

An analysis of the relationship between higher education performance and socio-economic and technological indicators: The Latin American case study

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ABSTRACT

This paper reports on a study that analyzed the research output of higher education systems in a select number of Latin American countries and its relationship to several socio-economic and technological success indicators. This was placed within a broader discussion of the changing role of the university in society. The study used the rankings of the countries surveyed with respect to two major indicators: 1. higher education and training (Global Competiveness Report 2012-2013) and 2. scientific productivity of higher education institutions (HEI) as measured by the number of research papers published in international, peer reviewed journals as archived in the Scopus Database (Elsevier B.V.) and available in the SIR Iberoamericano Ranking Reports 2009-2013. The relationship of both indicators with various socio-economic and technology indicators was examined to assess the extent to which the quality and scientific productivity of a country's higher education system affected a number of country performance indices such as global competitiveness, innovation, health and primary education, government effectiveness, knowledge and technology output and GDP per capita. The relationship between scientific productivity in the form of published, refereed papers and a country's investment in R&D, researcher headcount per million inhabitants and the quality of its research institutes was analyzed as well. The findings at the Latin American level were compared to the research effectiveness of higher education institutes at the global level. The study found that, notwithstanding the huge variation that existed between the countries studied in the survey, the education and training country rank and the country average HEI publication record correlates with several important socio-economic indicators. Although improvements have been made many Latin American countries still trail their global counterparts in the area of research and publication.

Keywords: Higher education institutes, research intensity, scientific productivity, country ranking, Latin America.

RESUMEN

Este manuscrito presenta un estudio que analiza la producción científica de los sistemas de educación superior en un número selecto de países de América Latina y la coloca dentro de un debate más amplio sobre el rol cambiante de la universidad en la sociedad. El estudio utilizó la clasificación de los países encuestados con respecto a dos indicadores principales: 1. la educación superior y la formación (Informe de Competitividad Global 2012-2013); y 2. la productividad científica de las instituciones de educación superior (IES) tanto medido por el número de artículos de investigación publicados en revistas internacionales revisadas por pares como archivados en la base de datos Scopus (Elsevier B.V.) y disponible en los informes del Ranking Iberoamericano SIR 2009-2013. La relación de ambos indicadores con diversos indicadores socioeconómicos y de tecnología se examinó para determinar la medida en la que la calidad y la productividad científica de los sistemas de educación superior de un país afectan una serie de índices de desempeño del país tales como la competitividad global, la innovación, la salud y la educación primaria, la eficacia del gobierno, el conocimiento y la producción

tecnológica y el PIB per cápita. Se analizó también la relación entre la productividad en forma de publicaciones científicas y de la inversión de un país en I + D, el número de investigadores por millón de habitantes y la calidad de sus institutos de investigación. Los resultados a nivel de América Latina se compararon con la eficacia de la investigación de los institutos de educación superior a nivel mundial. El estudio reveló que, a pesar de la gran variación que existe entre los países estudiados en la encuesta, el ranking del país en base de la educación y la formación y el récord promedio de publicación por IES se correlaciona con diversos indicadores socio-económicos importantes y, si bien se han llevado a cabo mejoras, muchos países de América Latina siguen estando detrás de sus contrapartes globales en el ámbito de la investigación y la publicación.

Palabras clave: Institutos de educación superior, la intensidad de la investigación, producción científica, ranking de países, América Latina.

1. INTRODUCTION

1.1. *The changing role of higher education in society*

While all of society's actors must contribute in the transition towards a sustainable world, awareness is growing that universities should be major catalysts for change in that process. Universities have always played a historic role in transforming societies and in serving the greater public good, yet the urgent societal need for global sustainable development that now exists has pushed universities even more into assuming a fundamental and moral responsibility to guide society on its path towards a sustainable future (Barlett and Chase, 2004; Wright, 2004). A significant proportion of our improved health, wealth and general wellbeing (whether environmental, cultural, social or spiritual) was made possible by the research performed by universities and research institutes and through the actions of people who were drawing on the benefits of their university education (The Group of Eight, 2013).

The importance of higher education to a country's overall socio-economic development is growing daily, given the world's rapid evolution towards a global knowledge economy. Higher education not only fosters the economic development of nations and the provision of opportunities for individuals but it also extends to the promotion and harmonization of cultural diversity, political democracy and economic trade (Marginson, 2010). Scott (1998) states that modern research universities are major drivers of globalization and they often function as primary agents in opening up nations to global engagement. Research-based universities assist countries in understanding the growing complexity of modern society and in dealing with the increasing pressure a still expanding world population places on earth's limited resources and fragile ecosystems (Vörösmarty *et al.*, 2000; Steffen *et al.*, 2007; Rajendran, 2010). Following Lélé (1991) the immense environmental, social and economic risks the world faces will be much harder to manage if we are not able to change our current path of destruction and if higher education systems are neither able to guide society towards the inevitable and necessary changes nor come up with timely technological solutions to the problems that exist. As stated by Brundtland *et al.* (2012) progress towards sustainable global development is imperative. The state of the environment, which is currently seriously threatened, has significant implications for the well-being of humans and other species on earth. Waas *et al.* (2010) feel that humanity will increasingly be confronted with important societal problems, such as failing socio-economic and institutional systems that need answers and solutions.

Improving the effectiveness of HEIs in finding solutions requires that they are more intensively engaged with industry, commerce and the community at large, in a way that was not always apparent in the past. Ciferri and Lombardi (2009) suggest that universities should better understand business objectives and actively seek to engage in a dialogue about what each societal actor could contribute. In doing so, universities might generate more start-ups (Di Gregorio and Shane, 2003) and enhance the role that society expects the higher education system to play in both a concrete and a sustainable manner. The formation of well-qualified professionals who can lead society in the future is one important role universities have to fulfill. In addition to that, higher education systems should help society in reaching sustainability for both current and future generations, a task for which they should

increasingly deploy research activities in close cooperation with all societal actors, from governments to industry.

Higher education institutions have two principal responsibilities: teaching and research. Synergy between both is becoming increasingly important as research adds value to the teaching process and as teaching adds value to research. It is a well-known fact that present-day university graduates are better prepared for the roles society expects them to play than in the past: in addition to having been taught in the classical way where theory drives the learning process, they have also been exposed to application of theory to practice or learning by doing and by self-study. They have received a better initiation into the role and importance of research than past generations. If universities are to play a role in educating the world for sustainable development, graduates must be close to the research being undertaken to understand it more fully (Ciferri and Lombardi, 2009). Knowledge will change, priorities will emerge and new thinking will develop as a result. For teaching not to be connected with research would mean that higher education would rapidly be out-of-date, possibly irrelevant and almost certainly inadequate to face and solve the world's problems. In modern institutions of higher education teaching and research are strongly interwoven and those universities that manage to connect and incorporate the two successfully are the leading institutions of higher education at both national and international levels.

Given the ever-changing needs of society, universities are continuously forced to update their teaching curricula, to improve the skills of their teaching staff and to enhance teaching with socially relevant research. In doing so they will maintain and enhance their credibility in society and they will be able to attract financial resources to expand their activities. The success of the teaching performance of a university can be measured by the quality of the contributions its graduates make to society and by the way in which they perform them. The quality of teaching can be directly monitored by peer review committees evaluating an institution's study programs or by subjecting the study programs to accreditation processes. The advantage of accreditation is that it offers an assurance that graduating professionals have a solid educational foundation and that they are capable of leading the way in innovation, in developing new technologies and in anticipating the welfare and safety needs of the public (Rhoades and Sporn, 2002; Prados *et al.*, 2005). Possible indicators quantifying and qualifying the research capacity of a university are the financial resources it harnesses through research and extension projects, university spin-offs, the numbers of patents it generates and its scientific productivity in terms of both the number and the quality of its publications and citations.

1.2. Ranking universities

Information on academic research and technology commercialization by way of spin-offs is very hard to obtain, given that every country adheres to different policies and systems of data collection and storage. Moreover, universities are not always prepared to share this information. Finding accurate data on the funding resources that universities acquire on the basis of research projects is a complex exercise as well because funding is coming from different sources and/or donors and research groups within universities are not always keen on communicating this information to a central office, which in turn could make this information available at the country level. Information on patents is easier to gather since a patent is normally granted by a national institute that is bound by international patent cooperation treaties. Information on the number of patents of a country is obtainable from the Global Innovation Index, annually published by INSEAD, The Business School for the World. Unfortunately one cannot derive and separate the number of patents that emerge either from universities or from private industry in a particular country from the available data. Yet, the total number of patents generated by a country provides some measure of its research progress and its future potential.

A widely used index for measuring the research strength of an HEI is its scholarly productivity as expressed by the number of research papers archived in national and international databases. The information in these databases is generally reliable and correlated to the impact factor of the journals in which the articles appear. A multitude of journal databases with scholarly and professional articles exists; some of them are freely accessible whereas others require a subscription. There are area specific scientific journal databases and databases covering a wide range of thematic journals.

Considered most valuable in this regard are the Thomson Scientific database, the Scopus Database (Elsevier B.V.), Wiley's Online Library and PubMed.

Since the development of the Academic Ranking of World Universities (Shanghai AWRU Ranking) in 1998 and first published in 2003, several integrated university evaluation systems have seen daylight, such as *The Times Higher Education World University Ranking* (2004), the *US News and World Report (USNRW)* and the *Reitor Global Universities Ranking*. These systems attempt to quantify a university's quality of education, quality of faculty, research output and the per capita performance of the institution. Over time, ranking systems that concentrate solely on research performance have also been developed such as the *Leiden Ranking* in 2008, the *Taiwan Higher Education Accreditation and Evaluation Council Ranking (HEEACT Ranking)* and the *Assessment of University-Based Research (AUBR)* report developed and published by the Directorate General for Research of the European Commission since 2010. Additionally, multi-ranking systems have emerged that use a greater number of indicators; these normally do not produce a league table of results like the others but rather present the results of individual indicators separately. A detailed description of the underlying concept and the indicators used in each of these systems can be found in Rauhvargers (2011). A common characteristic of most of these ranking systems is that they limit their rankings to only 1.000 out of the more than 17.000 universities around the world and only publish a listing of the world's top 100-500 institutions periodically.

1.3. Ranking Latin America's HEIs

A comparative assessment of the research intensity of Latin America's HEIs using the more elite ranking systems is not possible since the majority of the HEIs in Latin America is not listed given their low to moderate research profiles in comparison to the universities in the northern hemisphere. For this reason the authors decided to use the *SCImago Institutions Rankings (SIR)* reports, which have been published annually since 2003 by the SCImago Research Group. Additionally, SCImago has also published the rankings of HEIs in the Latin American region in a separate report entitled the *SIR Iberoamericano Report* since 2009. The indicators used in this report specific to Latin America are 1. scientific productivity (output); 2. international collaboration; 3. normalized impact; 4. high quality publications; 5. a specialization index; 6. excellence rate; and 7. leadership. The rankings are based on a 5-year record of indexed publications archived in the *Scopus Database* (Elsevier B.V.). Whereas the *SIR World Report* includes only institutions meeting the threshold of 100 indexed papers annually during the past 5 years, the *Iberoamericano SIR Report* lists institutions in Latin America with at least one document published during the last year of the 5-year period. This in itself is already indicative of the differences in publication levels that exist. The *SIR World Report 2012* listed 3290 institutions of higher education that together were responsible for more than 80% of the worldwide scientific output during the period 2006-2010 and that each had published at least 100 indexed papers per year during the five-year period. The *SIR Iberoamericano Report 2013* lists 1635 HEIs and research organizations in Latin America who all had published at least one indexed article during the last year of the period.

As stated earlier, the SIR reports are based on indicators in the Scopus Database that enable the analysis of scientific productivity in a large number of scientific domains at the country level and at the university level, given that their publications are indexed and archived within the database. This database is generally recognized as the world's largest abstract and citation database of peer reviewed literature. It covers nearly 20.500 titles from over 5.000 international publishers, 19.500 of which are peer reviewed journals in the scientific, technical, and medical and social sciences (including arts and humanities). The *SIR Iberoamericano Report* encompasses Portugal and Spain in addition to the Latin American and Caribbean countries and so far five SIR Iberoamericano Ranking reports have been published. The number of Latin American HEIs increased from 1400 to 1635 in the period 2009-2013 and this number will further increase when more universities embark on research and start publishing in peer reviewed journals that are archived in the *Scopus Database*.

As can be derived from the SIR Reports, the universities in Latin America are at a disadvantage as compared to those in the developed countries. According to Ferrari and Contreras (2008) key factors explaining the overall lower ranking at world level of the Latin American HEIs are the low to moderate number of graduates in relation to the population, the low number of research projects and

the low budgets dedicated to science and technology, the small time-window for research (Latin American universities started doing research much later), a general lack of university resources and appropriate facilities and a limited supply of postgraduates to continue and enhance the research effort. They concluded that universities in Latin America are still primarily geared toward teaching, which not always is of the best quality. They are uncompetitive internationally and they teach to limited numbers of students. Furthermore, they state that research is either inadequate or nonexistent. Latin American universities train professionals for roles in society and according to the authors, these graduates are not always well prepared nor do they possess the necessary skill sets that society needs.

In light of the above observations, the focus of this paper is to examine to what extent research is developed and practiced in the higher education systems in a number of Latin American countries and the effect it has on several socio-economic quality performance indicators. The analysis is conducted at the country level and does not go into individual rankings of universities. It was based on the following hypotheses that are each captured in separate paragraph headings below:

- (a) Research output as measured by the number of refereed publications is a reliable indicator of the quality of a country's higher education system;
- (b) The average research output of HEIs at the country level is positively related to a country's investment in R&D, talent and infrastructure;
- (c) Good higher education and training positively affect a country's global competitive index, its technological readiness, innovation, business sophistication and health and primary education; and
- (d) The scientific productivity of a country's higher education system is a useful barometer of its government's effectiveness, knowledge and technology output and GDP per capita.

A review of Latin America's higher education ranking and publication records enables us to compare them to countries and universities worldwide, permitting us to draw some conclusions about the state of research. Based upon this and as stated by Ahmed and Abdallah (2013), it will be possible to draw avenues for the development and improvement of the country's research status, gauge the conduciveness of the country's environment for an effective use of knowledge in the economic development process and assess a country's competence in the adoption and diffusion of knowledge.

2. MATERIALS USED

For this study the following databases were consulted:

- (a) Total number of documents published by the HEIs of a country in scholarly journals, as indexed in Scopus and as published in the *SCImago Institutions Ranking* (SIR) reports of Iberoamericano. Each report gives the ranking of the HEIs based on their 5-year research output in the form of the number of manuscripts indexed in the *Scopus Database*. Instead of the yearly record, SIR reports on the number of publications a HEI published in indexed journals over 5 years to circumvent the annual fluctuations in research output. In other words, the SIR 2009 report lists the scientific production of the HEIs in the period 2003-2007 and the SIR 2013 report for the period 2007-2011. The consulted SIR reports Iberoamericano are freely downloadable from <http://www.scimagoir.com/> and provide the scientific output of Latin American HEIs on the basis of the Scopus Database of 1400 HEIs in the 2009 report and 1635 HEIs in the 2013 report. On top of the number of papers a HEI publishes, the SIR reports also provide a profile of the scientific activity of HEI's through bibliometric indicators.
- (b) *The Country Economic profiles* published by INSEAD (The Business School of the World) and the WIPO (The World Intellectual Property Organization). Their website can be consulted at the following address: <http://www.globalinnovationindex.org/gii/main/countries.html>. The parameters used in the analysis are the inversion in R&D (2009), the number of researchers per million inhabitants (2008), the quality of the research institutes (2011), government effectiveness (2011), number of patents (2010), public investment in education (2008), pupil-teacher ratio in the secondary school system (2009), knowledge and technology output (2012)

and GDP per capita (2011). The numbers between brackets indicate the year to which the data refer.

- (c) The *Global Competitiveness Report 2012-2013* of the World Economic Forum, accessible at http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf. The parameters downloaded from the 545-page report and as edited by Schwab (2012) are the global competitiveness index (GCI), business sophistication, innovation, technological readiness, health and primary education, and higher education and training. Those parameters are the pillars expressing a country's ability to generate, adopt and diffuse knowledge and whether the environment is conducive for knowledge to be used effectively for economic development according to Chen and Dahlman (2005). Instead of the parameter values, the country rank per parameter was used, enabling the positioning of the studied countries in a world perspective. The total number of countries per parameter is 144. The lower the rank the better the performance of a country is for a given parameter.
- (d) The *World Factbook of the Central Intelligence Agency* (CIA), which can be consulted on the following website: <https://www.cia.gov/library/publications/the-world-factbook/index.html>. The parameters derived from this database and used in the study are the population and the GDP per capita (PPP).

The Latin American countries included in the study are (in alphabetical order): Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Ecuador (ECU), Mexico (MEX), Peru (PER) and Venezuela (VEN). Cuba was not included because most of the consulted databases do not provide its values for the considered parameters. Paraguay (PRY) and Uruguay (URY) were excluded since in both countries there is only one university which publication-wise is visible. The publication record in the Scopus Database for the Universidad de la Republica in Uruguay is moderate, varying between 2074 and 3411 publications per moving 5-year in the period 2009 to 2013; however the remaining 7 Uruguayan universities with publications in the Scopus Database is low, on average between less than 5 to 50 records per 5-year. Similarly, in Paraguay there is only one university, the Universidad Nacional de Asuncion, with a publication record in the range 134 to 180 (2009-2013), whereas all other 6 universities included in the Scopus Database do not manage to get 30 research papers published in peer reviewed international journals in 5 consecutive years. On the other hand, Spain (ESP) and Portugal (PRT) were included in the analysis as belonging to the Iberoamericano region, in order to establish a link to the middle group of countries in Europe and in reference to their Latin origins.

Table 1. Population and GDP per capita (PPP). Data derived from The World Factbook, downloaded from <https://www.cia.gov/library/publications/the-world-factbook/index.html> (17 September 2013).

Country	Population ¹	Country rank	GDP (PPP) ²	Country rank
Spain	47.370.542	28	31.100	47
Portugal	10.799.270	80	23.800	65
Argentina	42.610.981	32	18.400	74
Bolivia	10.461.053	82	5.200	157
Brazil	201.009.622	5	12.100	106
Chile	17.216.945	62	18.700	72
Colombia	45.745.783	29	11.000	110
Ecuador	15.439.429	67	10.200	118
Mexico	116.220.947	11	15.600	88
Peru	29.849.303	42	10.900	111
Venezuela	28.459.085	45	13.800	97

Legend: ¹ July 2013 estimate; ² 2012 estimate

Table 1 provides some general data of the selected countries, such as total population and GDP per capita (PPP), named gross domestic product and purchasing power parity per capita. The total populations (July 2013 estimate) of the 11 countries included in the survey varied from as low as 10,5 million (BOL) to 201 million (BRA). The population of MEX is 116,2 million. SPA and ARG have comparable population sizes, 47,3 and 42,6 million inhabitants respectively. Similarly, PER and VEN have comparable populations equal to 29,8 and 28,5 million citizens. The other countries are less densely populated: CHL has 17,2 million citizens, ECU 15,4 million and POR 10,8 million. The variation in GDP per capita (2012 estimate) is less dramatic: SPA has the highest economic output equal to 31.100 USD/capita, followed by POR (23.800 USD/capita). The people in ARG and CHL have comparable GDPs/capita, 18.400 and 18.700 USD/capita respectively, followed by MEX (15.600 USD/capita) and VEN (13.800 USD/capita). The gross domestic product at purchasing power parity per capita of BRA, COL, ECU and PERU varies from 10.200 to 12.100 USD. BOL has the lowest overall GDP/capita, estimated at 5.200 USD.

The data interpretation was based on a visual inspection of the graphs relating to the parameters that could provide answers to the postulated hypotheses. In some cases a linear regression between pairs of parameters was calculated. The objective of the study was not to derive a statistical model that explained the effect of higher education and training on a set of independent variables such as health and primary education, technological readiness, government competitiveness, GDP per capita among other variables (Ortega and Marín, 2008) since the datasets were too small. Rather, the explorative aim of this study was limited to verifying if relationships between the inventoried parameters existed and if these relationships were meaningful and helpful in drawing conclusions.

Caveats

The authors acknowledge that not all Latin American countries are included in this comparative analysis. The intent of the study was not to generate a complete analysis of the scientific output of all Latino American countries but rather to explore if any relationships existed between several prominent socio-economic variables and a country's scientific output and to provide an overview of how the countries highlighted in this study compared to each other and to the world at large. We also recognize that additional socio-economic variables are available and could have been used and that the accuracy of the various analyses was dependent on the quality and availability of the information provided by the various reports and databases used. We further acknowledge that research output as measured by articles published in peer-reviewed journals is only one indicator of output and that other measures are available. However, it is a very common measurement. Finally, this study does not make any value judgments, not does it determine whether any of the HEIs are funded publically or privately.

3. RESULTS

3.1. Research output is an indicator of the quality of a country's higher education system

The number of indexed papers published in peer reviewed journals was used as an indicator for the characterization of the research intensity of a HEI. Instead of analyzing the research productivity of each individual HEI, the total numbers of papers published in peer reviewed journals by country were considered in this study. It was assumed that the higher the total registered output, the higher the research capacity of a country. Figure 1 depicts the distribution of HEIs on the basis of the total number of indexed papers per 5-year period as listed in the *SIR Iberoamericano Reports 2009 to 2013*, yet only for a limited number of countries (ARG, BRA, ECU, ESP and MEX). A first observation is that the number of HEIs with at least 1 indexed paper in 5 years as archived in the *Scopus Database* (x-axis) varies from country to country and ranged from 41 in ECU to 442 in BRA (as reported in the *SIR Iberoamericano Report 2013*).

Figure 1 reveals also that the number of HEIs with at least 1 publication in 5 years increased over the reporting period, very much so in ECU (33,9%) and MEX (36,7%), moderately so in ARG (7,8%) and BRA (8,6%), and hardly in ESP (2,1%). HEIs in Spain have developed over a much longer period

in history, whereas the development of the higher education systems in most Latin America countries is of more recent date. In ECU and MEX there is still an expansion of the number of HEIs, yet the trend is decreasing somewhat and HEIs that were primarily focused on teaching are slowly converted to a somewhat increased research focus. At present ECU even pursues a policy of reducing the number of HEIs that only focus on teaching and that do not meet national higher education standards. As can be observed in Fig. 1, the total number of publications in 5-year periods per HEI varies greatly between the depicted countries, yet overall an increase in scientific productivity per HEI has taken place.

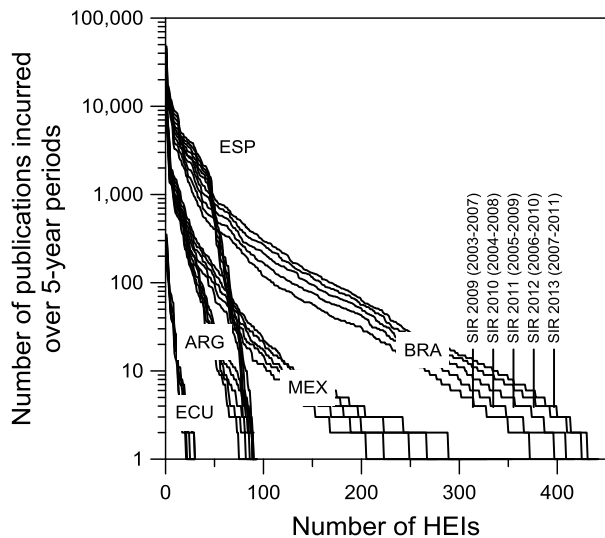


Figure 1. Distribution of the HEI's of the countries ARG, BRA, ECU, MEX and ESP on the basis of the number of publications incurred over 5-year periods (SIR Iberoamericano Reports 2009-2013).

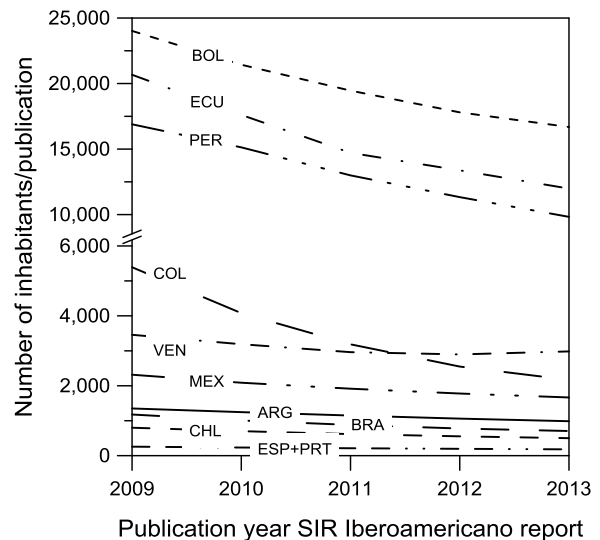


Figure 2. Number of inhabitants per publication and per country (SIR Iberoamericano Reports 2009-2013).

The 5-year publication record (*Scopus reports* 2009 to 2013) of the top ranked university in ARG increased from 8.845 to 11.452 (29,5% increase), in BRA it went from 32.580 to 47.833 (46,8%), ECU went from 173 to 352 (103,5%), ESP from 12.676 to 16.914 (33,4%) and MEX from 15.828 to 19.349 (22,2%). From the steepness of the distribution curves in ESP one can conclude that the 5-year scientific output of most universities is in the range of 1.000 to 10.000 publications and that the group of universities with a 5-year output between 1 and 1.000 publications is narrow. For ECU there is an almost linear variation of the 5-year publication output between the top university and the universities with just one publication. In ARG there exists a small group of top universities of which the 5-year scientific output ranges from 1.000 to 10.000 publications. The majority of higher education institutions in this country have a 5-year publication record between 10 and 1.000 publications, with a small group of institutions still having an annual record of 1 publication in the *Scopus Database*. The distribution of HEIs in BRA and MEX is very analog and shows a small top of HEIs with a 5-year publication record varying between 10.000 and 20.000 for MEX and between 10.000 and 50.000 for BRA. The distribution of HEIs is fairly linear in the range 10 to 1.000 publications per 5-year period and in both countries there is still a fairly large group of HEIs with less than 10 publications in 5 years. The total scientific output of the HEIs in ARG increased by 42,7% according to the *SIR Iberoamericano Reports 2009-2013*. In BRA this was 73,1%, in ECU 82,7%, in ESP 45,7% and in MEX 45,4%. The data clearly reflect that scientific productivity of the Latin American HEIs is following the same trend as ESP: it is growing rapidly yet the growth is primarily coming from a small number of top universities that employ the country's leading scholars and scientists.

Figure 2 depicts the evolution per country of the number of inhabitants per publication during the period 2009-2013. Based on the information depicted in this figure, the 11 countries in this survey can

be classified in three groups: BOL, ECU and PER at the top with 15.000 to 25.000 inhabitants per publication, COL, VEN and MEX in the middle with 2.000 to 6.000 inhabitants per publication and ARG, BRA, CHL, ESP and PRT at the bottom with less than 1.000 inhabitants per publication. Furthermore, Fig. 2 also shows that there is a fairly strong decreasing trend in the number of inhabitants per publication for BOL, ECU, PER and COL, indicative of the fact that the number of publications is growing faster than the population, a positive development. The trends are virtually flat with regard to the other countries and are indicative of the fact that the increase in scientific output in those countries is in balance with their population growth. For VEN a slight increase in number of inhabitants per publication is observed, suggesting that either the scientific productivity in this country is declining or that population growth is stronger than the increase in scientific productivity.

In general, the scientific output of Latin America, as measured by the number of indexed articles published, is on the rise as more universities embark on research efforts and contribute to their country's scientific output. However, this growth in output is still mostly concentrated in a limited number of top universities in a few countries. This suggests that the focus of a majority of the higher education institutions in the countries surveyed is still on training professionals rather than on research. Figures 1 and 2 also reveal that there is still a huge difference in scientific output between the various countries in Latin America: BOL, ECU and PER are lagging in productivity notwithstanding the progress that has been made in research output. COL is catching up to MEX and VEN but those three countries are still somewhat less research oriented and less efficient in translating research results into articles than ARG, BRA and CHL. The latter three countries are almost as productive as ESP and PRT with regard to publication productivity and BRA alone accounts for nearly 54% of the total scientific output in Latin America.

3.2. *The scientific productivity of a country's higher education system is directly related to its investment in R&D, talent and infrastructure*

Investing in basic and applied research and experimental development is critical for a sustained research effort and to positively affect the socio-economic growth of a country. Traditionally, national R&D investment has been expressed as a percentage of a country's gross domestic product (GDP) and is also called *R&D intensity* (OECD, 2011). In 2007 the top global investors in R&D were Israel (4,7 % of GDP), Sweden (3,7%), Finland and the Republic of Korea (3,5%), Japan (3,4%), the United States (2,7%), Singapore (2,6%) and Canada (2,0%) (UNESCO Institute for Statistics, 2009). For European countries with a strong socio-economic profile the R&D Intensity varies between 2,0 and 3,0% (UNESCO Institute for Statistics, 2009). R&D Intensity for most economically emerging and developing countries is less than 1,5% of GDP. Figure 3 illustrates that R&D intensity (2009 values) in the 11 countries included in this survey varied between 0,0 and 2,0 % of GDP (x-axis). The R&D intensity of PRT (1,66%) and ESP (1,38%) places both countries in the lower range of the European economic area as they are around the 1,5% threshold value.

Of the Latin America countries in the survey BRA possesses the highest R&D intensity (1,08%), followed at a considerable distance by ARG (0,52%), CHL (0,39%) and MEX (0,37%). BOL and ECU invest roughly the same percentage in R&D, respectively 0,28 and 0,26% of their GDPs. COL and PER have the lowest R&D intensity, equal to 0,16% and 0,15% of their GDPs respectively. The investment level in both those countries is low and comparable to the investment level of many developing countries. This is in clear contrast with the status of *emerging economic region* that both countries claim. As depicted in Fig. 3, a significant linear relation ($R^2 = 0,8128$) exists between R&D intensity and the scientific productivity of a country in terms of average publication record per HEI during the period 2007-2011. CHL is the only country that falls outside the 95% confidence interval (CI), exceeding the upper level. This might hint at other factors being responsible for the fact that the publication efficiency in CHL is higher than what the linear regression would predict. Similarly, ARG is also situated on the upper level of the 95% CI as it is able to publish proportionally more papers per unit of GDP invested in R&D than the other countries in the sample.

The situation in BOL and ECU is clearly different: most likely the overall investment levels in those countries and the dispersion in the allocation of their limited resources is such that the scientific production is considerably less than what one would expect according to the linear regression.

Whereas PRT is situated on the regression line with an average HEI publication rate of 1030, ESP is considerably more efficient in the conversion of its R&D investment in papers than all other countries in the survey, having an average publication record per HEI of 2823 papers. This suggests that the average research output of the academic staff in ESP is higher than in the other countries and that its HEIs in general are more focused on research.

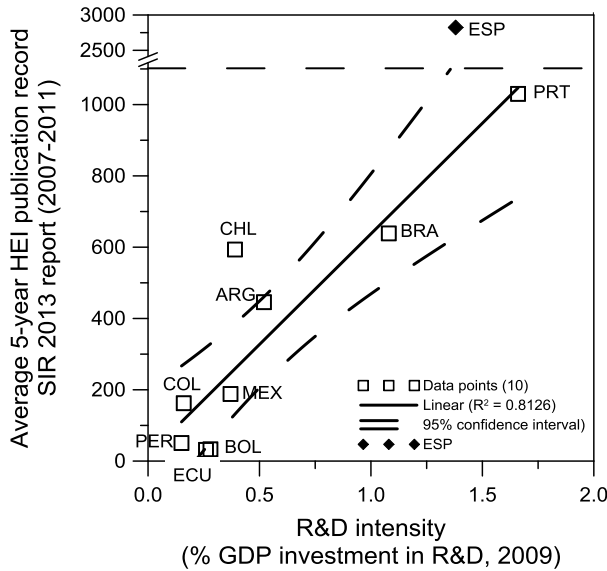


Figure 3. Relation between the average 5-year HEI scientific productivity and R&D intensity (SIR 2013 report, period 2007-2011).

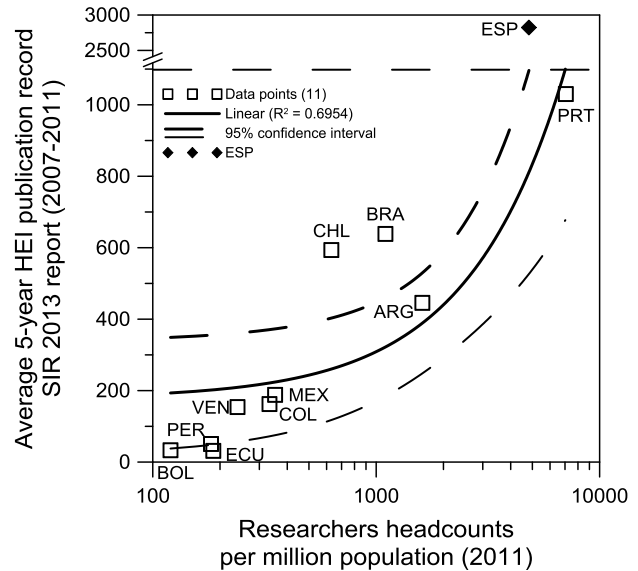


Figure 4. Relation between the average 5-year HEI scientific productivity and the researcher's headcounts per million population (SIR 2013 report, period 2007-2011).

Figure 4 confirms that the average capacity level of researchers in ESP is considerably higher than in PRT, given that both countries have a comparable number of researchers per million inhabitants (4822 and 7059 respectively) and as compared to the other countries in the survey. The second group with most researchers per million inhabitants consists of ARG (1610 researchers per million inhabitants), BRA (1100/million) and CHL (630/million). The number of researchers per million inhabitants in the remaining six countries (MEX, COL, VEN, ECU, PER and BOL) varies between 353/million for MEX and 120/million for BOL. It is evident that scientific productivity is correlated with the headcounts of researchers in service in a country ($R^2 = 0,6854$). Figure 4 further reveals that researchers in BRA and CHL are considerably more successful in translating research results into publishable material, followed by ARG. The overall efficiency in getting material published is lower in COL, MEX and VEN and considerably lower in BOL, ECU and PER, suggesting that a minimum threshold in R&D intensity and talent is required to reach the same scientific productivity per researcher as in countries having higher numbers of researchers per million inhabitants.

The trend between scientific output and the quality of research institutions (Fig. 5) is very similar to the trend between output and number of researchers per million inhabitants (Fig. 4). This is not surprising as it is to be expected that a higher concentration of researchers goes hand in hand with better infrastructure and better research facilities and with a research-oriented operation. From this analysis it can be concluded that when a country wants to improve its scientific productivity it is essential that it increase its R&D intensity (Ponomaniov and Boardman, 2010; Li, 2012; Lakitan *et al.*, 2012) but also that those additional resources should be well allocated to talent and infrastructure. Furthermore, it is important that institutions should develop a policy that stimulates researchers to publish in both high-profile and medium-impact journals. BRA in particular succeeded in creating a policy focusing on improving its productivity/investment ratio, a tough but necessary step on the way to establishing a mature higher education system in which the quality of scientific papers supersede

quantity as a focus of research strategy. ARG and CHL follow in the footsteps of BRA. However, the conditions in MEX, COL and VEN are still less than favorable and inhibiting the growth of their science output, although pressure from funding agencies and institutions to publish more papers has increased their scientific rankings across Latin America. BOL, ECU and PER are less productive: probably a lot of material in those countries is published in low-impact journals that are not recorded in Scopus and other international journal databases.

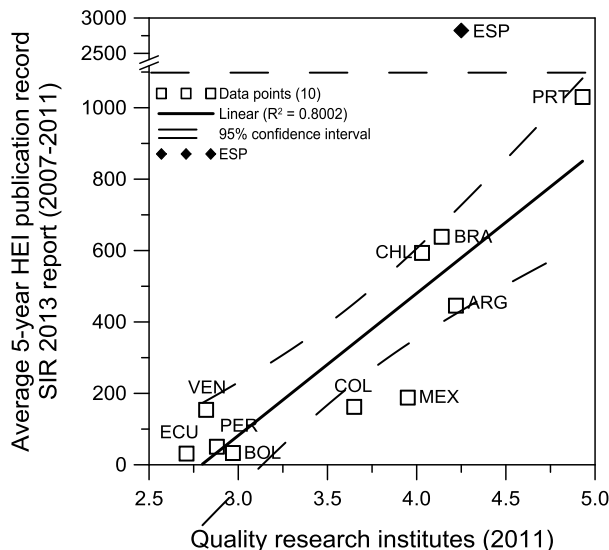


Figure 5. Relation between the average 5-year HEI scientific productivity and the quality of research institutes (SIR 2013 report, period 2007-2011).

As an example, in the BRIC countries (Brazil, Russia, India and China), economic growth and pressure to publish have dramatically increased the quality of science and technology (Lemarchand, 2012; Dragos and Dragos, 2013), suggesting that the lower ranked countries in this survey urgently have to develop policies and measures to enhance the evolution of a primarily teaching oriented higher education system into a system whereby teaching and research are equally present and interconnected, with academic staff associated to faculties responsible for teaching as well as research in disciplinary and/or interdisciplinary departments.

3.3. Higher education has a beneficial effect on a country's socio-economic and technological performance

Confirmation of this hypothesis is provided in Figs. 6 to 10. The content of these figures is based on the country ranking (from 1 to 144) of the independent variable *higher education and training* (x-axis) and various dependent variables on the y-axes in each of the figures. The dependent variables presented on the y-axes are *global competitiveness index (GCI)* (Fig. 6), *technological readiness* (Fig. 7), *innovation* (Fig. 8), *business sophistication* (Fig. 9) and *health and primary education* (Fig. 10). Instead of relating the value of the dependent to the independent parameters, the country ranking for both is presented. For the interpretation of these graphs one has to consider that the lower the country ranks on the x-axis the higher the value and progress of the higher education system of a country are. Similarly, the lower a country rank on the y-axis the higher the country scores in comparison to other countries for the dependent variable.

The effect of the quality of higher education system on Global Competitiveness Index

Figure 6 reveals that the *Global Competitive Index* of the countries is positively related to the quality of their higher education systems, given that abstraction is made of ARG and VEN. The coefficient of determination (R^2) which expresses how well the linear regression line approximates the real data points is 0,777, suggesting that the independent variable can be used as a predictor of the value of the

dependent variable without considerable risk. All countries in the sample, with the exception of ARG (country rank: 53) and VEN (country rank: 68) are situated within the 95% CI.

Despite the fact that both these countries score relatively well on the quality of their HEIs, they are underperforming on the GCI for other reasons. This can be explained perhaps by a failure of local policies and measures designed to stimulate their global competitiveness. Another reason could be that competitiveness, particularly in the case of VEN, is dormant because VEN's economy is largely based on the petroleum and manufacturing sectors which account for 18% of the country's GDP and 95% of its total exports. ESP, PRT and CHL have a better higher education and training system in general, resulting in a higher value of GCI than BRA, COL, MEX and PER (the middle group). BOL scores lowest and ECU performs a bit less than the middle group.

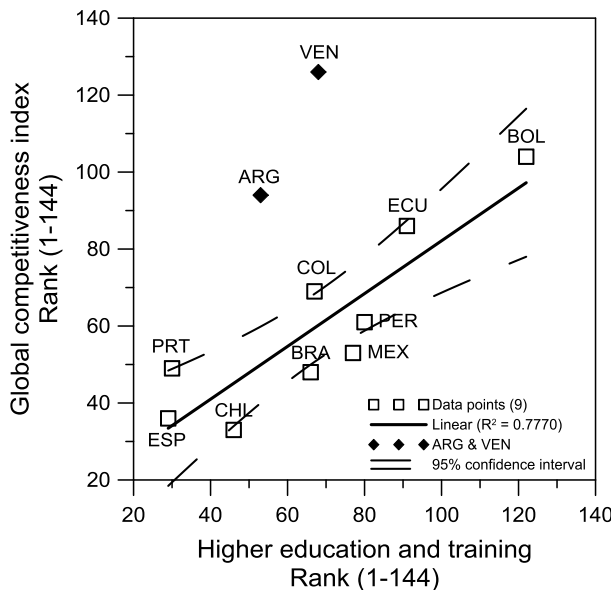


Figure 6. Country rank based on the Global Competiveness Index (GCI) versus the country rank of Higher Education and Training (GCI report 2012-2013).

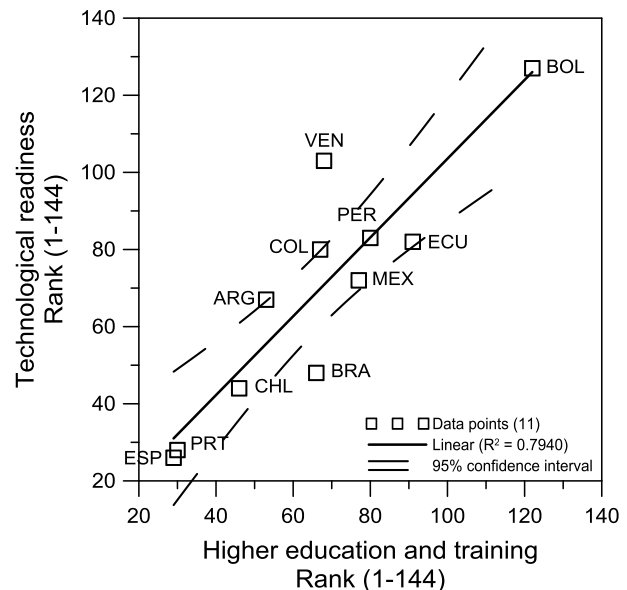


Figure 7. Country rank based on the Technological Readiness versus the country rank of Higher Education and Training (GCI report 2012-2013).

The effect of quality of higher education system on Technological Readiness

Figure 7 shows the relationship between the technological readiness of a country and the quality level of its higher education and training. The better a country scores for higher education and training, the better its technological readiness is. This applies to all countries in the survey. Only BRA and VEN are somewhat outside the 95% CI: VEN underperforms with respect to the derived linear relationship and BRA performs better than one would expect. All other countries are situated within the 95% CI. The coefficient of determination (R^2) is 0,7940, which is a good fit once again, with ESP, PRT, CHL and BRA at the lower (and better) end, the countries ARG, MEX, COL, MEX, PER and ECU forming the middle group and with BOL possessing the least technological readiness and therefore situated at the upper end of the linear relationship. The derived relation permits comfortable prediction of the technological readiness of a country on the basis of the ranking of its higher education system.

The effect of quality of higher education system on Innovation

On the basis of the innovation index the countries in the survey can be split into four groups (see Fig. 8). PRT and ESP rank between the 30th and 40th country position for innovation which relates very well to the good rankings of the higher education systems in those countries. CHL, BRA and MEX rank between the 40th and 60th country rank for innovation whereas for the rankings of the quality of higher education and training those countries are situated between the 40th and 80th country ranks. ARG, COL, ECU and BOL are ranked between the 60th and 100th country rank for innovation; for

the quality of their higher education system they are situated between the 50th and 120th country ranks. Although the quality of the higher education systems in those countries varies considerably, their performance on innovation does not differ greatly. PER and VEN are situated in the last group with respect to the innovation barometer and both countries score between ranks 60 and 80 on the quality of their higher education systems. The scattering of the data in Fig. 8 does not permit for a significant linear relationship to be derived as other factors inhibit accurate or meaningful prediction of the level of the country for innovation on the basis of the country rank for higher education and training.

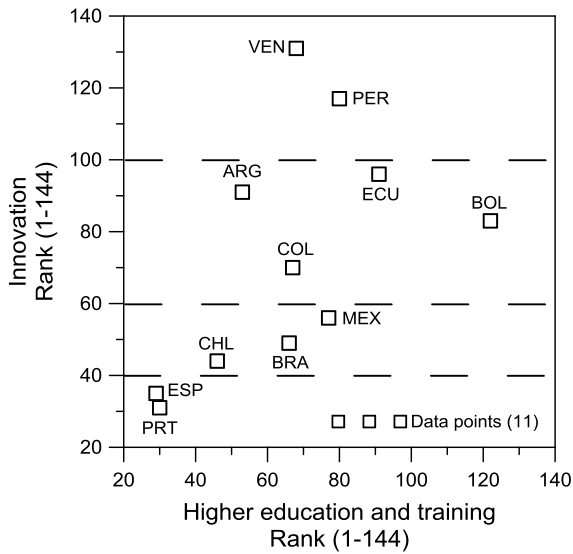


Figure 8. Country rank based on Innovation versus the country rank of Higher Education and Training (GCI report 2012-2013).

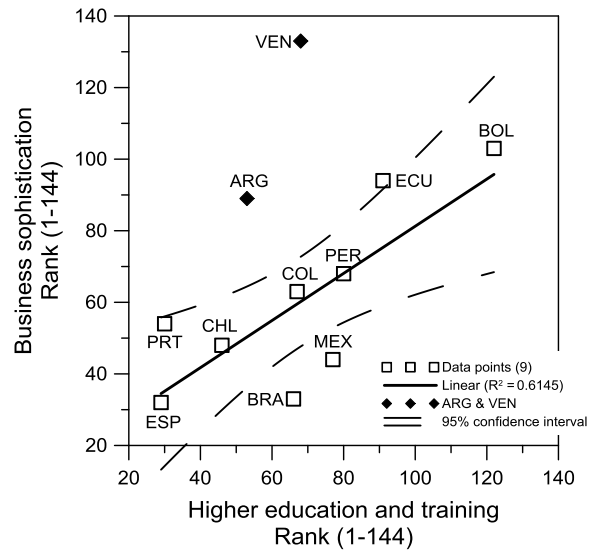


Figure 9. Country rank based on the Business Sophistication versus the country rank of Higher Education and Training (GCI report 2012-2013).

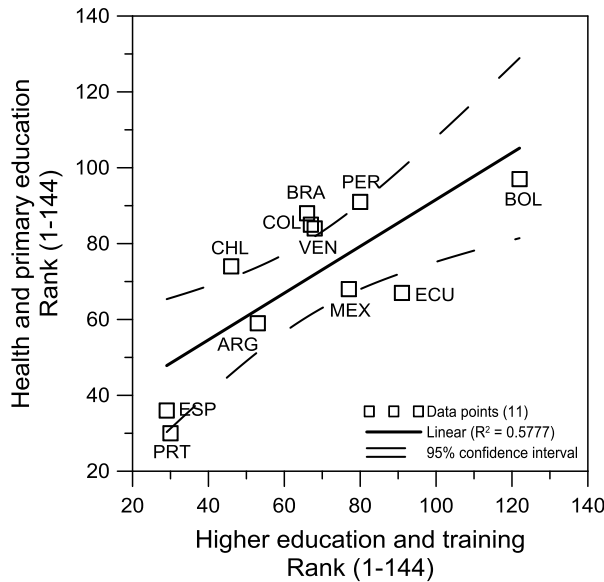


Figure 10. Country rank based on Health and Primary Education versus the country rank of Higher Education and Training (GCI report 2012-2013).

The effect of quality of higher education system on Business Sophistication

The ranking of the countries on the basis of their business sophistication versus the quality of higher education and training yields a less significant, yet still considerable, linear relation ($R^2 = 0,6145$), given that VEN and ARG are excluded (see Fig. 9), as was the case in Fig. 6. Although BRA and MEX are situated somewhat outside the lower level of the 95% CI, all 9 countries are situated along the linear regression in the same order as the ranking for GCI in Fig. 6. With the ARG and VEN data points located in similar locations in Figs. 6 and 9, this indirectly reveals that Global Competitiveness (Fig. 6) and Business Sophistication (Fig. 9) are mutually related; in other words a country's business sophistication strongly defines a country's GCI.

The effect of quality of higher education system on Health and Primary Education

Finally, Fig. 10 depicts that a country's rank for health and primary education is linearly related with its rank for higher education and training, with an R^2 of 0,5777. ESP, PRT, ARG, MEX and ECU are situated at the lower level of the 95% CI, while CHL, BRA, COL, VEN and PER are at the upper level, indicating that the countries at the lower level for the same ranking of the quality of the higher education system possess a better health and primary education system than the others. BOL once again scores lowest.

The analyses presented in the previous figures show that country rankings based on several socio-economic indicators published in the GCI report 2012-2013 correlate well with a country's ranking of its quality of higher education and training. This makes that a country's quality of higher education a relatively good predictor is of its socio-economic development. ARG and VEN, given their moderate to good rankings for education, underperform ranking-wise for the analyzed socio-economic indicators. VEN and BOL score low (high country rank) for most parameters and ESP and PRT score moderate to high (low to moderate country rank). The other countries form a middle group, in which CHL, BRA, COL, MEX perform better than ARG, PER and ECU in general. Figures 6 to 10 show that investment in higher education with an emphasis on quality pays off.

This also confirms the third hypothesis that a high quality higher education and training system positively affects a country's socio-economic and technological performance as well as its global competitive position. It is to be expected that a workforce having undergone mainly a passive system of education is inclined to produce simple manual products primarily, lacking the right skills and capability to absorb new technology and generate new ideas and innovations that promote productivity and bring about new products (Zahlan, 2007). Transition to a knowledge-based economy greatly depends on the development of innovative capacities in its workforce. These are strongly interlinked with the system of education in which learning outcomes should emphasize promotion of critical thinking skills together with creativity and problem solving capacities. In order to achieve this, students and faculty should be exposed to more advanced research activities.

3.4. *The scientific productivity of a country's higher education system is a good barometer of government effectiveness, knowledge and technology output, and the GDP per capita*

In the Figs. 11, 12 and 13 the average scientific productivity of the HEIs at the country level is used as a predictor for estimating the effectiveness of their government, their knowledge and technology output and their GDP per capita. The government effectiveness indicator (see Fig. 11) is a measure of the quality of a country's public services, the quality of its civil service and its independence from political pressures, the quality of policy formulation and implementation and the credibility of the government's commitment to its stated policies. This indicator is an index combining up to 15 different assessments and surveys, depending on availability. Each indicator receives a different weight, depending on its estimated precision and country coverage. The index values range from -2,5 (very poor performance) to +2,5 (excellent performance).

The knowledge and technology output indicator measures the following characteristics of a country: knowledge creation, knowledge impact and knowledge diffusion. It covers all the variables that are traditionally considered to be the fruits of inventions and/or innovations. The overall score for

a country ranges from 0 to 100. Based on their calculated scores, the countries in the survey were ranked and their country rank is depicted in the y-axis of Fig. 12. Figure 13 relates the average scientific productivity of the HEIs at the country level to their GDP per capita.

The linear relationships in all three figures are significant with R^2 values of 0,5642, 0,8113 and 0,6688 respectively. In all graphs a similar pattern of data points can be distinguished: ESP falls out of the range of the other 10 countries of the survey. The average HEI publication record of this country cannot be used as a predictor, at least not within the group of the countries studied. PRT, although belonging to Europe, fits very well within the group of the Latin America countries. It is within the 95% CI (or very close) in each of the figures. This is also the case with BOL but then at the extreme lower end.

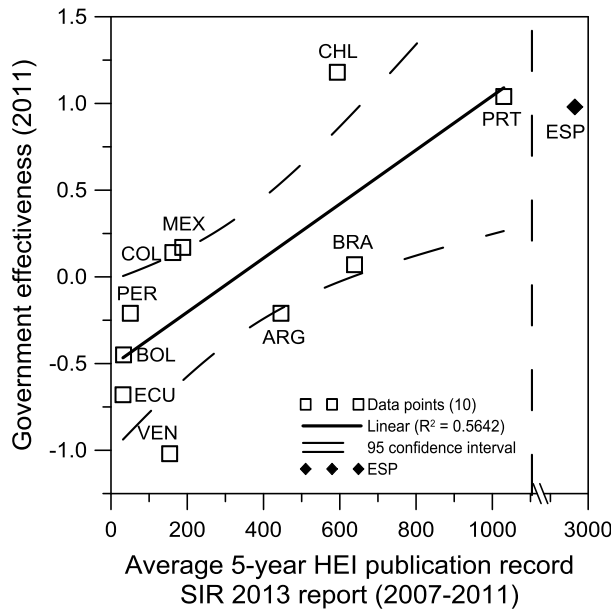


Figure 11. Relation between the Government Effectiveness indicator (2011) and the average 5-year HEI scientific productivity (SIR 2013 report, period 2007-2011).

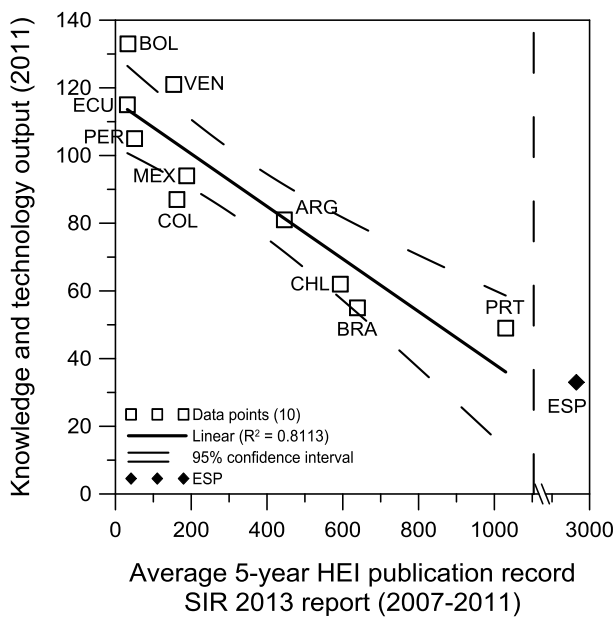


Figure 12. Relation between the knowledge and technology output (2011) (country rank) and the average 5-year HEI scientific productivity (SIR 2013 report, period 2007-2011).

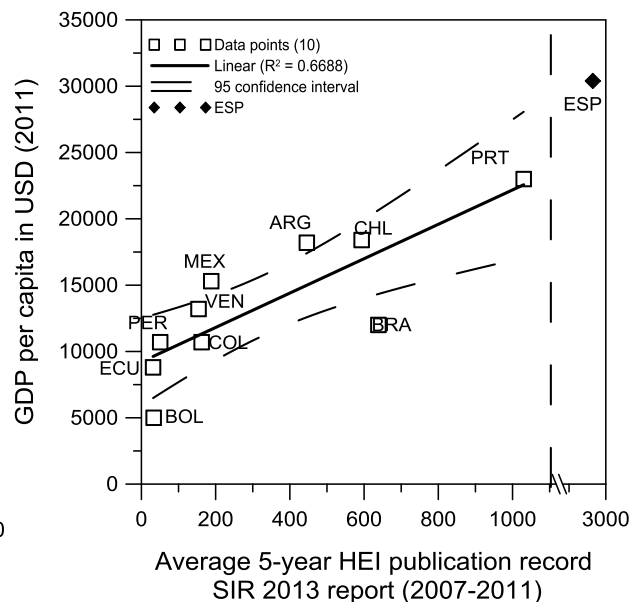


Figure 13. Relation between GDP per capita (USD) and the average 5-year HEI scientific productivity (SIR 2013 report, period 2007-2011).

ARG, BRA and CHL form a middle group, whereas BOL, COL, ECU, MEX, PER and VEN have a lower average scientific output per HEI and as such score lower (meaning a higher country rank in Fig. 12) for government effectiveness, knowledge and technology output and GDP per capita. In fact, this group can be further divided into two distinct groups: the countries COL, MEX and VEN with an average 5-year publication record in the order of 150-200, and BOL, ECU and PERU with a considerably lower HEI average 5-year scientific output between 30-50 research papers. With respect to the dependent variable, MEX in general scores better than COL and COL is considerably better than VEN. In general, BOL has a higher country rank than ECU and PER has a lower country rank than ECU.

4. DISCUSSION

The relation between higher education and a number of country performance indicators was discussed for 11 countries of the Latin American region. It was shown that the scientific output of HEIs in addition of being a useful barometer for the quality of higher education institutes is also a useful indicator of the government effectiveness, the knowledge and technology output of a country and the country's overall economic output (GDP). The analysis further revealed that ESP and PRT, belonging to the European Community, possess a better quality education system with considerable higher scientific output than the analyzed countries in Latin America. BRA, CHL and ARG form a middle group, with low to moderately performing HEIs and a considerably lower research output in terms of indexed papers than ESP and PRT. These countries possess some outstanding HEIs that meet international standards and generate high research output. However, the top is very narrow and it would be of great interest to determine if those institutions were operated on private or public funding. A third group of countries that can be discerned are COL, MEX and VEN. The HEIs in these countries are of a lower quality as measured by a much smaller scientific output than ESP and PRT but also ARG, BRA and CHL. Ultimately, the higher education institutes in BOL, ECU and PER score lowest and have a meager average 5-year publication record. In each of the countries surveyed a huge variability in the quality and research output of their individual HEIs exists.

In order to compare the average research intensity of the HEIs of the 11 surveyed countries in Latin American to their global counterparts, their position was examined using the classification of the HEIs as published in the *SIR 2012 World Report*. The *SIR 2012 Iberoamericano Report* lists only HEIs possessing one or more paper registered in Elsevier's *Scopus Database*, covering the period 2006-2010, a total of 1598 HEIs. The *SIR 2012 World Report* includes 3290 institutions that together are responsible for more than 80% of worldwide scientific output during the term 2006-2010. This means that all HEIs with less than 100 publications per year, indexed in the *Scopus Database*, are excluded from the *SRI World Report*, excluding a large number of HEIs, primarily those situated in developing and emerging countries.

Table 2 provides the following information for each country in the survey: the number of HEIs that are ranked in both the *SIR 2012 Iberoamericano Report* and the *SIR 2012 World Report*, the number of HEIs in world's top 100 HEIs, the range of the country rank of Latin American HEIs in the *SIR 2012 World Report*, the range of papers indexed in Elsevier's *Scopus Database* and the range of excellence.

As Table 2 shows, neither BOL nor ECU contains an HEI that ranks among the first 3290 HEIs in the *SIR 2012 World Report*. The number of HEIs in COL, MEX, PER and VEN that classify for inclusion in the *World Report* is less than 10% of the national HEIs, varying from 3,3% (PER), 4,0% (COL), 6,8% (MEX) to 9,8% (VEN). The HEIs in ARG, BRA, and CHL tend to have a better quality on average and are better represented in the world forum of universities, with 18,9% of Brazil's HEIs qualifying for inclusion in the *SIR 2012 World Report*, 19,4% of HEIs for ARG qualifying and 23,3% of HEIs in CHL qualifying for inclusion. The HEIs of ESP and PRT, being at the top of the surveyed group of HEIs in this study, include 42,0% (PRT) and 56,4% (ESP) of their HEIs in the *World Report* and thereby contribute to the 80% of the worldwide scientific output.

Only one university in the Latin American region belongs to the world's 100 top universities: the Universidade de Sao Paulo of Brazil occupies the 11th world rank, with a 5-year scientific output of 44.619 indexed papers. The scientific productivity of the first ranked universities in the other countries varies between 832 for PER and 18.568 for MEX in the period 2006-2010.

Table 2. Position of the HEIs of the surveyed countries in the SIR World Report 2012.

Country code	Number of HEIs in the SIR World Report 2012 ¹	Number of HEIs in world's top 100 HEIs ²	Range country rank ³	Range total published papers in the period 2006-2010 ⁴	Range excellence rate (%) ⁵
ESP	53 (56,4%)	-	165 - 3254	15.611 - 373	7,2 - 19,4
PRT	19 (42,0%)	-	270 - 3023	11.159 - 571	7,5 - 19,3
ARG	18 (19,4%)	-	285 - 3040	10.675 - 565	2,9 - 11,0
BOL	-	-	-	-	-
BRA	83 (18,9%)	1	11 - 3288	44.619 - 236	1,0 - 17,2
CHL	14 (23,3%)	-	421 - 3242	7.874 - 401	5,0 - 12,6
COL	7 (4,0%)	-	757 - 3088	4.367 - 534	5,1 - 12,9
ECU	-	-	-	-	-
MEX	24 (6,8%)	-	115 - 3260	18.568 - 350	2,4 - 19,2
PER	2 (3,3%)	-	2565 - 3153	832 - 504	7,3 - 12,6
VEN	6 (9,8%)	-	1195 - 3236	2.536 - 409	2,7 - 4,7

Legend:

¹ Number of HEIs in the SIR Iberoamericano Ranking report 2012 listed in the SIR World Ranking report 2012. Numbers between brackets gives the percentage of the HEIs in the SIR World Ranking report with respect to the HEIs listed in the SIR Iberoamericano Ranking. The total number of HEIs in the Sir World Ranking report is 3290.

² Number of HEIs in Latin America listed in the top 100 HEIs.

³ Country rank of the HEI with respectively the highest and lowest 5-year total number of published papers archived in Scopus.

⁴ Range of the total number of papers archived in Scopus in the period 2006-2010.

⁵ Range of the excellence rate (%) indicating the amount of an institution's scientific output that is included into de set of the 10% of the most cited papers in their respective scientific fields. It is a measure of the high quality output of HEIs.

5. CONCLUSION

The distribution of the top 100 HEIs per subcontinent is as follows: Africa 0%, Eastern Europe 0%, Middle East 0%, Latin America 1,2%, Oceania 5%, Western Europe 18,8%, Asia 26,3%, North America 48,7%. These percentages show that the research universities in Canada and the United States by and large dominate science, followed by Asia and Western Europe. They are also reflective of the funding efforts (either private or public) that are made in support of research development on those continents and of the important position it holds in those societies. Clearly, North-America, Asia and Western-Europe have realized the important role science plays in society and they look for answers to their problems in their universities in return for the funding they provide their HEIs. It is not an exaggeration to state that Latin America boasts some giant universities, some having an impressive scientific output, yet there are only a few. With the exception of a limited number of institutions in a limited number of countries, research output is unimpressive, teaching techniques are old-fashioned and students tend to drop out in or do not complete their studies in droves (Paus, 2004).

A growing percentage of HEIs in ARG, BRA and CHL is entering the world forum of universities and these countries are leading the way when it comes to research development on the continent. Their governments, more so than in other countries, are increasingly aware of the value of research and of

the growing role universities can play in addressing their problems. As this analysis showed Latin America is not a major player in the international research arena and a tremendous effort is required in order for more Latin American HEIs to qualify among the top 100 world group of universities and for the HEIs to increase their research output. For this to happen, governments and funding agencies need to realize at the macro-level that there is a clear correlation between investment in research productivity and a country's socio-economic growth. For universities in Latin America to improve they need to be given the resources and the infrastructures to grow. Yet, at the same time universities should also look inward to see what can be done at the micro-level to improve not only their research productivity but also their teaching efforts.

These failings in research output all matter: faster economic growth is driving a big increase in demand for better higher education in the region. It has established a need for more and better HEIs that focus increasingly on research and that are able to answer some of a country's burning questions. Yet this effort is a two-way street: it is not only a matter of enhanced government interest in and support of the research effort, but also a matter of universities looking at how they themselves can change age-old mentalities and their narrow emphases on teaching. The continent is growing by leaps and bounds and its economic position in the world is growing: now it is the time to translate that position and those changes into concrete and long-term strategic decisions in favor of some structural societal changes. The development of the research effort in the university systems is one of those changes and it will bring long-term benefits and further enhance the role that South America plays on the world stage.

Future research could be directed at several important questions: What are the likely reasons that the higher education systems in Latin America are under performing as compared to those in other continents? Are there any causal factors that inhibit the growth of scientific development? And finally, what needs to be done to enhance the quality and quantity of their scientific output?

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