

Characterization Of Universities In Countries With High GDP Investment In Research And Development

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Abstract.

Investment in public spending on research and development is a widely used indicator in studies of countries on their economic development, innovation and research. According to the World Bank, 36 countries (16.6%) devote 1% or more of their GDP to this sector. A descriptive analysis of the main universities by country in this group is carried out with respect to their positioning in rankings of scientific production, age and type of institution, applying descriptive statistics and clustering. The Research and Development expenditure (% of GDP) of the countries did not show significant correlation with the number of universities ranked in CRS per inhabitant, nor with the positioning of the country in SCimagoJCR. However, these countries occupy the first 60 positions in this global ranking. Moreover, the positioning of these universities in the SIR and Innovation Rank published by Scimago does show a moderate correlation with the investment in research and development in the country, occupying the first two quartiles of positions. With respect to antiquity, 78% of these institutions are more than 100 years old, and 8% of them have been in operation for more than six centuries. Regarding the type of institution, 86% are public and 9% private.

Keywords: Investment in research and development, GDP, universities, countries, ranking.

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1 Introduction

According to the World Bank (2020) [1], the Research and development expenditure (% of GDP) represents the percentage of GDP devoted to basic and applied research and experimental development. On the other hand, the Frascati Manual published by the OECD [2] also adds that this expenditure is that made by the Government in R&D and in the higher education sector in R&D carried out within the country, and financed internally, excluding payments for R&D carried out abroad.

Various studies on competitiveness, report relationships between economic policies, scientific production, education levels and innovation of countries, which contributes to the definition of national and regional strategies to achieve higher levels of development and international positioning [3][4][5]. Thus, higher education, as a variable that influences

the development of countries, is part of the factors that drive economic growth and development, in addition to being a determinant of the competitiveness of nations. The studies on this subject began with a greater boom in the nineties with the advent of the theories of endogenous growth [6].

The analysis of scientific production in universities and its relationship with the economic development of the countries, in addition to the evaluation of the level of innovation achieved in the nations, have in common as the main input variable the expenditure on research and development. In this order of ideas, the higher education is subject to global challenges when being evaluated by excellence, quality and pertinence, being one of the instruments to measure the university rankings, of wide diffusion and heterogeneity, which compare and order the institutions in a descending way, as a result of evaluating a set of criteria and indicators of quality [9].

Then again, spending on research and development contributes to improving the position in global rankings, which, in addition, as instruments of transparency, provide relevant, reliable and valid information, which serves as a basis for funding and political decisions by governments [10][11]. Thus, efforts in research and development, and advances in innovation, have proven to have an effect on the economic development of countries, and consequently on higher education. To this end, countries with

investment in research and development equal to or greater than 1%, according to the World Bank [1], make up a select group of 36 countries which represent 16.6% worldwide. It is worth asking what are the characteristics of universities in countries whose investment in research and development exceeds 1% and how this affects the positioning of both the country and these institutions in global rankings of scientific production, such as SJCR [12] and SIR [13], published by Scimago).

Nomenclature

GRD	Research and Development expenditure (% of GDP)
SJCR	Scimago Journal & Country Ranking
SIR	Scimago Institutions Ranking
WB	World Bank
Top1plus	Set of countries with Research and Development Expenditure (% of GDP) equal to or greater than 1%

2 Methodology

Among the development indicators published by the World Bank [1] is Research and development expenditure (% of GDP) (GRD) which represents gross domestic expenditure on R&D, expressed as a percentage of GDP, where R&D covers basic and applied research and experimental development. Considering this indicator in this database, the following is done:

- Identify the countries whose GRD value is the most current, and equal to or greater than 1%. There are 36 countries, representing 16.6% of the total countries reported by the World Bank (see Table 1). The updated values found correspond to the period 2017-2018.
- Collect from each selected country its position in the Scimago Journals and Countries Ranking

- (SJCR) [12], which is a classifier of countries according to the quality of their scientific publications, reporting a list of 234 countries; this includes scientometric indicators developed from the information contained in the Scopus® database.
- Collect for each country: population and number of universities.
- Identify the two main universities by country, according to the Scimago Institutions Ranking in 2019 [13], thus totaling 71 universities for this study. In the case of Luxembourg, only one university was found to be ranked in SIR.
- Collect data on each university in addition to scientometric indicators published in the Scimago Database.

Table 1. Countries with investment in research and development equal to or greater than 1% of their GDP.

Country's Name	Country's Code	%GRD ^a	SJCR ^b Position	Population ^a (x1000)	Total universities ^c in SIR Rank
Israel	ISR	4.95	36	9053	11
Korea, Republic of	KOR	4.81	13	51709	87
Switzerland	CHE	3.37	19	8575	16

Sweden	SWE	3.34	20	10285	28
Japan	JPN	3.26	6	126265	178
Austria	AUT	3.17	28	8877	19
Germany	DEU	3.09	5	83133	83
Denmark	DNK	3.06	25	5819	8
United States	USA	2.84	2	328240	477
Belgium	BEL	2.82	24	11484	11
Finland	FIN	2.77	38	5520	13
France	FRA	2.20	8	67060	119
China	CHN	2.19	1	1397715	443
Netherlands	NLD	2.16	16	17333	18
Norway	NOR	2.07	33	5348	12
Iceland	ISL	2.03	87	361	2
Singapore	SGP	1.94	37	5704	6
Slovenia	SVN	1.94	60	2088	5
Czech Republic	CZE	1.93	31	10670	21
Australia	AUS	1.87	11	25364	42
United Kingdom	GBR	1.72	3	66834	119
Canada	CAN	1.57	9	37589	60
Hungary	HUN	1.55	50	9770	14
Estonia	EST	1.43	71	1327	4
Italia	ITA	1.40	7	60297	70
New Zealand	NZL	1.37	41	4917	9
Portugal	PRT	1.37	26	10269	26
United Arab Emirates	ARE	1.30	52	9771	11
Brazil	BRA	1.26	14	211050	122
Spain	SPN	1.24	12	47077	65

Luxembourg	LUX	1.24	78	620	1
Poland	POL	1.21	17	37971	59
Greece	GRC	1.18	39	10716	22
Ireland	IRL	1.15	42	9053	11
Russian Federation	RUS	1.11	10	144374	112
Thailand	THA	1.00	40	69626	22

Sources:

^a World Bank 2017, 2018 [1].

^b Scimago Journal & Country Rank (SJR) 2019 [12].

^c Scimago Institutions Ranking 2019 (SIR) [13].

For data analysis, descriptive statistics, data correlation and scatter diagrams are applied as tools to characterize country and university clusters regarding:

- Countries in the study with Research and Development Expenditure (% of GDP) equal to or greater than 1%.
- Major universities in these countries in terms of: relationship of the indicator Research and Development Expenditure (% of GDP) of the country with respect to the positioning of the universities in the SIR Ranking and the Innovation Rank published by Scimago; and, age and type of university.

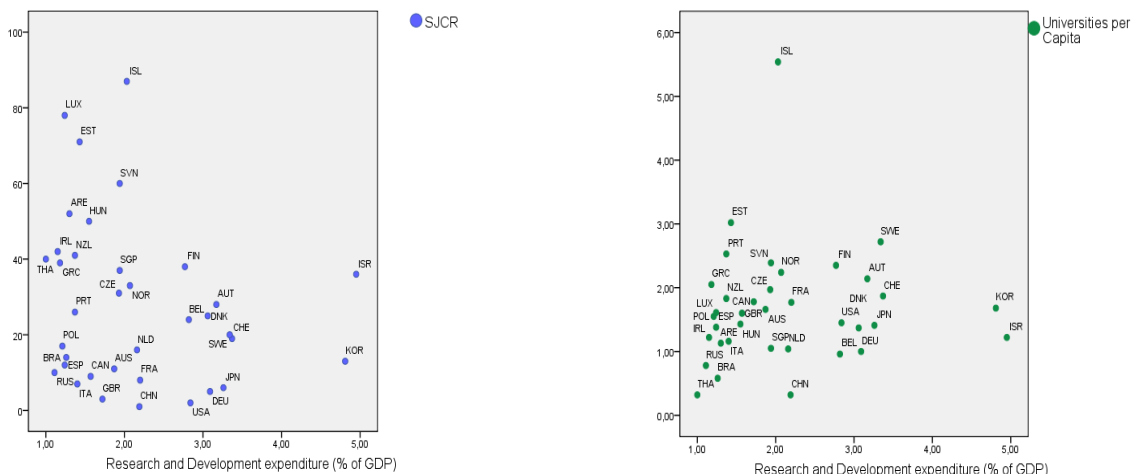
3 Results

3.1 Characterization of countries with Research and Development Expenditure (% of GDP) equal to or greater than 1%

By country, the indicator *Universities Per Capita (UPC)* was calculated from the *Country's Population*

and the number of universities listed in the Scimago Institution Ranking (SIR); a moderate correlation (0.544) was found between this indicator and the country's position in the Scimago Journal & Country Rank (SJCR). There is also a high correlation (0.792) between the country's population and the number of universities ranked in SIR.

The relations between Research and Development expenditure (% of GDP) (GRD) with *Universities per capita* (0.058) and the Positioning in SJCR (-0.234) are very low (Figure 1), being these not significant. It is observed that most countries show a percentage of investment below 3%, and are occupying the first 60 positions in a global ranking of scientific production that catalogues countries up to position 500. In addition, they present an average of 1.6 universities positioned in the SIR ranking for every million inhabitants



a) Relationship between Investment in Research and Development and the country's positioning in the SJCR Ranking.

b) Relationship between Investment in Research and Development, and Universities per capita.

Fig. 1. Ratio of Research and Development expenditure (% of GDP) with the country's position in the Global Ranking of Scientific Production (SJCR) and with the number of universities per inhabitant.

3.2 Characterization of universities

The first two universities were identified in the national ranking published by the Scimago Institution Ranking (SIR) for the year 2019 for each of the 36 countries that make up this study. A total of 71 institutions were collected. In the case of Luxembourg, only one university was found in this national ranking

(Table 2). The following are the results of the characterization of the universities according to the criteria of: relation of their worldwide positions in the SIR Ranking with respect to the GRD of the country, age and type of institution.

Table 2. Main Universities of the countries selected for the study.

Country	Universities	Acronym	Country	Universities	Acronym
ARE	Masdar Institute of Science and Technology	Masdar	IRL	University College Dublin	UCD
ARE	United Arab Emirates University	UAEU	IRL	Trinity College Dublin	TCD
AUS	University of Melbourne	UNIMELB	ISL	Reykjavik University	HR
AUS	University of Sydney	SYDNEY	ISL	University of Iceland	HÍ
AUT	Medizinische Universität Wien	MedUniWien	ISR	Tel Aviv University	TAU
AUT	Universität Wien	Univie	ISR	Weizmann Institute of Science	WIS
BEL	Ghent University	UGent	ITA	Università degli Studi di	UNIMI

BEL	Catholic University of Leuven	KUL	ITA	Milano Universita degli Studi di Roma La Sapienza	Sapienza
BRA	Universidade Estadual Paulista Julio de Mesquita Filho	UNESP	JPN	University of Tokyo	Utokyo
BRA	Universidade de Sao Paulo	USP	JPN	Kyoto University	KyotoU
CAN	University of Toronto	UofT	KOR	Seoul National University	SNU
CAN	The University of British Columbia	UBC	KOR	Yonsei University	YONSEI
CHE	Swiss Federal Institute of Technology	ETH	LUX	Universite du Luxembourg	UNILU
CHE	Ecole Polytechnique Federale de Lausanne	EPFL	NLD	Utrecht University	UU
CHN	Tsinghua University	THU	NLD	University of Amsterdam	UvA
CHN	Peking University	PKU	NOR	University of Bergen	UiB
CZE	Masaryk University	MUNI	NOR	University of Oslo	UiO
CZE	Charles University	CUNI	NZL	University of Auckland	Auckland
DEU	Technische Universitat Munchen	TUM	NZL	University of Otago	Otago
DEU	Ludwig-Maximilians Universitat Munchen	LMU	POL	University of Warsaw	UW
DNK	Aarhus University	AU	POL	Jagiellonian University	UJ
DNK	University of Copenhagen	UCPH	PRT	Universidade de Lisboa	UL

ESP	Universitat de Barcelona	UB	PRT	Universidade do Porto	Uporto
ESP	Universitat Autònoma de Barcelona	UAB	RUS	Lomonosov Moscow State University	MGU
EST	Tallinn University of Technology	TalTech	RUS	Saint Petersburg State University	SPBU
EST	University of Tartu	UT	SGP	Nanyang Technological University	NTU
FIN	Aalto University	Aalto	SGP	National University of Singapore	NUS
FIN	University of Helsinki	HY	SVN	Jozef Stefan International Postgraduate School	IJS
FRA	Sorbonne Université	Sorbonne	SVN	University of Ljubljana	Ulj
FRA	Ecole Pratique des Hautes Etudes	EPHE	SWE	Karolinska Institute	KI
GBR	University College London	UCL	SWE	Lunds University	LU
GBR	University of Oxford	OX	THA	Mahidol University	MU
GRC	Aristotle University of Thessaloniki	AUTH	THA	Chulalongkorn University	CU
GRC	University of Athens	NKUA	USA	Harvard Medical School	HMS
HUN	University of Szeged	SZTE	USA	Harvard University	HU
HUN	Semmelweis University	Semmelweis			

Table 4. Universities by age and type.

Age	Average (years)	Number of Universities	Public	Private	Private not for profit	Federal state-owned	Public research university
1 Less than 50 years	24	8 11%	5 8%	1 17%	2 100%		
2 Between 50 and 100 years	81	8 11%	8 13%				
3 Between 100 and 200 years	136	30 42%	28 46%	2 33%			
4 Between 200 and 300 years	235	8 11%	6 10%	1 17%		1 100%	
5 Between 300 and 400 years	380	6 8%	5 8%	1 17%			
6 Between 400 and 600 years	536	5 7%	4 7%	1 17%			
7 More than 600 years	716	6 8%	5 8%				1 100%

All of them 71 61 86% 6 9% 2 3% 1 1% 1 1%

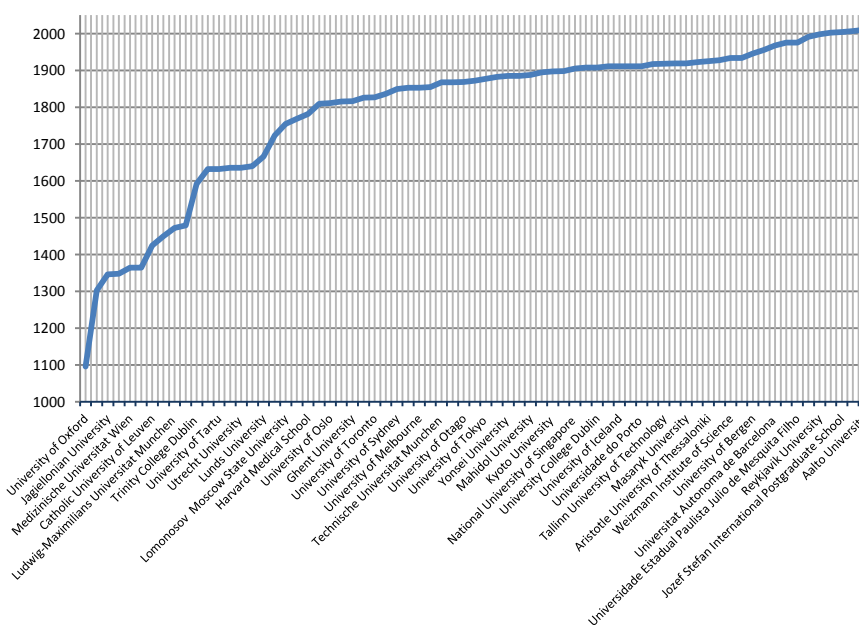


Fig. 3. Chronology according to the year of foundation of the universities of the study.

4 Conclusions

The investment of public expenditure in research and development is a useful indicator for studies on economic development, innovation and research in the countries. In this study, 36 countries were identified in the report published by the World Bank that reflect contributions to development and research equal to or greater than 1% of their GDP, representing 16.6% of countries worldwide. It is therefore of interest to know

some characteristics of the main universities in this particular group of countries. A descriptive analysis of the countries is made based on this investment with respect to their universities and their positioning as a country in rankings of scientific production. Additionally, two of the main universities per country were compiled, totaling 71 institutions, which were characterized according to their positioning in global rankings of universities, age and type of institution.

Among the most outstanding findings is that most of these countries are below 3% of Research and Development expenditure (% of GDP), and have an average of 1.6 universities positioned in the SIR ranking for every million inhabitants, which is a very favorable figure about the academic offer of these countries. On the other hand, no significant correlation was found between Research and Development expenditure (% of GDP) and the number of universities per inhabitant (universities ranked in SIR). Likewise, no significant correlation was found with the country's positioning in the Scimago Journal & Countries Ranking. However, this group of countries occupies the first 60 positions in this ranking, which catalogues up to the position 500, being evident the leadership and excellence at world-wide level of these countries with respect to their scientific production.

In relation to the positioning of universities in the SIR and Innovation Rank published by Scimago, it was found that there is a moderate correlation with investment in research and development in the country. These universities occupy the first two quartiles of positions in these rankings. Regarding their age, 78% of these institutions are more than 100 years old, and 8% have been in operation for more than six centuries. With regard to the type of institution, 86% are public and 9% are private.

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