

Article

Innovation and Scientific Research as a Sustainable Development Goal in Spanish Public Universities

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Abstract: One of the Sustainable Development Goals for 2030 is building resilient infrastructure, promoting inclusive and sustainable industrialisation, and fostering innovation. This paper aims to analyse the possible consequences of stimulating commercial exploitation of academic research, encouraged by recent policy initiatives and legislative changes, on the quantity and quality of scientific knowledge in Spain's public universities. We collected data of innovation variables (national patents, R&D and consultancy agreements, services rendered, licenses and PCT extensions and spin-offs), publications and number of citations for 48 Spanish public universities in 2009–2018 from *Observatorio IUNE*, which obtains data from the Spanish Patent and Trademark Office, the Network of Research Results Transfer Offices and Web of Science. The results of linear regressions models showed that universities that render more services and have a greater number of PCTs (patent cooperation treaties), have a positive impact on the quantity and quality of the publications in Spanish universities. However, the number of national patents has no impact on the scientific output. Finally, universities with a greater number of patents have a lower number of citations.

Keywords: academic patenting; publications; universities; Spain



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1. Introduction

Universities have always been seen as institutions aimed at teaching and research. The first academic revolution in Germany, when universities began to engage in research, took place in the 19th century. The idea that one of the objectives of a university should be the economic and social development of the region began in the second half of the 20th century; in other words, the university must have a “third mission”, and the concept of “entrepreneurial university” was born at this time [1]. According to the definition of Grimaldi et al. [2], an entrepreneurial university refers to the commitment of the university to the commercialisation of research, including formal mechanisms [3–5] and informal mechanisms [5–7]. In recent decades, most European universities have created transfer technology offices (TTOs), whose main objective is to serve as intermediaries between university scientists and those who could help commercialise innovations [8].

According to Philpott et al. [9], Schmitz et al. [10], Guenther and Wagner [11], Miller et al. [12] and Liu and van der Sijde [13], the universities' entrepreneurial activities should include:

- Teaching and producing high-quality students: to provide the public and private sectors with skilled undergraduates and postgraduates;
- Providing specialised teaching and lifelong learning opportunities: to offer training courses outside of the traditional programmes, especially serving employees from the public and private sectors;
- Teaching entrepreneurship: to produce future entrepreneurs;

- Publishing and communicating scientific information: to disseminate knowledge and to communicate through publishing scientific papers, books among others, after the preservation of intellectual property, and through publishing in informal journals;
- Patenting and licensing: to preserve intellectual property rights to research findings and technology invented within the universities;
- Consulting: to provide consulting services to the public and private sectors to help them improve their operations;
- Conducting contract and collaborative research: to conduct research based on signed contracts in cooperation with the public and private sectors;
- Participating in incubator facilities/science and technology parks: to maintain or participate in social and business incubator facilities and science and technology parks to do research and create and developing new ventures;
- Forming spin-off firms: to create firms based on the universities' research findings;
- Maintaining university technology transfer offices (TTOs): to transfer knowledge and technology to new or existing companies.

In 2015, heads of state and government met at the historic Sustainable Development Summit, where they approved the 2030 agenda. This agenda contains 17 Sustainable Development Goals (SDGs) of universal application that govern countries' efforts to achieve a sustainable world by 2030. The 9th goal is building resilient infrastructure, promoting inclusive and sustainable industrialisation and fostering innovation. Our article is associated with Target 9.5, which aims to enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per one million people and public and private research and development spending.

The study analyses the scientific research and innovation in the 48 Spanish public universities for the years 2009–2018 with multiple linear regression to establish if innovation affects the quantity and quality of scientific research. This investigation fills a research gap since there are no university-level studies in Spain.

The paper is organised into the following sections: Sections 2 and 3 present the literature review and methodology. Section 4 provides information about the spatial distribution of public universities in Spain. Section 5 presents the results of the econometric analysis of Spanish universities. Lastly, Section 6 concludes this study.

2. Literature Review

Certain studies have suggested that increasing academic patenting is having a negative impact on the dissemination of scientific knowledge, resulting in a substitution effect between the generation of scientific and technological knowledge [14–18]. By contrast, other groups of studies reveal that academic researchers who obtain patents due to their research are more active in the generation of scientific knowledge. Van Looy et al. [19] conducted a study for the Catholic University of Leuven in Belgium, and they found out that inventors publish more than their peers who do not patent but who work in similar fields and have similar careers. Stephan et al. [20], using a survey of doctoral recipients in the U.S. in 1995, revealed that patents have a positive and significant effect on the number of publications. Crespi et al. [21] conducted a survey of academic researchers who had received grants from the U.K. Engineering and Physical Sciences Research Council (EPSRC) in the period 1999–2003 and concluded that academic patenting complements publishing up to 10 patents, after which they found evidence of a substitution effect. Kang and Lee [22] studied the relationship between patents and publications in a sample of scientists in the field of biotechnology and who are members of the Korean Society for Biochemistry and Molecular Biology, based on a survey in April 2008. The survey consisted of a series of questions relating to patent applications, technology transfer, commercialisation of patents, etc. They analysed the data using statistical and econometric methods. The results showed that productivity technology enhanced scientific productivity. Grimm and Jaenicke [23]

analysed university patentees at the German Laender Bavaria, Saxony and Thuringia. They used the Granger causal-effects methodology and concluded a positive correlation between patenting and publication performance. Furthermore, personal characteristics such as seniority, academic degree and non-university work experience were associated with a higher publication output.

Other studies obtained the same conclusion in different countries such as Italy [24], France [25], Taiwan [26], the United Kingdom, Germany and Belgium [27] and the United States [28], or by studying specific fields, for example, Van Looy et al. [29] in the biotechnology sector, Klitkou and Gulbrandsen [30] for life sciences, and Lakner et al. [31] for the pharmaceutical sector.

On the other hand, many works show a positive effect of patents on scientists' publications in terms of quality. The pioneering work by Agrawal and Henderson [32] analysed a sample of professors from the Department of Mechanical and Electrical Engineering at the Massachusetts Institute of Technology in the period 1983–1997. The study established a positive correlation between the increase in patents and the increase in citations in publications. The results of Murray and Stern [33] in which the data are based on all the articles published in the journal *Nature Biotechnology* during the period 1997–1999, refer to the fact that the publications' citations decreased after granting related patents. Fabrizio and Di Minin [34], whose sample comprised university professors between 1975 and 1995, concluded that inventors decreased the average number of citations of their publications. Goldfarb et al. [35] carried out an analysis at Stanford University, in the Department of Electrical Engineering and for the years 1990–2000, in which they find some evidence that an inventive step increases the quality of scientific publications. Tsai-Lin et al. [36], from a panel data set (2001–2010) from 377 faculties of the National Tsing Hua University, concluded that inventors have a higher quality scientific output than scientists who did not apply for patents.

The majority of the literature analyses the relationship between patents and publications at the individual level, and there is little research at the university level.

Owen-Smith [37] conducted an investigation using the 89 American universities with the highest scientific production during the period 1981–1998 as the unit of analysis. The patent data for the period 1976–1998 were extracted from the United States Patent and Trademark Office, identifying four variables—volume of patents (number of patents assigned to a given university in a given year), previous patents (number of patents assigned to a particular university in previous years), patents in collaboration with companies (number of patents in collaboration with companies per university in a given year) and patents before the Bayh–Dole Act (number of patents assigned to a university in the period 1976–1981). The indicators of scientific reputation were public funding for research personnel in training (in thousands of dollars) and the average of the impact factor of the publications standardised by the average of the impact factor of all the articles published in a given year (collected from the Institute for Scientific Information's database). On the other hand, the universities' research capacity was measured through research and development expenditures from all sources, research and development expenditures from industrial funds, and researchers' total number. Among the variables related to experiential learning (among which are those discussed above, such as prior patents and patents prior to the Bayh–Dole Act), there was also the age of the Technology Transfer Office, measured as the number of years since the university first devoted at least 0.5 full-time staff exclusively to patenting and licensing activities. Lastly, institutional wealth was measured using the book value of heritage assets. The authors carried out five econometric models, the main ones being those in which the number of patents and the impact factor were used as dependent variables. Its main conclusions were that technological and scientific production mutually reinforce each other and that the impact factor of scientific publications has a positive effect on the number of patents.

Wong and Singh [38] examined the relationship between the inventive step and the quantity and quality of the publications of the 281 best universities in the world, using

three databases—United States Patent and Trademark Office (USPTO), Shanghai Jiao Tong University's Academic Ranking of World Universities (ARWU) and Times Higher Education Supplement's World University Ranking (WUR). For the selection of the universities, three requirements were used:

- (1) Those in the WUR ranking in any of the following years: 2004, 2005 or 2006, and whose disciplines were arts and humanities, technology, biomedicine, sciences and social sciences.
- (2) Those included in the ARWU in the period 2002–2006.
- (3) Those who had been granted at least one patent in the United States in 1976–2005.

In order to analyse the information, the 281 universities referring to 29 different countries were grouped into “North America”, “Europe and Australia/New Zealand”, and “Others”. Information from the European Patent Office (EPO) was also used to avoid bias problems using the USPTO database. Scientific production was measured through the number of publications in the Science Citation Index and Social Science Citation Index. In contrast, in the case of quality, the number of citations per university provided by the WUR, calculated according to the Thomson Reuters' Essential Science Indicators (ESI) database. The multiple linear regression results showed that technological productivity is significantly correlated with the quantity and quality of scientific production, although there are some regional differences. For universities in “North America” there were positive effects on the quantity and quality of publications, but for “Europe and Australia/New Zealand”, only a positive correlation with quantity was found; whereas for other universities outside North America, Europe, Australia and New Zealand, only the quality of the publications mattered.

There have been only two studies in Spain, but the level unit analysis is the academic article [39] and the research group [40].

Martínez et al. [39] considered the existing differences between academic institutions in Spain, distinguishing between public universities and the different types of non-university public research organisations. Non-university public research organisations refer to traditional mission-oriented public research centres (MOCs specialised in different fields (agriculture, health, defence and energy), dependent on the corresponding ministries; and independent public research institutes (IRIs), these being a new type of research centre that has been promoted by governments and research funding agencies in many countries belonging to the Organization for Economic Cooperation and Development. In this study, the academic article was considered the unit of analysis; therefore, all Spanish authors' publications from 2003–2008 in journals indexed in Scopus were considered. The authors who have had an inventive step were identified by joining the authors' names with the inventors' names who have made an application at the European Patent Office. The dependent variables that measured the scientific impact were the citations received up to December 2009 and the journal's prestige (SCImago Journal Rank). Additionally, the independent variables included the number of authors; the visibility of the Spanish authors, not the academic inventors; the Spanish academic characteristics, the scientific field of the article, the year of publication of the article, and the various affiliation dummy variables. Through a negative binomial regression and ordinary least squares, it was shown that scientists who belong to universities or MOCs that have ever applied for a patent publish in journals of scientific impact, whereas, this conclusion could not be reached for researchers belonging to IRIs.

Acosta et al. [40] used a sample of 1120 research groups affiliated with the leading public research institutions in Andalusia—public universities, the Higher Council for Scientific Research (CSIC), and research institutes and hospitals of the Public Health System. The dependent variable, obtained from the Spanish Patent and Trademark Office, was the number of patents requested by these public institutions from 2002 to 2005. The independent variables, extracted from the Ministry of Innovation, Science and Business, were the number of articles published in international journals during the 1999–2002 period, the number of scientific–technical contracts with public or private companies in the 1999–2002 period, the number of PhD researchers in the research group, the number of publicly funded research

projects awarded to the group during the 1999–2002 period, the institutional affiliation of the research group, and the area of knowledge of each group. The different econometric models (Poisson, negative binomial, Poisson with inflated zeros and negative binomial with inflated zeros) indicated that the research groups' technological production was positively and significantly correlated with the variables related to scientific production and private collaboration.

3. Methodology

We constructed a database with data of the 48 Spanish public universities for the period 2008–2019. The reason for this period of 12 years is that there is no data available for the variable “number of national patents of public universities” for the years 2020 and 2021 because in Spain, there is a period of 18 months between the filing of the application and its publication, so it can be estimated that the average period of granting a patent will be approximately 21 months.

We extracted the information from *Observatorio IUNE*. The *Observatorio IUNE* results from the work carried out by a group of researchers belonging to the universities that make up the “4U Alliance”—Carlos III University of Madrid, Autonomous University of Madrid, Autonomous University of Barcelona and Pompeu Fabra University. The development of the *Observatorio IUNE* has been funded by the Ministries of Science and Innovation and Education. The Ministry of Education, Culture and Sport has agreed with the 4U Alliance to support the *Observatorio IUNE*. Table 1 summarises the variables of the study and the sources.

Table 1. Dependent and independent variables of the study.

Variable	Definition	Source
PUB	The scientific output of public universities	Web of Science platform (Science Citation Index, Social Science Citation Index, and Arts & Humanities Citation Index).
CIT	Citations received by universities	
PAT	Number of national patents of public universities	INVENES (Spanish Patent and Trademark Office).
R&D	Value of R&D and consultancy agreements (thousand euros)	Network of Research Results Transfer Offices
SER	Amount billed for services rendered (thousand euros)	
LIC	Patent licence revenues (thousand euros)	
PCT	Number of patent cooperation treaties (PCT) extensions	
SPIN	Number of spin-offs	

Source: Own elaboration.

The *Observatorio IUNE* methodology obtains the information about innovation from the database INVENES, created by the Spanish Patent and Trademark Office. The number of patents is related to the quantity of “patents awarded” to each university in the respective year.

The variables related to the value of R&D and consultancy agreements, the amount billed for services rendered, the patent licence revenues, the number of patent cooperation treaties (PCT) extensions and number of spin-offs were extracted from the Network of Research Results Transfer Offices, a yearly survey of universities.

The scientific activity is the records with at least one Spanish address in the address field that were downloaded and filtered by institution type (University). The following are included: output, (national and international) collaboration, impact (citations received) and visibility (% of papers in first quartile journals and the top three journals in each discipline).

Finally, we performed linear multiple regressions models in order to analyse to the following hypothesis:

Hypothesis 1 (H1). *The universities with more patent activity are the ones with more scientific output.*

Hypothesis 2 (H2). *The universities with more citations are the ones with more number of patents.*

4. Spatial Distribution of Public Universities in Spain

The distribution of Spanish universities resulted from the Spanish Constitution of 1978, which had consequences for the distribution of universities at a regional level. Administrative decentralisation and increased demand for higher education were supposed to create many new universities throughout the Spanish territory. We excluded ‘Open University of Catalonia’ because it is an online university, and ‘The International University of Andalusia’ and ‘Menendez Pelayo International University’ because they are not members of the TTO Universities Network. In Table 2, we present the Spanish universities by region and year of creation.

Table 2. Spanish public universities by region.

Region	University	Established
Andalusia	University of Almeria (UAL)	1993
	University of Cadiz (UCA)	1979
	University of Cordoba (UCO)	1972
	University of Granada (UGR)	1531
	University of Huelva (UHU)	1993
	University of Jaen (UJAEN)	1993
	University of Malaga (UMA)	1972
	University of Seville (U.S.)	1505
	Pablo de Olavide University (UPO)	1997
Aragon	University of Zaragoza (UNIZAR)	1542
Asturias	University of Oviedo (UNIOVI)	1608
Balearic Islands	University of the Balearic Islands (UIB)	1978
Basque Country	University of the Basque Country (EHU)	1980
Canary Islands	University of La Laguna (ULL)	1927
	University of Las Palmas de Gran Canaria (ULPGC)	1989
Cantabria	University of Cantabria (UNICAN)	1972
Castile–La Mancha	University of Castile–La Mancha (UCLM)	1985
Castile and Leon	University of Burgos (UBU)	1994
	University of Leon (UNILEON)	1979
	University of Salamanca (USAL)	1218
	University of Valladolid (UVA)	1241
Catalonia	Autonomous University of Barcelona (UAB)	1968
	Polytechnic University of Catalonia (UPC)	1971
	Pompeu Fabra University (UPF)	1990
	Rovira i Virgili University (URV)	1991
	University of Barcelona (U.B.)	1450
	University of Girona (UDG)	1991
	University of Lleida (UDL)	1297
Extremadura	University of Extremadura (UNEX)	1973
Galicia	University of A Coruña (UDC)	1989
	University of Santiago de Compostela (USC)	1495
	University of Vigo (UVIGO)	1990

Table 2. Cont.

Region	University	Established
La Rioja	University of La Rioja (UNIRIOJA)	1992
Madrid	Autonomous University of Madrid (UAM)	1968
	Carlos III University of Madrid (UC3M)	1989
	Complutense University of Madrid (UCM)	1499
	National University of Distance Education (UNED)	1972
	Rey Juan Carlos University (URJC)	1996
	Polytechnic University of Madrid (UPM)	1971
Murcia	University of Alcala (UAH)	1977
	University of Murcia (U.M.)	1914
Navarre	Polytechnic University of Cartagena (UPCT)	1998
	Public University of Navarra (UNAVARRA)	1987
Valencian Community	James I University (UJI)	1991
	Miguel Hernandez University of Elche (UMH)	1996
	Polytechnic University of Valencia (UPV)	1968
	University of Alicante (UA)	1979
	University of Valencia (UV)	1499

Source: Own elaboration.

5. Econometric Analysis: Patenting and Publishing in Spanish Universities

5.1. Quantity Model

In this section, we perform a first multiple linear regression econometric model. The sub-index i refers to university i . The dependent variable is the scientific output of public universities (PUB), i.e., the number of publications of the database Web of Science (Science Citation Index, Social Science Citation Index and Arts & Humanities Citation Index). The independent variables are the number of national patents of public universities (PAT), the value of R&D and consultancy agreements (R&D), the amount billed for services rendered (SER), the patent licence revenues (LIC), the number of PCT extensions (PCT) and the number of spin-offs (SPIN). Finally, ε is the error term. Equation (1) shows the formula of the linear multiple regression model.

$$PUB_i = \beta_0 + \beta_1 PAT_i + \beta_2 R\&D_i + \beta_3 SER_i + \beta_4 LIC_i + \beta_5 PCT_i + \beta_6 SPIN_i + \varepsilon \quad (1)$$

Table 3 summarises the descriptive statistics of variables in our sample.

Table 4 shows the Pearson correlations for all variables used in the first regression analysis.

Table 3. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
PUB	48	12,379.560	10,256.590	2109.000	47,199.000
PAT	48	105.708	79.330	14.000	368.000
R&D	48	58,369.150	71,163.530	3655.000	429,969.000
SER	48	11,960.540	14,623.440	682.000	78,988.000
LIC	48	565.646	826.040	0.000	3542.000
PCT	48	62.563	62.499	1.000	251.000
SPIN	48	20.604	28.782	0.000	174.000

Table 4. Pearson correlation coefficients of the variables.

	PUB	PAT	R&D	SER	LIC	PCT	SPIN
PUB	1.000						
PAT	0.351	1.000					
R&D	0.469	0.795	1.000				
SER	0.687	0.348	0.532	1.000			
LIC	0.479	0.517	0.659	0.768	1.000		
PCT	0.615	0.816	0.715	0.600	0.632	1.000	
SPIN	0.326	0.667	0.808	0.299	0.464	0.562	1.000

Table 5 shows the results of the linear multiple regression model. The R-square of 0.590 shows that PAT, R&D, SER, LIC, PCT and SPIN explained 59% of the regression model variance. The multiple regression model results show that the number of patents has no significant effect on the number of publications at the university level (PUB), so we reject hypothesis H1. Moreover, the value of R&D and consultancy agreements, the patent licence revenues and the number of spin-off (R&D, LIC and SPIN) have no impact on the scientific output. In relation with our results, Buenstorf [41], in his study of the Max Planck Institute (Germany), found a growing number of publications for those inventors who signed a license agreement with private companies. However, the spin-off founders experienced a decline in their long-term scientific output.

Table 5. Linear multiple regression model (dependent variable = PUB).

Variable	Coefficient	Std. Dev.
C	6513.614 ***	−1967.172
PAT	−44.824	−29.978
R&D	0.023	−0.035
SER	0.400 ***	−0.128
LIC	−3.527	−2.199
PCT	96.336 ***	−35.181
SPIN	21.354	−62.803
R ²		0.590

*** Significant at the 1% level.

However, the amount billed for services rendered (SER), positively relates to the number of publications, i.e., universities that render more services, have a higher number of publications. In addition, the number of PCTs (PCT), has a positive effect on the number of publications with a significant level of 1%.

5.2. Quality Model

In this section we carry out the second multiple linear regression econometric model. The sub-index I refer to university *i*. The dependent variable is the number of citations received by university (CIT), i.e., extracted from the database Web of Science (Science Citation Index, Social Science Citation Index and Arts & Humanities Citation Index). The independent variables are the same as Section 5.1, the number of national patents of public universities (PAT), the value of R&D and consultancy agreements (R&D), the amount billed for services rendered (SER), the patent licence revenues (LIC), the number of PCT extensions (PCT) and the number of spin-offs (SPIN). Finally, ε is the error term. Equation (2) shows the formula of the linear multiple regression model.

$$CIT_i = \beta_0 + \beta_1 PAT_i + \beta_2 R\&D_i + \beta_3 SER_i + \beta_4 LIC_i + \beta_5 PCT_i + \beta_6 SPIN_i + \varepsilon \quad (2)$$

Table 6 summarises the descriptive statistics of variables in our sample.

Table 6. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
CIT	48	213,229.90	212,000.10	28,003.00	1,031,115.00
PAT	48	105.71	79.33	14.00	368.00
R&D	48	58,369.15	71,163.53	3655.00	429,969.00
SER	48	11,960.54	14,623.44	682.00	78,988.00
LIC	48	565.65	826.04	0.00	3542.00
PCT	48	62.56	62.50	1.00	251.00
SPIN	48	20.60	28.78	0.00	174.00

Table 7 shows the Pearson correlations for all variables used in the first regression analysis.

Table 7. Pearson correlation coefficients of the variables.

	CIT	PAT	R&D	SER	LIC	PCT	SPIN
CIT	1.000						
PAT	0.216	1.000					
R&D	0.371	0.795	1.000				
SER	0.706	0.348	0.532	1.000			
LIC	0.440	0.517	0.659	0.768	1.000		
PCT	0.528	0.816	0.715	0.600	0.632	1.000	
SPIN	0.238	0.667	0.808	0.299	0.464	0.562	1.000

Table 8 summarises the results of second linear multiple regression model. The R-square of 0.608 shows that PAT, R&D, SER, LIC, PCT and SPIN explain 61% of the regression model variance. The results show that the number of patents has a negative and significant effect on the number of citations at the university level (CIT), so we reject hypothesis H2. Besides, the value of R&D and consultancy agreements and the number of spin-offs (R&D and SPIN) have no impact on the number of citations. However, the variable services rendered by universities (SER) and the number of PCTs (PCT), has a significant and positive relationship to the number of citations, i.e., universities that render more services, have higher number of citations. In addition, the number of licenses (LIC), has a negative effect on the number of citations with a significant level of 10%.

Table 8. Linear multiple regression model (dependent variable = CIT).

Variable	Coefficient	Std. Dev.
C	$1.20 * + 10^5$ ***	−39,766.772
PAT	−1274.073 **	−606.002
R&D	0.354	−0.717
SER	9.892 ***	−2.585
LIC	−82.060 *	−44.462
PCT	1971.057 ***	−711.200
SPIN	572.521	−1269.575
R ²		0.608

* Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

6. Conclusions

In this paper, we have conducted an econometric analysis of the patenting and publishing activity of universities. We have shown that there is no relationship between patenting and publishing activities at the university level in Spain. However, the quality of scientific research, measured by the number of citations, has a negative effect on the number of patents. These results are consistent with the papers of Murray and Stern [33] and Fabrizio and Di Minin [34].

Furthermore, our results show that in Spanish universities that render more services, this has a positive impact on the quantity and quality of the publications. According to Davis and Lotz [42] there is a highly significant relationship between a strong publication record and experience of cooperation with industry (contract research, joint projects, consulting). Other studies reached the same conclusion [43–46].

However, according to Perkmann et al. [47] there is little evidence of the impact of academic engagement on research. Therefore, it cannot be assumed that activities of this type are always beneficial and should be promoted. In this way, it is important to carry out additional studies that allow policy makers to decide which variables to promote, whether academic commitment or research of excellence. The decision will depend on the causal relationship between these two variables.

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