The growth of the scientific production of Colombian universities: An intellectual capital-based approach

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Abstract

This paper proposes that the knowledge production of universities is related to their accumulation of intellectual capital (IC). Therefore, universities with an historic process of the accumulation of IC present an exponential growth in their scientific production. This work studies the trends of the scientific publications of Colombian universities and the relationship between these trends and their IC. Universities were categorized into four groups according to the growth in number of their publications: exponential growth –early-; exponential growth –late-; linear growth and irregular growth. In addition, we present some factors relating to the accumulation of IC in Colombian universities.

Introduction

Research activity in Colombian universities began approximately 50 years ago as a consequence of different reforms and institutional changes. For instance, the modernization of the Universidad del Valle (1962), the Universidad de Antioquia and the "Reforma Patiño" of the Universidad Nacional gave rise to changes in other universities (Villaveces & Forero, 2007). It is important to emphasize the creation of Colciencias[7] and The Colombian Institute for Educational Evaluation (ICFES)[8] in 1968, the two Inter-American Development Bank (IDB) credits for the ICFES and the three IDB credits for Colciencias, and also the creation of the national systems of science and technology in 1991 (Villaveces & Forero, 2007). Hence, research is a recent activity in Colombian universities.

Colombian universities have an important role to play in the country's research activities. These institutions concentrate the financial resources, qualified personnel and motivation to carry out research (Aldana, 2010; Villaveces & Forero, 2007). Most of Colombia's knowledge production capabilities are concentrated in its universities (Development University Center [CINDA], 2010). For instance, 89.5% of all researchers in Colombia were working at higher education institutions (HEIs) in 2007, and more than half of the country's expenditure on research and development was spent by universities (Aldana, 2010).

We found that the growth of knowledge production by Colombian universities follows four different trends: exponential growth –early-, exponential growth –late-, linear growth and irregular growth. We propose that these behaviors are related to the intellectual capital (IC) accumulation process. In this way, this work classifies universities into the four categories listed above and shows the relationship between these trends and indicators that represent universities' IC.

[7] Colciencias is the Administrative Department of Science, Technology and Innovation. Colciencias coordinates the National System of Science, Technology and Innovation (SNSTI) of Colombia.

[8] ICFES is a specialized entity that offers educational assessments at all educational levels in order to support the Ministry of National Education.

This paper is organized in two sections, as follows. The first section presents the relationship between the IC of a university and its scientific publications and a brief description of the methodology. The second section presents the preliminary results and a discussion.

Methodology

The relationship between the IC of universities and the number of their scientific publications

IC is the potential capability of organizations to produce value. "Intellectual capital is intellectual material – knowledge, information, intellectual property, experience – that can be put to use to create wealth" (Stewart, p. XX). In the case of universities, IC can be understood as the capability to produce knowledge. The knowledge production is a process in which some resources are leaked out while others are capitalized in order to be used in the next time period (Bucheli, Villaveces, & Daza, 2008). In other words, the capabilities which are accumulated over a period of time form the potential capital for knowledge production in the next period. IC is usually composed of human capital, structural capital and relational capital (Bernárdez, 2008; Brooking, 1996; Meritum, 2002; Marr & Moustaghfir, 2005). In the context of this study, we also use the financial capital.

One of the indicators which is used to represent scientific activity is the number of scientific publications, and this has been used since the first studies were carried out in the field of scientometrics (De Solla Price, 1963). This indicator is currently used for several rankings[9] which are used to evaluate universities' performance in terms of their scientific activity. Consequently, one way to represent the dynamics of a university's knowledge production is the growth in its publications.

Trends in scientific publications data

The aim of this work is to study the different trends in the growth of the scientific publications of Colombian universities in order to understand the dynamics of capital accumulation. Price (1963) studied the exponential growth of science and noticed that the growth of science follows the logistic growth curve: the initial stage of growth is exponential, then saturation begins, and the growth slows and finally stops.

This work proposes that exponential growth in publications results from successive processes of IC accumulation. This means that universities with increasing resources dedicated to research activities – such as the number of PhD professors and PhD programs and their levels of research expenditure and participation in research networks – will experience exponential growth in their knowledge production. The research resources in one period may be capitalized, and these will increase the resources for knowledge production in the following period. In this way, universities create research systems with feedback structures.

Information about the scientific publications of Colombian institutions was retrieved from WoS[10] (search strategy cu=(Colombia)). We retrieved 19,928 records from a period of 50 years (1958-2008), and the year of publication and information regarding institutional affiliations were extracted from each document.

Colombian universities were classified according to the trend and the acceleration of growth in their time series data of publications. We defined four growth groups: exponential growth -early-, exponential growth -late-, linear growth and irregular growth (due to fluctuation between productive and unproductive years). For each case, series data were fitted to an exponential curve and a linear curve, and the comparison between the two adjusted R square

[9] Academic world-ranking universities, such as Academic Ranking of World Universities (ARWU) , Times Higher Education - World University Rankings (THES) and Scimago.

[10] ISI Web of Knowledge Expanded Citation Databases: science citation index, social sciences citation index, arts & humanities citation index.

values was used to classify the universities into either the linear group or the exponential group. In some cases, the time series data did not fit any of the listed trends (universities with strong fluctuations in the number of publications), and so these universities were classified into the irregular group.

The universities which were classified into the exponential growth group were divided into two groups (see Figure 1):

- Exponential growth -early-: The growth of publications fitted an exponential curve, and furthermore, the universities had been publishing research for at least 25 years and had published more than 100 documents per year over the two last years;
- Exponential growth -late-: The growth of publications fitted an exponential curve, and furthermore, the universities had been publishing for less than 25 years and had published fewer than 100 documents per year in the two last years.

IC of Colombian universities

The following indicators were defined in order to aid our study of the IC of Colombian universities. These indicators have been classified into the four categories of IC.

Table 1. Indicators for each category of IC

Category of capital	Indicator	Description
Human Capital	Full-time equivalent (FTE) faculty	The workforce (in terms of the number of professors) of a university and its activities can then be added up and expressed as the number of full-time equivalents
	Full-time equivalent (FTE) faculty with PhD	Number of full-time faculty with PhD
	Growth rate of FTE faculty	Quantifies the change in the number of professors over four years (2004-2007)
	Percentage of FTE faculty with PhD	Percentage of full-time equivalent faculty with PhD
Structural capital	Institutional accreditation	High Quality Institutional Accreditation granted by the National Accreditation Council (NAC)[11]
	Research excellence center	A research excellence center is a national network of research groups. This indicator identifies whether or not the university participates in at least one research excellence center
	PhD programs	This indicator identifies whether or not the university has at least one PhD program
	Students in PhD programs	This indicates whether or not students are enrolled in the PhD programs
Relational capital	Research groups	The number of research groups weighted by category (Colciencias categorized the Colombian research groups into A1, A, B, C and D)
	Research financial leverage ratio	The ratio between research expenditure from external sources and the total research expenditures (2008)

[11] National Accreditation Council (Consejo Nacional de Acreditación): autonomus governmental entity; it has to perform a technical evaluation of academic programs that have demonstrate high quality levels. Retrieved from: http://unesdoc.unesco.org/images/0013/001310/131066e.pdf

Category of capital	Indicator	Description
	Social network measurements of co-authorship networks	The density and centrality of the co-authorship network
	Social network measurements of institutional relations in co-authorship networks	The density and centrality of the co-authorship network
	Growth rate of social network measurements in co-authorship networks	The increase in the density or centrality of a social network over four years (2004-2007)
	Ratio repetition	The number of connections repeated between the same actors of a co-authorship network over four years (2004-2007)
Financial capital	Income	The flow of cash or equivalents received
	Research and development expenditure	The money spent on creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this knowledge to devise new applications (Organisation for Economic Co-operation and Development [OECD] , 2005)
	Research income	Income received exclusively for research activities
	Growth rate income	The increase in income over four years (2004-2007)
	Growth rate research expenditure	The increase in research expenditure over four years (2004-2007)
	Percentage research income	The percentage of total income which is assigned to research

The information required for each Colombian university was obtained from the National Information System of Higher Education (SNIES)[12]. This information comprised: the number and educational level of the professors; financial information; PhD programs and PhD students. Additional information about institutional accreditations was acquired from the NAC and other data regarding research activity in Colombian universities were retrieved from the report entitled "The role of universities in the science and technology development. Report 2010" (CINDA, 2010).

Results and discussion

Figure 1. shows the time series data of universities classified into the four categories explained in the methodology section.

[12] National Information System of Higher Education (SNIES).

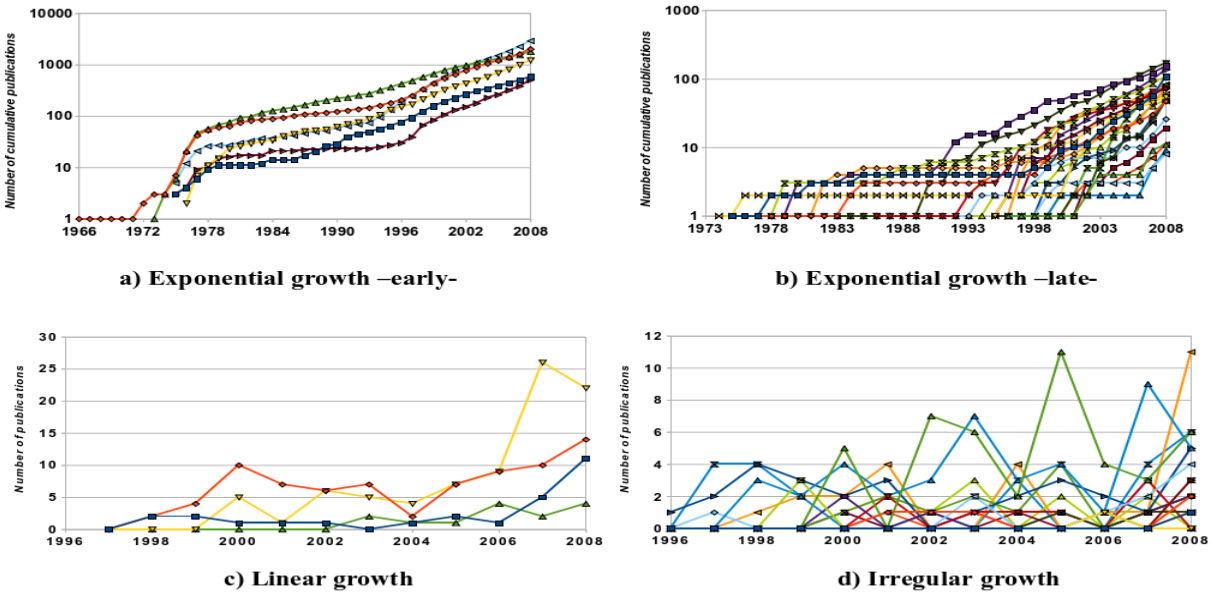

Figure 1. Time series of the scientific publications of Colombian universities: (a) exponential growth –early- (log-normal plot); (b) exponential growth –late- (log-normal plot); (c) linear growth; and d) irregular growth

Colombia has 77 universities, and 11% of these had not published anything, meaning that 68 universities had published work over a period of 50 years. Of these universities, 56% were experiencing exponential growth in their publications, and thus, more than half of Colombian universities have an accumulation process of capabilities of the kind which is associated with positive feedback structures.

Only 9% of the universities were classified into the group of exponential growth –early-. These universities had published at least one piece of work over the past 25 years; consequently, this group had the longest period of capital accumulation (42 years). Currently, universities into this group publish more than 100 papers per year; this is the best performance in terms of scientific activity in the Colombian science, technology and innovation system. Figure 2 and Table 2 show the accumulation of IC which is associated with this group of universities.

The exponential growth –late- group was characterized by a shorter period of accumulation than the exponential growth -early- group; and, the publications of each university were of the order of 10^1 per year, in the last five years. The linear and irregular growth groups were composed of 43% of the universities. These universities began to publish only recently, meaning that their rates of publication have not experienced accelerated growth. In addition, the number of publications of universities in the irregular growth group fluctuated strongly over time.

IC

In this first approach, four universities from each group were selected[13] and their IC indicators (as defined in the methodology section) were calculated; some of the results are presented in Figure 2 and Table 2. Figure 2 shows that the exponential groups exhibited major human capital accumulation; these universities had the most accelerated growth in terms of FTE

[13] In the event of a linear group, only two universities were selected because it was not possible to get information about their intellectual capital.

faculty, and had the highest percentage of FTE faculty with PhD. In the same way, the exponential groups had the highest growth rates for their research and development expenditure. In the case of structural capital, the averages of the indicators for the exponential growth groups were double those of other groups (see Table 2). We propose that our future research should calculate indicators of relational capital and complete human, structural and financial capital indicators for Colombian universities.

Figure 2. Financial capital and human capital indicators for each growth category

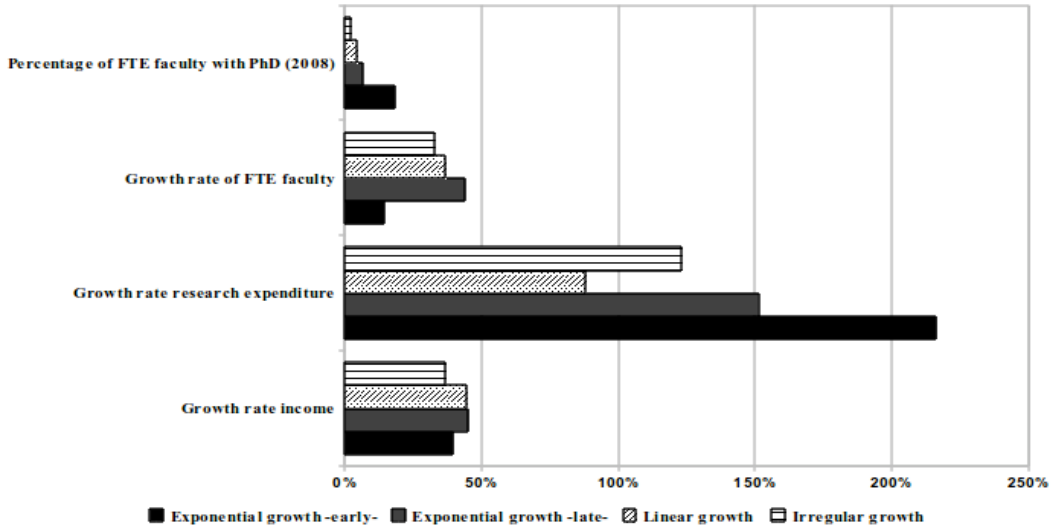

Table 2. Structural capital for each group of universities in 2008

	University	Institutional acreditation	Programs acreditation	Research excellence center	PhD programs	Students in PhD programs	Total
Exponential growth -early-	U. ANTIOQUIA	1	1	1	1	1	5
	U. VALLE	1	1	1	1	1	5
	U. INDUSTRIAL DE SANTANDER	1	1	1	1	1	5
	U. NACIONAL DE COLOMBIA	1	1	1	1	1	5
	Average						**5**
Exponential growth -late-	U. NARIÑO		1		1	1	3
	U. QUINDIO		1	1			2
	U. PAMPLONA		1				1
	U. CAUCA		1	1	1	1	4
	Average						**2.5**
Linear growth	U. LLANOS		1				1
	U.T. CHOCO		1	1			2
	Average						**1.5**
Irregular growth	U. CUNDINAMARCA		1				1
	U. CESAR		1				1
	U. SURCOLOMBIANA		1				1
	U. GUAJIRA		1				1
	Average						**1**

In conclusion, the universities that had created research systems with positive feedback structures related to their IC gave better performances in terms of their research activity. Therefore, universities which increase their human capital in terms of PhD professors, financial capital in terms of research expenditure and structural capital in terms of doctoral programs or institutional accreditations create feedback loops that reinforce their scientific production in a positive way. We observed that the differences in the growth of publications are related to the accumulation of IC; for instance, the groups of universities which experienced exponential growth had the highest number of publications, and in the last five years had published more than 80% of all Colombian publications.

This work is focused on the study of the dynamics of knowledge production in Colombian universities and the relationship between these dynamics and the universities' IC accumulation as a growth process. There are other works which are related to this topic, but they have been focused on input-output indicators. As Jin and Rousseau (2005, p.512) declare:

> Scientists and decision makers have understood that, at least at the macro level, analyses based on scientometric and bibliometric indicators may provide a benchmark and bring trends to the fore [...] At the micro level, in particular in performance evaluations of scientists, scientometric and bibliometric indicators have severe limitations. For really ground breaking research the required activities are complex phenomena performed by human beings with high intelligence.

Consequently, we are interested in studying the underlying relationships in the knowledge production systems of universities in order to understand the trends in scientific production in Colombian universities. In this way, our results could support universities in making decisions regarding research activity.

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