with the assessment of universities' IC (Araujo, 2000; Bezhani, 2010; Campos, 2003; Cañibano and Sanchez, 2008; Ramírez Córcoles *et al.*, 2011; Silvestri and Veltri, 2011), few studies have investigated the relationship existing between the IC of the universities and their performance (Brătianu, 2009; Bueno *et al.*, 2014; Kianto, 2007; Secundo *et al.*, 2016). To date, not enough attention has been paid to the quantitative analysis of the IC value creation process in universities. In this paper, we mean by value the capability of transferring to the society the IC derived from technology, innovation, research, marketable and applicable skills, and relationships between academic institutions and industry.

This paper aims to explore the relationship between IC and performance of universities in emerging countries, in order to identify patterns and provide recommendations that may turn the universities' IC into development opportunities. We chose the Colombian public universities as a suitable target for our exploratory analysis. Indeed, the Republic of Colombia represents a typical emerging country showing a transition phase from low educational standards, low tertiary attainment, inadequate infrastructure, high level of inequality and suboptimal ICT and scientific infrastructures (OECD, 2012) toward a more knowledge-oriented condition supported by IC investments.

We identified suitable IC and performance variables from official and publicly available databases. We performed a cluster analysis based on five performance variables, followed by a comparison of the IC of the universities pertaining to the three resulting clusters. Subsequently, for each performance variable, we compared the IC of above-average and below-average universities.

The remainder of this paper is structured as follows. The second section reviews the current role of IC within universities and summarizes the main IC approaches as instruments to face the new challenges in universities. The third section presents the detailed description of the methodology and of the sample. The fourth section presents and discusses the analysis of the results. Finally, conclusions are drawn in the fifth section.

Literature review

IC and university performance

The last two decades have seen the growth of the role that knowledge-based assets and IC can play in the organizations (Campos, 2003; Cuozzo *et al.*, 2017; Mouritsen *et al.*, 2001; Silvestri and Veltri, 2011). Consistently, the importance of acquiring knowledge through the internal organizational processes, the relationships with the environment, and the scientific production is increasingly recognized (Secundo *et al.*, 2016).

After a long period, during which plenty of generic definitions of IC have been adopted in scientific papers, the Meritum (2001) guidelines have agreed on the fact that the noun "intangible assets" was used with the same meaning of IC. In essence, IC expresses all knowledge, information, intellectual property, and experience possessed by an organization (Stewart, 1997), and represents one of the most important elements for the management and assessment of the internal and external organizational processes (Bounfour *et al.*, 2005; Vidrascu, 2016). The broad concept of IC has been often split into different categories, commonly defined as human, relational, and structural capital (Edvinsson and Sullivan, 1996), on which there is an almost general agreement in literature (Bucheli *et al.*, 2012; Cañibano and Sanchez, 2008; Feng *et al.*, 2012; González and Rodríguez, 2011; Leitner, 2004; Sánchez and Elena, 2006; Ramírez Córcoles *et al.*, 2011; Secundo *et al.*, 2016).

Universities are organizations where a strong social interaction prevails, leading to a very specific kind of organizational culture. Their progress and ability to strive for success rely upon their capacity for continual renovation and change (Teece *et al.*, 1997). Such capacity is becoming the very essence of their strategy. Moreover, universities have an important role in favoring the development of the contemporary society as they have the specific responsibility for the production and the dissemination of knowledge and for the development of research and human resources. The results of the research and of the capability of transmitting knowledge are IC components that determine the assessment of their performance (Bezhani, 2010; Bucheli *et al.*, 2012; Ramírez and Gordillo, 2014). Important issues are related to the assessment of university performance, including, first of all, the adequacy of the policy with the proposed goals in teaching and research, and, second, the conformity of resource allocation to the expected results (Ramírez *et al.*, 2016). Equally relevant is the universities' capability of keeping pace with the progress of science and technology by updating the activities of training, research, and management (Misas, 2004) that have great influence on the organization of education and training performance (Lu, 2012). However, most of all, it is necessary for the universities to implement initiatives to satisfy their stakeholders, which, in the specific case, are composed of administrative and teaching staff, students, political structure, social organizations and national and international organizations (Leitner, 2004; Secundo *et al.*, 2016).

In Europe, the national and local governments have implemented models for the identification of IC in public universities, such as the IC reports in Austrian universities (Silvestri and Veltri, 2011); the intellectus model in Spanish universities and public research organizations (Campos, 2003; Cañibano and Sanchez, 2008); the research-development-knowledge transfer (Araujo, 2000); the IC in higher education institutions and research organizations (HEROs) (Leitner and Warden, 2003); and the intellectual capital maturity model (ICMM) to improve strategic management in European universities (Perez *et al.*, 2015). The initiative for the measurement of IC in public universities has been justified by a need for transparency of the

activities of the institutions, in order to compare systems of IC management, to strengthen relations between industry and universities, and to evaluate the performance of public universities (Fazlagic, 2005; Ramírez Córcoles *et al.*, 2011).

In particular, the IC model implemented by the Austrian Government in 2002, following the IC report of the Austrian Research Centre published in 1999, requested that public universities, starting from 2007, ought to prepare a report on their IC. Such report should contain information about the indicators of human, structural and relational capital, as well as the results of research, teaching, and activities related to the third mission (Silvestri and Veltri, 2011).

A further knowledge management project was developed under the form of a strategic cross-organizational process called "research-development-knowledge transfer" at the University of the Basque Country. The strong belief of the initiative was not only the promotion of a solid and well-organized development of knowledge in response to the increasingly competitive context but also the analysis of the relationships between demand and supply, that is including the socioeconomic context and the research/knowledge providers (Araujo, 2000). The project was created with the conviction that knowledge management in universities was a crucial response to the new challenges that they have to face: defending their leadership position in the field of creation and diffusion of knowledge in an increasingly competitive context.

Also, an ad hoc organization, the HEROs was established by the members of the European Association of Research Manager and Administrators in collaboration with the European Center for the Strategic Management of Universities, with the aim of managing and reporting IC among universities and research organizations (Leitner and Warden, 2003).

Moreover, the "intellectus" model, implemented by the Madrid Ministry of Education and applied to universities and public research organizations, focused on obtaining information about the economic and social performance of the resources made available to universities and public research organizations (Campos, 2003). Similarly to these initiatives, several governments of the autonomous communities in Spain allocated funds to several institutions (Cañibano and Sanchez, 2008). One of these initiatives is the PCI Project (2000-2003), which developed an IC program applied to the research activity of universities and research centers in the Madrid community.

The ICMM for universities (Perez *et al.*, 2015) is a flexible framework for defining and implementing IC measurement and management approaches, as a part of the strategic management of universities, under the "Quality Assurance in Higher Education through Habilitation and Auditing" project framework, initiated by the Executive Agency for Higher Education and Research Funding of Romania.

In addition to the European models of IC in the university, there are notable further research proposals, such as those applied to Taiwanese universities (Feng *et al.*, 2012; Lu, 2012). Furthermore, some authors conducted studies in the Republic of Colombia, such as Bucheli *et al.* (2012), which focused on the scientific production and its relationship with the accumulation of IC in a group of 77 public and private universities; and Cárdenas *et al.* (2013), who proposed some metrics to determine the impact of the IC in knowledge management. These two studies applied to IC have shown that the accumulation of IC positively affects the performance of university in terms of scientific production and the transmission of knowledge. Also, Hernández *et al.* (2008) and Tovar (2016) performed an IC analysis, at the regional level, on a group of universities. Finally, Sánchez-Torres and Rivera Torres (2009) have proposed some metrics to determine the impact of the IC in knowledge management.

Human capital and university performance

The human capital is a fundamental part of IC and represents the combination of knowledge, skill, innovation, and the ability of employees (Campos, 2003; Seleim *et al.*, 2004). In addition, the knowledge exchanged by individuals increases their cognitive abilities and

strengthens their productivity and efficiency (Davidsson and Honig, 2003). On the contrary, any loss of individuals impoverishes the human capital of organizations (Sánchez and Elena, 2007; Sánchez, 2008), showing that personal motivation and professional growth are key factors in empowering organizations (Brătianu, 2009, European Commission, 2006).

The human capital refers to all persons who develop their activity within the university context, such as teachers, researchers, managers and administrative staff (Campos, 2003; Ramírez Córcoles, *et al.*, 2011), PhD students (Feng *et al.*, 2012), and students in general (Leitner, 2004; Secundo *et al.*, 2016). In the human capital of universities, tacit and explicit knowledge often converge (Ramírez Córcoles *et al.*, 2011). In particular, the IC of professors and researchers resides both in teaching capacities and in research competencies (innovation in teaching, teaching quality, research quality, participation in national and international projects, the percentage of doctors, etc.). The administration and service staff works at one of the applicative transformation of tacit into explicit knowledge by integrating their IC into the university production structure. Finally, students represent a sort of knowledge pipeline, a connection that lets knowledge flow from professors toward the business world, and eventually back toward the university.

Structural capital and university performance

The structural capital includes a wide range of elements. It usually refers to the organizational culture that provides a uniform way of looking at things, establishes the decision-making pattern, and determines the value system (Itami, 1987). As a whole, it represents the accrued intellectual resources of an organization (Secundo *et al.*, 2016), including know-how, organizational routines, products, internal processes, capabilities and technological components as well as intellectual properties (Leitner, 2004; Sánchez and Elena, 2007; Sánchez, 2008; Bueno *et al.*, 2014). In other words, structural capital is the backbone that supports the IC within organizations (Bontis, 1998; Brătianu, 2009; Alcaniz *et al.*, 2011; Maldonado, 2013).

The structural capital of universities is the knowledge that arises from the internal organizational processes. It also derives from the management of internal relations among research, technological components, and organizational culture (Feng *et al.*, 2012; Ramírez Córcoles *et al.*, 2011; Lu, 2012). The performance of structural capital within universities shows its intrinsic value from the recognition of intellectual property, technological development, patents, licenses, publications, databases, bibliographic resources, and processes of management (Ramírez Córcoles *et al.*, 2011). It also includes the procedure of obtaining accreditations and certifications (Koch *et al.*, 2000). The above factors are relevant indicators that demonstrate the true institutional performance, its organizational management and budget execution in the fields of research, development, and innovation (Cañibano and Sanchez, 2008).

Relational capital and university performance

According to the literature, relational capital is associated with the establishment of relationships between an organization and its environment (Alcaniz *et al.*, 2011; Silvestri and Veltri, 2011). Such relationships can be established with customers, intermediaries, suppliers, inter-organizational alliance partners, regulators, institutional figures, pressure groups, communities, creditors, and investors (Marr, 2008). Bontis (1998) affirms that the relationships established with the environment provide the organization with knowledge that increases throughout the life of the organization itself, becoming an asset of great potential that is difficult to quantify.

The establishment of links with outside subjects or organizations are the basic components of the relational capital of universities (Ramírez *et al.*, 2007; Feng *et al.*, 2012). Furthermore, the internal and external mobility of researchers, the hosting of and

participation in meeting and conferences, the attraction of international scientists, the participation in international research programs, and the cooperation contracts constitute a fundamental contribution to the relational capital (Leitner, 2004; Bezhani, 2010; González and Rodríguez, 2011).

The concept of relationship is very relevant in the network of academic social interactions as it associated to a greater productivity in terms of economic, political, and institutional developments. Indeed, one-to-many relationships open a substantial number of opportunities to enlarge the university relational capital by linking to economic, political, and institutional organizations, as well as to non-academic partners, enterprises, local governments, and society in general (Ramírez Córcoles *et al.*, 2011).

Methodology

Drawing inspiration from the model approaches proposed by Campos (2003), Leitner (2004), and Silvestri and Veltri (2011), we have considered the university as a system (Figure 1) that reconfigures itself continuously, nourished by frequent inputs of knowledge (Brătianu, 2009; Ramírez Córcoles *et al.*, 2011). In turn, the system gives back knowledge output under the form of scientific production, education, and scientific support to the economic and social environment (Leitner, 2004).

In order to analyze the relationship between IC and university performance, we conceived a model including elements of IC (human, structural, and relational) as the inputs able to generate the outputs, such as research, innovation, and education to be addressed to the society. The capability to successfully transform the IC inputs into a valuable contribution to the society assesses the quality of university performance.

Sample and measures

The model above was applied to the Republic of Colombia, in consideration of its very low levels of R&D. The country shows a late implementation of growth policies and very difficult relationships with the productive sector (Morales *et al.*, 2014). As it was illustrated by OECD (2012), "its research sector is small and it faces major societal challenges: low educational standards, low tertiary attainment, inadequate infrastructure, a high level of inequality and suboptimal ICT and scientific infrastructures. […] These shortcomings

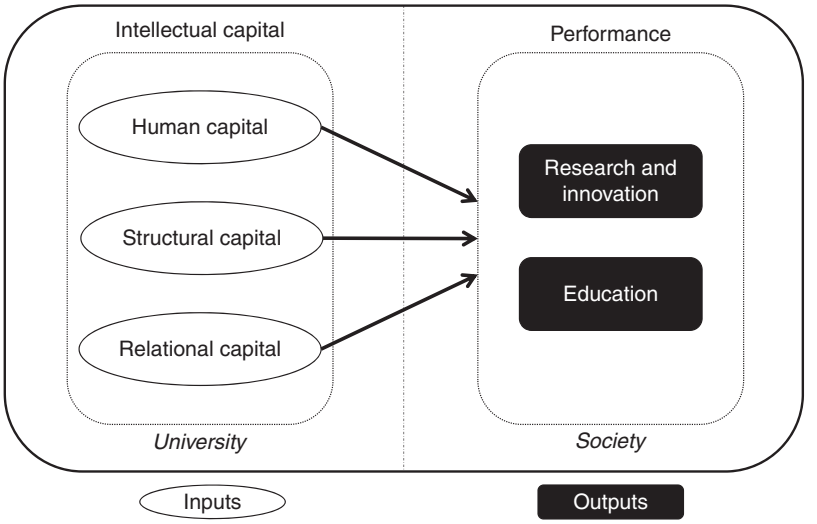

Figure 1.
Research model

have to be addressed if Colombia is to realize its ambitious STI objectives and become a knowledge-intensive economy."

The university system in Colombia has suffered from a number of transformations in the result of political, economic, and technological reforms, following both national social events, and international interventions that had changed its original conception. In order to strengthen its reorganization, in 1968, Colciencias was established, which is the National Council of Science Technology and Innovation of the country.

In 1992, a law defined the legal nature of public universities, giving them academic, administrative, and financial autonomy, and guidelines were delivered to design their activities and allocation of resources, granted by the government. By the same law, the state university system was created and approved by the government, while the functions of monitoring the administrative management, transferring and establishing indicators in order to evaluate the efficiency of public universities were officially determined. In 2010, the Government of Colombia identified innovation among the drivers of future economic growth and social development and a national innovation strategy is currently being developed, as evidenced by the project "Hoja de Ruta spin-off Colombia," aimed at strengthening the capability of Colombian higher education institutions to effectively implement the technology transfer mechanism (Ministerio de Educación de Colombia, 2013). Moreover, government initiatives strived to achieve a higher percentage of full-time teachers in universities and to reinforce regional scientific and technological capabilities by strengthening master and doctoral programs (OECD, 2012).

At present, the system of public higher education in Colombia consists of 31 universities[1]. Consequently, in order to achieve the economic advance and development of Columbia, obtaining information about IC measures in Colombia public universities would represent one step toward the systematic assessment of their performance.

In order to conduct this explorative study, we collected data from several Colombian official sources, including the Ministry of Education – System of State Universities (SUE), the Ministry of Education – National Information System for Higher Education, the Ministry of Education – Labor Observatory (SNIES), the Ministry of Hacienda and Colciencias. The data refer to the entire population of Colombian public universities. Data were collected for the years 2011 and 2012 (latest data available), in order to allow a one-year lag between inputs and outputs. Among the enormous amount of information we had retrieved, we identified suitable variables of IC and university performance. To them, we added also a performance variable drawn from the Scopus database, in order to assess the scientific productivity of Colombian public universities.

The rationale of the chosen variables is discussed below.

Human capital variables. The choice of the human capital variables takes into account the role of the human resources inside the university system (Campos, 2003; Maldonado 2013; Ramírez *et al.*, 2016) that can represent an important source of value for it (Secundo *et al.*, 2016). We identified three variables aimed to assess the universities' human capital.

$h1\_scholars_{11}$ describes the equivalent number of full-time scholars, as found in the literature (Feng *et al.*, 2012; Lu, 2012). The value is estimated by the Ministry of Education – System of State Universities – taking into account both full-time and part-time, tenured and non-tenured, scholars. The number of scholars of a university is a proxy of the abundance and diversity of tacit competencies that are owned by it, and that can have an impact on its performance, both in terms of pedagogical and research successfulness.

$h2\_admexpenditure_{11}$ identifies the expenditure for the wages of non-teaching staff, i.e. of the human resources that support both scholars and students in their activities. Such variable is similar to an indicator established by the Austrian universities (Leitner, 2004). The tacit competencies owned by non-scholarly human resources may have a dramatic role in enhancing both teaching and research activities.

h3_phdenrolment$_{11}$ refers to the number of students enrolled in PhD, Master, and Specialization programs, as done in the literature (Ramírez *et al.*, 2007). PhD students can support scholars in their research and teaching activities, while the Master and Specialization students can enrich, through their own experiences or advanced studies, the areas of expertise of the scholars.

Structural capital variables. We assessed the structural capital of Colombian universities by exploring their financial, didactic, and scientific resources. To this aim, we defined the following four variables.

s1_financialresources$_{11}$ measures the Colombian Government's funding resources assigned to the universities. This is the Colombian universities fundamental endowment, from which all research and didactic activities originate.

s2_indexedjournal$_{11}$ describes the weighted number of scientific journals published by the universities, according to the classification established by Colciencias[2]. Colciencias classifies journals according to four classes and assigns a different score to each one (A1 class, 15 points; A2 class, 12 points; B class, 8 points; C class, 3 points). To publish scientific journals is considered important in the Colombian university system and is representative of how many ongoing activities are pursued by a university.

s3_allprogrammes$_{11}$ is representative of the number of Bachelor, PhD, Master, and Specialization programs. The richer the amount of programs offered by a university, the higher will be the chances of cross-fertilization, the capability to catch funding opportunities in different areas, and the capability to nurture human resources with the skills needed to enrich the university's own staff in the future.

s4_ researchgroups$_{11}$ identifies the number of research groups officially recognized by Colciencias (2012) that are considered to contribute to the solution of problems of the Colombian society, through the production of knowledge oriented to the productive system of the country. In this vein, we advance that the number of recognized research groups describes the diversity of the research competencies owned by the universities.

Relational capital variables. The analysis of the relational capital in Colombian universities refers to internal and external links with public and private subjects, to the participation in collaborative activities with industry in training activities, the collaboration with international research centers, the networking with teachers, and the international exchange of students (Secundo *et al.*, 2016). We assessed the relational capital through four variables:

r1_studentsextra$_{11}$ describes the number of students involved in extra activities, as scholars' assistants or firms' trainees. Thus, these activities are both representative of internal links (students-scholars) and external links (students-firms).

r2_foreignstudents$_{11}$ refers to the number of foreign students enrolled in the universities. This variable is representative of the attractiveness of a university and of its capability of entering foreign "markets."

r3_studentsmobility$_{11}$ is specular with respect to the previous variable and shows the number of Colombian students involved in international mobility programs, allowing them to conduct a part of their studies in a foreign university. The variable is both representative of the university's capability to sign mobility agreements with foreign universities, and of its capability to enrich its IC through the experiences made by the students involved in such mobility programs.

r4_scholarsmobility$_{11}$ identifies the number of scholars involved in international mobility programs. As seen for the previous variable, also this one is both representative of the university's capability to sign mobility agreements with foreign universities, and of its capability to enrich its IC through the experiences made by the scholars involved in such mobility programs. Indeed, international scholar mobility is likely to enhance the involved scholars didactic and/or research skills, and favor international collaborations.

Performance variables. We identified five variables to assess Colombian universities performance: three describe performance associated with research and innovation (R&I) activities, while two describe educational results. Noticeably, we allowed a one-year lag with respect to the IC variables and normalized the variables in order to make them independent of the universities' size.

$p1\_scopusarticles_{12}$ describes the number of published articles, by scholars affiliated with each university, in journals indexed in the Scopus database. This measure is representative of the quantity of research products that are accepted in reasonably reputed international publications, representing a fair proxy of research performance. As the variable could have been clearly influenced by the number of scholars affiliated with the university, we normalized the number of articles dividing it by the equivalent number of full-time scholars in the same year.

$p2\_financedprojects_{12}$ identifies the amount of public funds obtained by the universities for R&D projects. This measure shows the scholars' capability to conceptualize and develop successful research projects, which are an important source of funds for Colombian universities. As made for the previous variable, we normalized the amount of funds dividing it by the equivalent number of full-time scholars in the same year.

$p3\_patents_{12}$ refers to the number of the patents registered by each university. This measure shows the scholars' capability to conceptualize and develop breakthrough technologies that can have an impact on the Colombian industry. As made for the previous variables, we normalized the number of patents dividing it by the equivalent number of full-time scholars in the same year.

$p4\_graduabachelors_{12}$ accounts for the number of the graduated bachelor students and is often considered a relevant measure of how the universities succeed in bringing their students to their final goal. As this variable is clearly related to the size of the university, we normalized the number of graduates dividing it by the number of first-year enrolled students in the same year.

$p5\_employability_{12}$ expresses the number of students of each university in any program (Bachelor, PhD, Master, and Specialization) who graduated in the year 2011 and found a job by 2012. As this variable depends on the number of graduates, we normalized this value dividing it by the total number of graduates in 2011 in the corresponding university.

Table I briefly summarizes the variables of the study and their institutional sources.

Methods

In order to achieve our research aim, we have adopted the research protocol summarized in Figure 2.

First, we have performed a cluster analysis aimed to classify the Colombian public universities according to their performance. We have adopted a similar approach to the one used in a recent article exploring the relationship between IC and performance in small and medium enterprises (Agostini *et al.*, 2017), resorting to a K-means method. Indeed, we decided to exclude hierarchical methods, which suffer from the defect that they can never repair what was done in previous steps (i.e. pairing of objects or splitting of clusters is not reversible), whereas partitioning methods like K-means can (Kaufman and Rousseeuw, 1990). Furthermore, the K-means method is considered less affected by outliers (which could have been an issue in our sample for certain performance variables) and the presence of irrelevant clustering variables than hierarchical methods. For the K-means purposes only, the five performance variables were converted into unit-less variables, using the z-scores as recommended by Kaufman and Rousseeuw (1990).

Given the relatively small number of Colombian universities targeted in this study, we have opted to avoid too many clusters with a few members, but at the same time, we wanted to go beyond a typical high-performing vs low-performing dichotomy. Therefore, in our

Class	Variables	Description	Source
Human capital	$h1\_scholars_{11}$	Equivalent of full-time scholars working for each university in 2011	1
	$h2\_admexpenditure_{11}$	Amount spent (pesos) by each university in 2011 for the salary of administrative staff enrollment	2
	$h3\_phdenrolment_{11}$	Number of students enrolled in PhD, Master and Specialization programs in each university in 2011	1
Structural capital	$s1\_financialresources_{11}$	Financial resources (pesos) assigned by the Colombian Government to each university in 2011	3
	$s2\_indexedjournal_{11}$	Weighted number of scientific journals published by each university in 2011	1
	$s3\_allprogrammes_{11}$	Number of Bachelor, PhD, Master and Specialization programs offered by each university in 2011	1
	$s4\_researchgroups_{11}$	Number of research groups of each university recognized by Colciencias in 2011	1
Relational capital	$r1\_studentsextra_{11}$	Students of each university performing extra activities while enrolled in 2011	1
	$r2\_foreignstudents_{11}$	Number of foreign students enrolled in each university in 2011	1
	$r3\_studentsmobility_{11}$	Number of students of each university involved in international mobility programs in 2011	1
	$r4\_scholarsmobility_{11}$	Number of scholars of each involved in international mobility programs in 2011	1
Performance	$p1\_scopusarticles_{12}$	Normalized number of articles published in Scopus in 2012 by each university	4
	$p2\_financedprojects_{12}$	Normalized amount of public funds provided in 2012 for R&D projects submitted by each university	5
	$p3\_patents_{12}$	Normalized number of national and international patents registered by each university in 2012	1
	$p4\_graduabachelors_{12}$	Normalized number of graduates in bachelor degree programs of each university in 2012	2
	$p5\_employability_{12}$	Normalized number of graduates in 2011 of each university who are employed in 2012	6

Table I. Variables of the study

Sources: 1, SUE; 2, SNIES; 3, Ministry of Hacienda; 4, Scopus; 5, Colciencias; 6, Ministry of Education – Labor observatory

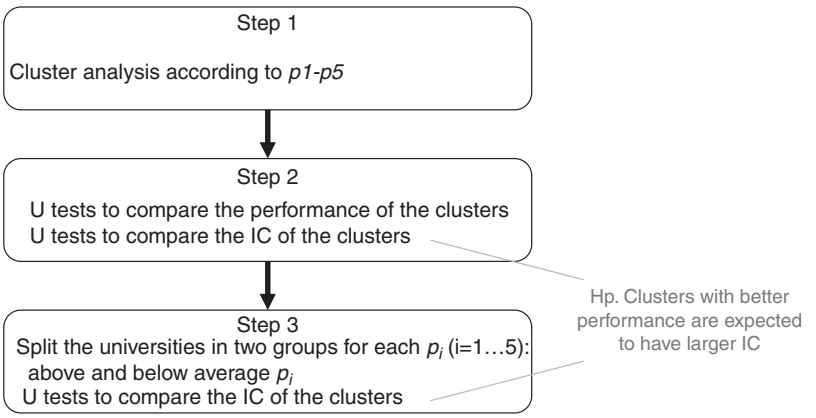

Figure 2. Research protocol

case, we have concluded that the resulting ideal number of clusters in order to provide the most meaningful interpretations of the data (Kaufman and Rousseeuw, 1990) would have been $K = 3$. However, such *ex ante* consideration should find support in reasonably improved measures (such as the within-cluster sum of squares) typically used in cluster analysis with the K-means method to identify a suitable number of clusters (Makles, 2012).

Second, we have compared the IC of the resulting clusters through non-parametric Mann-Whitney's U tests. In the U test, the null hypothesis to be tested is that the two clusters come from distributions with the same median (i.e. the universities in one cluster have a similar IC than those in another cluster), while the unilateral alternative hypothesis is that the universities in one cluster have a larger median value of the IC variables than the others. In our case, we have hypothesized that universities pertaining to clusters characterized by higher performance would have more IC than those pertaining to clusters characterized by a lower performance. While previous studies (e.g. Agostini *et al.*, 2017; Whiting *et al.*, 2017) resorted to the parametric student's *t*-tests for their analysis, in this case, we have chosen a non-parametric approach, which allowed us to compare small groups of universities without forcefully (and unrealistically) assuming that our variables follow normal distributions. Thus, we have used the U tests to understand which cluster was characterized by statistically significantly better performance, and then we have used the U tests again to verify whether such "high-performing universities" were likewise characterized by a stronger IC than the others.

Third, we have further delved into the data, exploring the relationship between each performance variable and the IC variables. To this aim, for each performance variable, we have split the universities into two groups: above the average value of the performance variable, and below the average value. Then, we have used the U tests to verify how the IC variables differed from one to another, always hypothesizing that above-average universities in terms of performance would also be characterized by larger values of the IC variables than the others.

Results and discussion

Table II shows the descriptive statistics of the variables of the study, while Table III displays the non-parametric Spearman correlation among the variables. A non-parametric correlation test is needed in our case, as we cannot hypothesize a linear relationship between the variables. The correlation coefficients show that most IC variables are strongly related

Variable	Ob.	Mean	SD	Min.	Max.
$h1\_scholars_{11}$	31	485.77	463.68	75	2,266
$h2\_admexpenditure_{11}$	31	24.8 M	54.6 M	2,601,537	307 M
$h3\_phdenrolment_{11}$	31	1,118	1,780	0	9,517
$s1\_financialresources_{11}$	31	72,400 M	120,000 M	9,550 M	668,000 M
$s2\_indexedjournal_{11}$	31	36.42	74.19	0	375
$s3\_allprogrammes_{11}$	31	82.19	89.01	8	376
$s4\_researchgroups_{11}$	31	271.55	456.40	12	2,480
$r1\_studentsextra_{11}$	31	2,082	2,861	64	12,853
$r2\_foreignstudents_{11}$	31	16.42	27.89	0	118
$r3\_studentsmobility_{11}$	31	43.68	76.04	0	381
$r4\_scholarsmobility_{11}$	31	78.19	171.79	0	936
$p1\_scopusarticles_{12}$	31	0.14	0.17	0	0.68
$p2\_financedprojects_{12}$	27*	6.5 M	7.9 M	191,805	34.4 M
$p3\_patents_{12}$	31	0.002	0.003	0	0.01
$p4\_graduabachelors_{12}$	31	0.70	0.59	0.03	2.25
$p5\_employability_{12}$	31	0.74	0.13	0.42	0.87

Notes: M, million. *Four universities could not be clustered due to missing data for p2_financedprojects12

Table II.
Descriptive statistics

Table III.
Spearman correlation indexes

	h1	*h2*	*h3*	*s1*	*s2*	*s3*	*s4*	*r1*	*r2*	*r3*	*r4*	*p1*	*p2*	*p3*	*p4*
h2	0.77***														
h3	0.84***	0.68***													
s1	0.70***	0.66***	0.69***												
s2	0.71***	0.53***	0.82***	0.69***											
s3	0.85***	0.72***	0.84***	0.80***	0.68***										
s4	0.81***	0.70***	0.83***	0.80***	0.72***	0.91***									
r1	0.73***	0.62***	0.72***	0.48*	0.43*	0.79***	0.71***								
r2	0.63***	0.60***	0.67***	0.77***	0.53**	0.74***	0.79***	0.57**							
r3	0.56**	0.50**	0.72***	0.68***	0.60**	0.68***	0.69***	0.46*	0.81***						
r4	0.72***	0.67***	0.82***	0.75***	0.61***	0.84***	0.81***	0.69***	0.79***	0.82***					
p1	0.68***	0.59**	0.82***	0.71***	0.68***	0.84***	0.88***	0.68***	0.84***	0.83***	0.87***				
p2	0.26	0.43*	0.27	0.48*	0.19	0.39*	0.41*	0.26	0.51**	0.55**	0.52**	0.50**			
p3	0.48*	0.54**	0.43*	0.50**	0.26	0.49**	0.50**	0.50**	0.58**	0.50**	0.59**	0.51**	0.61***		
p4	0.49**	0.32	0.35	0.17	0.24	0.43	0.30	0.40*	28	0.21	0.24	0.36	0.05	0.11	
p5	0.60***	0.48*	0.59**	0.36	0.52**	0.49**	0.61***	0.48*	0.42*	0.54**	0.66**	0.64**	0.37	0.38	0.32

Notes: Spearman correlation significant at the following levels *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

one with another, pre-configuring multicollinearity issues that would strongly affect the results of a regression model. Most likely, this is due to the fact that the size of a university strongly affects most of its IC variables. Instead, the five normalized performance variables are rarely correlated one with another, emphasizing the fact that they take into account different aspects that are worth being investigated.

Step 1 – cluster analysis

As discussed in the Methods subsection, we performed a cluster analysis through the K-means method, identifying three clusters including 27 universities (4 universities could not be clustered due to missing data for the variable $p2\_financedprojects_{12}$). We verified that the within-cluster sum of squares for three clusters is almost 30 percent smaller than that of two clusters, which was also extremely unbalanced, with the two clusters composed of 23 and 4 universities, respectively.

The results of the cluster analysis are shown in Table IV, together with the results of the U tests performed in accordance with the step 2 of our research protocol.

Step 2 – Mann-whitney U tests comparing clusters

Cluster 3 is composed of a very small number of universities (4), which makes more difficult to obtain statistically significant results when compared with cluster 2 (13 universities) and cluster 1 (10 universities). In this perspective, the abundance of statistically significant results emphasizes the remarkable differences existing among the clusters.

Cluster 3 is representative of top-class universities that are particularly successful in R&I terms, outperforming both cluster 2 and cluster 1 in the three relevant performance variables. Regarding the education-oriented performance variables, the universities of cluster 3 obtained similar results with respect to cluster 2 ones (U tests are not statistically significant), and only partially better than cluster 1 ones (U test is significant only for $p5\_employability_{12}$). In this view, we might roughly suggest that cluster 3 dominates the other two clusters, being more effective than them in R&I terms and not statistically different from them in education-oriented terms. Interestingly, cluster 3 turns out to be the most IC intensive of the three clusters for all of the IC variables included in our analysis. The only weakly significant result ($p = 0.069$) is associated with the weighted number of scientific journals published by the universities, which may raise questions about the appropriateness of the weights chosen. As most of the IC variable values are related to the university size, and they are all larger in cluster 3 than in other clusters, the main insight that we can draw is that the Colombian universities need to achieve a critical mass in order to obtain outstanding R&I results. Differently, with respect to education-oriented results, the critical mass is much less important.

Cluster 2 outperforms cluster 1 in terms of education-oriented performance, having obtained similar results to those obtained by the universities of cluster 3. With respect to R&I performance, cluster 2 outperforms cluster 1 in terms of Scopus journal articles only (with the former having a mean value of 0.16 against 0.04 of the latter). This result can be matched with the fact that among the 13 universities within cluster 2, only one obtained at least one patent (the actual average value of *p3_patents12* for cluster 2 is 0.00018), while none of the universities within cluster 1 obtained any patent. Similarly, there is no statistically significant difference between the amounts of funded projects of the two clusters. Therefore, even though cluster 2 is remarkably productive in terms of its research activity, it is not as much successful in pursuing the technological transfer or in obtaining grants. Interestingly, the universities of cluster 2 are equipped with more (equivalent) full-time scholars, but with a comparable amount of administrative human resources with respect to cluster 1 (on average, 14.6M$ vs 9.33M$, $p = 0.094$), and significantly less than cluster 3 (which averages 113M$), as discussed before. This may

Table IV.
Descriptive statistics of the performance variables by the three clusters identified through K-means

	Cluster 1			Cluster 2			Cluster 3					
Variable	Ob.	Mean	SD	Ob.	Mean	SD	Ob.	Mean	SD	Cluster 3 vs cluster 2	Cluster 2 vs cluster 1	Cluster 3 vs cluster 1
$p1\_scopusarticles_{12}$	10	0.04	0.06	13	0.16	0.13	4	0.42	0.20	*	**	**
$p2\_financedprojects_{12}$	10	2.9 M	2.18 M	13	5.14 M	5.25 M	4	19.8 M	11.3 M	*	ns	**
$p3\_patents_{12}$	10	0.00	0.00	13	0.00	0.00	4	0.01	0.00	***	ns	***
$p4\_graduabachelors_{12}$	10	0.34	0.21	13	0.88	0.68	4	0.91	0.73	ns	*	ns
$p5\_employability_{12}$	10	0.59	0.11	13	0.80	0.05	4	0.82	0.03	ns	***	**
$h1\_scholars_{11}$	10	266.40	207.63	13	451.62	167.18	4	1351.25	825.31	*	**	**
$h2\_admexpenditure_{11}$	10	9.33 M	5.65 M	13	14.6 M	10.3 M	4	113 M	132 M	**	****	*
$h3\_phdenrolment_{11}$	10	416.5	655.83	13	827.15	493.10	4	4,244.50	3,604.88	**	*	**
$s1\_financialresources_{11}$	10	42,100 M	33,400 M	13	47,600 M	24,800 M	4	284,000 M	264,000 M	**	ns	*
$s2\_indexedjournal_{11}$	10	8.30	8.97	13	23.46	27.41	4	269.00	137.93	****	ns	*
$s3\_allprogrammes_{11}$	10	42.20	30.09	13	64.54	21.55	4	143.75	101.52	**	*	**
$s4\_researchgroups_{11}$	10	116.00	102.05	13	195.85	108.08	4	1117.50	939.95	**	*	**
$r1\_studentsextra_{11}$	10	8,10.70	436.79	13	1,664.23	977.15	4	7,491.50	554.43	**	**	**
$r2\_foreignstudents_{11}$	10	3.40	5.08	13	13.23	16.10	4	73.50	37.92	**	ns	**
$r3\_studentsmobility_{11}$	10	12.30	19.86	13	28.15	24.03	4	181.00	15.03	*	*	*
$r4\_scholarsmobility_{11}$	10	14.60	22.79	13	44.69	23.77	4	397.75	363.62	**	**	**

Notes: M, million; ns, not significant. U tests significant at the following levels *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.10$

suggest that, in order to capitalize the research results, administrative human resources could play an important role, helping scholars in the complicated paperwork that is often needed to win grants and to patent an invention. Noticeably, this is not necessarily a matter of financial resources (not statistically different between the two clusters), but of how these resources are used. The weighted number of scientific journals published by the universities, which could have been considered related to the number of articles published in Scopus journals, is not statistically different between cluster 2 and cluster 1, producing a second warning about the effectiveness of the weights identified by Colciencias. Finally, also the number of foreign students is not statistically different between the two clusters, suggesting that the better performance of cluster 2 in education-oriented terms is not substantially related to this factor.

In order to have a synoptic representation of the differences among the three clusters, we normalized the performance and IC variables with respect to their own standard deviations and then displayed the average values of the transformed variables across the three clusters through two star plots. The resulting Figure 3 clearly shows how the three clusters are substantially inscribed one in another both in terms of performance and IC, with occasional overlapping values that were already discussed before (e.g. on the education-oriented performance variables of cluster 3 and cluster 2). The symmetry of Cluster 3 IC star contrasts with the more spiked ones of cluster 2 and cluster 1, suggesting that the former has a more balanced IC profile, which may be another of the strengths points that allowed the universities described by it to outperform the others.

On the whole, this cluster analysis allowed to draw several insights:

(1) The top-class universities in terms of performance (cluster 3) are also those equipped with the strongest IC, according to each of the IC variables chosen. This reinforces the literature about the role of IC in universities.

(2) The mid-class universities in terms of performance (cluster 2) obtained worse R&I results with respect to cluster 3, but similar education-oriented results, which are, in turn, better than those achieved by cluster 1. The analysis of the innovation performance variables (i.e. financed projects and patents) and of the IC variables brought us to advance that an improved dotation of administrative staff could help universities pertaining to cluster 2 to take advantage of the results of the research activities, improving the innovation performance results.

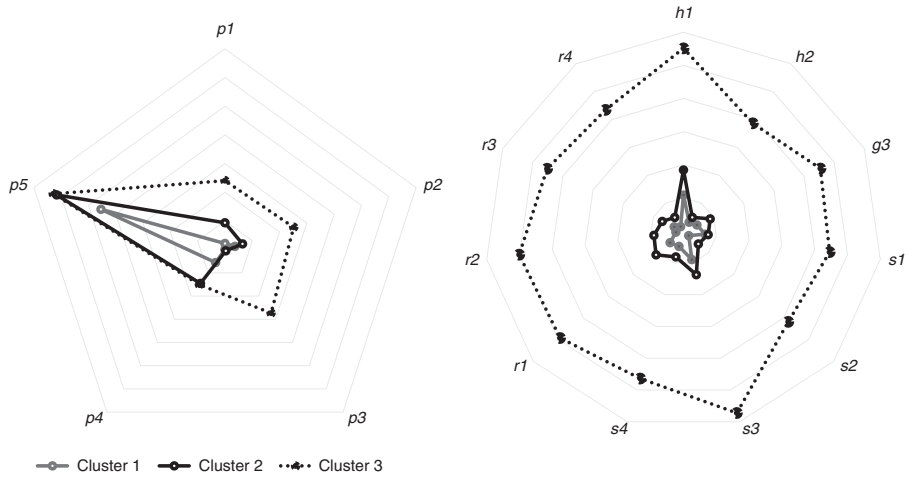

Figure 3.
Star plots of performance and IC variables (normalized with respect to their SD) across the three clusters

(3) The last class of universities in terms of performance (cluster 1) suffers from a lack of several IC resources. Among them, the small number of scholars (and of research groups) could possibly explain a fair portion of the comparatively low performance. These variables, along with the variable describing the number of Bachelor, PhD, Master, and Specialization programs, which are fewer than in the other clusters, suggest that cluster 1 universities are yet to achieve a critical mass that would allow the economies of scale and scope needed to fill the gap with the other Colombian universities.

(4) A balanced IC could be one of the keys to improving the universities' successful technological transfer and project activity.

Step 3 – creating and comparing groups for each performance variable

As described in our research protocol, we split the Colombian public universities into two groups for each of the five performance variables (above-average (A) vs below-average (B)), in order to explore how IC variables vary. The alternative hypothesis of the U test is that the group with better innovation performance should also be the one characterized by more IC.

Table V shows the differences between the A and B groups with respect to the R&I performance variables.

Regarding the normalized number of Scopus journal articles ($p1\_scopusarticles_{12}$), the U tests show that all the IC variables are likely to take larger values in the universities in A with respect to B ones. We estimated the probabilities of each variable being larger in the universities in A with respect to those in B. Interestingly, the largest probabilities are associated with the number of PhD, Master, and Specializing students; the number of programs offered by a university, the number of recognized research groups, and the internationalization aspects of relational capital. These values suggest several considerations. First, they emphasize the role of the educational mission of public universities that, far from weakening the research productivity, may actually be of help to fertilize it. Second, they show that recognized research groups are associated with improved research productivity, suggesting that the recognizing process is performed correctly. Third, they underline the importance of international collaborations, even at a student level, to nurture research productivity.

The results associated with a number of funds obtained for research projects provide additional insights ($p2\_financedprojects_{12}$). First, they confirm the importance of administrative staff for this performance variable, which is much clearer than that of the number of scholars. Financial resources also play a relevant role, as richer universities have better equipment that can help them to propose cutting-edge studies, which are, in turn, more likely to be funded. The weighted indexed journals represent the only variable that is not even nearly significantly different from one group to another, confirming the doubts expressed before about this peculiarity of the Colombian university system.

With respect to the third R&I performance variable, $p3\_patents_{12}$, the A and B groups basically describe the universities that patented at least one invention and those that did not, respectively. The only two weakly significant U tests are associated with the financial resources and the indexed journals of the universities. The scholar mobility is the variable with the highest probability of being larger in the group A with respect to the B one, emphasizing that the extent to which inventions are patented is strongly related to cultural aspects. Thus, an emerging country willing to encourage the patenting activity of its universities through IC levers may want to fund scholars mobility in more advanced countries, where patenting is much more frequent.

Table VI describes the differences between A and B groups with respect to the education-oriented variables.

Table V.
Comparison of the above-average (A) and below-average (B) groups with respect to the R&I performance variables

	p1_scopusarticles$_{12}$						*p2_financedprojects*$_{12}$						*p3_patents*$_{12}$					
	A group		B group		U test		A group		B group		U test		A group		B group		U test	
	Ob.	Mean	Ob.	Mean	*p*	*P*%	Ob.	Mean	Ob.	Mean	*p*	*P*%	Ob.	Mean	Ob.	Mean	*p*	*P*%
h1_scholars$_{11}$	10	768.7	21	351	*	73	8	855.1	19	373.6	****	72	6	1,015.8	25	358.6	*	83
h2_admexpenditure$_{11}$	10	54.7 M	21	10.6 M	****	71	8	66.5 M	19	10.7 M	*	81	6	79.4 M	25	11.7 M	*	83
h3_phdenrolment$_{11}$	10	2,379.9	21	517.4	***	88	8	2,483.4	19	633.1	****	73	6	3,226.2	25	612.3	**	85
s1_financialresources$_{11}$	10	145,000 M	21	37,800 M	*	78	8	166,000 M	19	44,300 M	*	75	6	198,000 M	25	42,400 M	****	75
s2_indexedjournal$_{11}$	10	89.9	21	11	**	79	8	92.6	19	16.2	ns		6	119.7	25	16.4	****	73
s3_allprogrammes$_{11}$	10	155.5	21	47.3	***	91	8	165.3	19	53.4	*	78	6	202	25	53.4	**	87
s4_researchgroups$_{11}$	10	583.8	21	122.9	***	88	8	665	19	150.3	*	79	6	786	25	148.1	*	83
r1_studentsextra$_{11}$	10	4,045.6	21	1,147	**	80	8	4,631.4	19	1,192.5	*	78	6	5,336.3	25	1,301	*	77
r2_foreignstudents$_{11}$	10	40.7	21	4.9	***	88	8	40.3	19	9.4	*	77	6	51	25	8.1	**	86
r3_studentsmobility$_{11}$	10	101.9	21	16	***	89	8	100.1	19	21.7	****	74	6	142.7	25	19.9	**	89
r4_scholarsmobility$_{11}$	10	193	21	23.5	***	90	8	218.1	19	30.2	*	80	6	282.8	25	29.1	**	92

Notes: M, million; ns, not significant. U tests significant at the following levels *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.10$. P% indicates the probability that probability that the IC variable for the A group is larger than the IC variable for the B group

Table VI.
Comparison of the above-average (A) and below-average (B) groups with respect to the education-oriented performance variables

	p4_graduabachelors$_{12}$						p5_employability$_{12}$					
	A group		B group		U test		A group		B group		U test	
	Ob.	Mean	Ob.	Mean	*p*	*P*%	Ob.	Mean	Ob.	Mean	*p*	*P*%
h1_scholars$_{11}$	10	622.6	21	420.6	*	77	21	585.5	10	276.3	**	81
h2_admexpenditure$_{11}$	10	21 M	21	26.6 M	ns		21	32.2 M	10	9.3 M	*	74
h3_phdenrolment$_{11}$	10	1258.9	21	1051.2	****	71	21	1,441.2	10	439.9	*	76
s1_financialresources$_{11}$	10	59'800 M	21	78,400 M	ns		21	86,100 M	10	43,800 M	ns	
s2_indexedjournal$_{11}$	10	47.3	21	31.2	ns		21	49.8	10	8.3	****	71
s3_allprogrammes$_{11}$	10	102.6	21	72.5	*	73	21	99.8	10	45.3	****	72
s4_researchgroups$_{11}$	10	271.0	21	271.8	ns		21	341.0	10	125.8	ns	
r1_studentsextra$_{11}$	10	2596.5	21	1837.0	ns		21	2,659.0	10	870.5	*	78
r2_foreignstudents$_{11}$	10	20.7	21	14.4	ns		21	21.0	10	6.8	ns	
r3_studentsmobility$_{11}$	10	47.5	21	41.9	ns		21	56.5	10	16.7	****	69
r4_scholarsmobility$_{11}$	10	66.9	21	83.6	ns		21	107.5	10	16.7	**	81

Notes: M, million; ns, not significant. U tests significant at the following levels *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.10$. *P*% indicates the probability that probability that the IC variable for the A group is larger than the IC variable for the B group

Regarding the normalized number of graduates of the universities ($p4\_graduabachelors_{12}$), we found that the universities in A are characterized by more teaching staff; more PhD, Master, and Specializing students, and more programs than the universities in B. Somewhat surprisingly, none of the other IC variables are significantly larger in the group A with respect to the B one. This is particularly unexpected if we consider variables such as the financial resources of a university, which should allow better educational equipment, and administrative staff expenditures, which might be representative of a more attentive support provided to the students in the bureaucratic aspects. Thus, the IC success factors of this performance variable are particularly associated with the human factor, which is quite good news for an emerging country with remarkable budget constraints.

Finally, the results according to the employability of the university graduates ($p5\_employability_{12}$) show an interesting outcome, especially in consideration of the underdeveloped labor market in emerging countries. Somewhat surprisingly, again financial resources are not statistically different between the two groups. Far more relevant is the number of scholars and their international vocation, as professors' social network is often pivotal to favor the recruiting of their graduates. Reasonably, the students of the universities in A are more involved in extra activities and in international mobility than those of the universities in B. This helps students to build competencies that are particularly appreciated by firms, favoring their employability. For the same reason, we are not surprised to find that universities that enroll students in more advanced programs (PhD, Master, Specialization) and build additional competencies are also those characterized by a better employability. Finally, it is worth emphasizing the role of administrative staff expenditure, which is larger in the universities in A and may be representative of the role of specialized offices (e.g. job placement) in supporting firms' recruiting activities. For the same reason, we are not surprised to find that universities that enroll students in more advanced programs (PhD, Master, Specialization) and build additional competencies are also those characterized by a better employability. Finally, it is worth emphasizing the role of administrative staff expenditure, which is larger in the universities in A and may be representative of the role of specialized offices (e.g. job placement) in supporting firms' recruiting activities.

Conclusions

This paper explored the relationship between IC and university performance in emerging countries, studying the case of Colombian public universities.

As emerging countries have typically very limited resources available for the university system, we assessed both IC and performance through variables that are available in most countries, without the need of making substantial additional investments for specific inquiries. This should favor the future replicability and comparability of our study in other countries.

Implications

The results of the study have implications that may be useful for Colombia in particular, and for emerging countries in general, to enhance university performance.

We observed that universities with a stronger IC are also, in most cases, those outperforming the others. Nevertheless, an in-depth analysis allowed us to identify several interesting patterns.

First, in order to obtain outstanding R&I results, universities need to achieve a critical mass in terms of size, while education-oriented results are less related to size. This might encourage creating a few centers of research excellence in the strategic zones of an emerging country, and more medium-sized universities mainly dedicated to facilitating the access to secondary education.

Second, while the normalized number of articles published in Scopus journals is associated with the number of scholars affiliated with a university, the extent to which such studies are converted into grants and patents is likely to be also influenced by the administrative human resources working for the university, and by the overall balancing of the university's IC. These factors should not be neglected when planning the public funding strategy of an emerging country.

Third, both scholars and students should be encouraged through appropriate funding to participate in international mobility projects. Indeed, in four out of five performance variables, the best performing universities also happened to have higher values of the variables measuring outbound international mobility. Scholars' mobility may be particularly helpful to increase their capability and willingness to patent their inventions, to write high-quality papers and to win grants, but also to favor graduates' employability. In turn, students' international mobility and extra-curricular activities are likely to build those hard and soft skills that firms seek, and that a developing country particularly needs.

Finally, with specific respect to the Colombian case, we recommend an in-depth review of the mechanism of measurement of the scientific journals published by the universities. In fact, the variable appears rarely related with the performance variables, questioning its reliability as a driver to assess the scientific productivity. Differently, the number of recognized research groups is positively associated with R&I results, suggesting that the process of recognition is likely to be reliable.

The implications of this study for society in emerging countries are remarkable. Based on our results, emerging countries may pursue the IC development by following two parallel paths:

(1) creating core research centers characterized by comparatively large universities (above a certain critical mass) in strategic areas (e.g. those associated to a more significant growth of the industry); and

(2) strategically positioning medium-sized universities in order to nurture the national human capital and support local industry.

Furthermore, the public authorities may use the panel of measures chosen in this paper in order to monitor the IC of their universities, identifying possible gaps and imbalances, and studying the relationship between IC and performance.

Limitations

We are aware that our study has at least three major limitations.

First, we adopted an explorative approach that does not allow making reliable causal inferences between IC variables and performance variables. This is mainly due to the strong correlation existing between the IC variables, most of them being strongly related to the university size, which impeded us from performing regressions. We could not overcome this issue through a factor analysis, whose results would have provided the reader with very little information (with one factor explaining more than 90 percent of the variance). Future studies may overcome this limitation by choosing size-invariant IC variables, although we recommend that such variables should not be excessively sophisticated, in order to favor their actual usage in emerging countries.

Second, the results obtained in the analysis of the Colombian university system may not be safely extended to all emerging countries, as country-specific peculiarities may play a major role. Nevertheless, the obtained results appear very reasonable and we encourage future studies aimed to make comparisons among different emerging countries, and analyzing the differences with respect to more advanced countries.

Finally, the results of this paper depend on our choices with respect to the clustering method and to the number of clusters that we decided to analyze. Further studies might choose different partitioning or hierarchical methods and a different number of clusters, depending on the characteristics and cardinality of the sample.

Notes

1. The University Francisco de Paula Santander actually has two headquarters, thus some official statistics report 32 public universities, counting the two as different universities. As some other statistics were only provided as the aggregation of the two headquarters, we considered them as a sole institution.
2. www.usbcali.edu.co/sites/default/files/guia-servicio-indexacion-2013.pdf

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Further reading

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