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Using PLS Path Modelling in Education System: A Model to Measure the Academic Performance Score

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ABSTRACT

Partial Least Square (PLS) was used the path modelling. Latent variables such as staff, institution (administration, number of enrolments, quality of laboratories, rooms, etc.), incentive applied for research and Academic Performance Score (APS) were proposed. The indicators available on Brazilian universities were chosen for this article, they were tested and duly validated, as well as the reliability of these items and the variables represented by them. The result was the model explains satisfactorily well the Academic Performance Score (APS) with a R2 of 70.6%, with the Institution contributing the most to the model, for approximately 35.4%. Next, the incentive to research contributes 29.2%. In addition, the hypotheses generated in this article, except one, adequately support the model.

1. Introduction

The knowledge of possible causes for a good academic performance of the universities can directly impact the image of the Institutions of Higher Education – IHEs (public or private) and influence in a positive or negative way in the choice of thousands of students who dream of a higher education (Bowman & Bastedo, 2009). In addition, it can support public policies and managers of universities that wish to improve academic performance. In this sense, currently several indicators define a global concept of an IHE, for example, quality (Williams, Rassenfosse, Jensen, & Marginson, 2013) e ranking (Robinson-Garcia, Torres-Salinas, Herrera-Viedma, & Docampo) in which the various international university rankings show scores (Millot, 2015).

This paper proposes a model for global usage, with universal variables, using country specific indicators, in this case, Brazil, applicable to educational systems with the purpose of measuring what is here referred to as Academic Performance Score (APS) which is a quantitative way of measuring the academic performance of a given educational institution by using structural equation modelling (SEM), a multivariate method of analysis, specifically the path of partial least squares (PLS path) (Mateos-Aparicio, 2011).

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2. Background

2.1. Pls-SEM

PLS-Path is an approach used to estimate the coefficients of a system of structural equations with the partial least squares methodology. One advantage of this technique is that it deals well with the dilemmas that arise with Structural Equation Models (SEM): their indeterminate nature and the various parameters for estimating the sample size of the project. Mainly due to the fact that latent variables are entirely unknown. However, PLS solves this problem easily by only creating latent variables as the weighted sum variables (Mateos-Aparicio, 2011).

The main advantage of PLS is the power given to smaller samples and the breakdown of statistical assumptions of variables (non-normal distribution, different measurement levels, multicollinearity, among others) (Arcentales et al, 2018).

2.2. Educational System

According to Draper (2006) the concept of education system can be basically defined as the school system, although it is much more than that. For the author, an educational system must follow the principles of what a system is, eliminating the chain of factual identification between education and school by aligning thoughts that accept the idea that formal agents and organizations of a society transmit knowledge and cultural patrimony and influence the social and intellectual growth of the individual.

2.3. Models for university measurement

The literature has models for universal measures of academic performance that aim to measure quality of the institution, capacity for innovation (Duque et al, 2018), productivity (Moore et al, 2018) or even comparative universities rankings (Özden, 2017).

International universities rankings are an integral part of the higher education landscape. However, they focus only on a few hundred universities in more than 20,000 higher education institutions around the world. Their conclusion is an attempt to compare the results of the university and system rankings, as well as to record an important warning for the challenge of addressing the inclusion of developing countries in a way that rankings become more relevant (Millot, 2015).

The rankings are projections created by public or private institutions. But they are composed of scales or measurements. A scale can be defined as the assignment of numbers to objects and events according to certain rules and the way these numbers are assigned determines the type of scale (Stevens, 1946)(Cohen & Cohen, 1975)(Saris & Stronkhorst, 1984).

The need to rank institutions is addressed by N.K., K., & Cherukodan (2018), demonstrating how the Indian government responded to this need in higher education.

Shawyun (2017) after analysing several university rankings and evaluating several metrics, proposed an internal Benchmarking system in which this methodology provided an objective evaluation of the performance of good practices within 58 processes centred on 11 norms and a quantifiable set of 56 KPIs. With these process scores it was possible to measure performance in a quantifiable and objective way. The use of the performance punctuation system per 1,000 points and the 22 sets of Results Criteria of its 56 KPIs (42 quantitative indicators and 14 qualitative indicators) are the basis of the proposed internal benchmarking system.

Moed (2016) , when evaluating comparatively 5 different university rankings, concludes that there is no such thing as "the 100 best universities" in terms of excellence. This evaluation depends on the classification system used and which universities constitute the top 100. In this

analysis, only 35 institutions appear in the top 100 lists of all 5 systems and the number of institutions overlapping per pair of systems ranges from 49 to 75. One implication is that national government systems that implement a science policy aimed at increasing the number of academic institutions the top 'ranking' of universities in the world, should not only indicate the reach of the top segment (for example, the top 100) but also specify which classifications are used as the standard and why they were selected from the broader set of world university rankings. This is the key for this paper, because this paper can improve these kinds of results, using as many indicators as possible, not just the ranking (Moed, A critical comparative analysis of five world university rankings, 2017).

Daraio et al .(2015) used a multidimensional conditional approach in which one attempted to overcome four of the main criticisms of university rankings: one-dimensionality; statistical robustness; dependence on the size of the university and the mix of disciplines; lack of consideration of inputs - outputs. The authors evaluate indicators related to staff (functional body) and quality and impact of scientific publications, among others. The authors further suggest that funding for government research be allocated according to criteria that generate research quality. In order to exercise evaluation or funding criteria based on formulas based on the quality of the research (Daraio et al., 2015).

The articles above make it clear that researchers use only indicators to measure academic performance. The contribution of this research is to use, in addition to the indicators, a structural model to assess academic performance, allowing the inference of causality (cause and effect) between the different constructs and the appropriate hypothesis testing. The consequence of this, if the model is validated, is that any other researcher around the world can use this same model, needing only to adjust the indicators for their region.

3. Methods

3.1. Data

Among the indicators that make up the model, data released by the Lattes Platform were used. The Lattes Platform is a virtual curriculum system created and maintained by the Council for Scientific and Technological Development (CNPq), a body linked to the Ministry of Science, Technology, Innovation and Communications of the Federal Government from Brazil. The following indicators were used: the number of researchers, the number of doctors, the percentage of doctors in the total number of professors, the percentage of doctors in the research, besides the amount of investments made by CNPq in research in a certain university (Plataforma Lattes, 2016).

From Shanghai Ranking Consultancy was extracted the Academic Ranking of World Universities, also known as Shanghai Ranking. This company is an independent organization dedicated to researching higher education. Several indicators were used, such as alumni (alumni of the institution who won the Nobel Prize or Fields medal), award (members or servants of the institution who received Nobel Prize or Fields medal), HiCi (numbers of highly cited researchers selected by Clarivate Analytics), N & S (number of papers published in Nature or Science), PUB (number of papers indexed in the Science Citation Index-Expanded and Social Science Citation, Web of Science) and PCP (weight of the scores of the above five indicators divided by the number of employees with full dedication) (Shanghai Ranking Consultancy, 2019).

MEC – in the past, the Ministry of Education and Culture, today only the Ministry of Education - is the body that manages education in Brazil (Ministério da Educação, 2019). The INEP - National Institute of Educational Studies and Research Anísio Teixeira - is the body that created indicators and measures the performance of educational institutions in Brazil (INEP,

2019). These indicators are the number of faculty members, the number of professors without a degree, the number of professors with a degree, the number of professors with a specialization, the number of professors with a master's degree, the number of professors with a doctorate, number of employees with incomplete elementary education, number of employees with complete primary education, number of employees with a high school education, number of employees with graduation, number of employees with specialization, number of graduates attending undergraduate courses, number of undergraduates at distance, number of undergraduate courses attended, number of undergraduate distance courses, number of undergraduate degrees attended, number of students with a master's degree, number of enrolment in distance education, number of total number of places offered for face-to-face graduation, number of distance graduation enrolments, number of candidates enrolled in a face-to-face degree, number of candidates enrolled in distance learning, number of students who entered through a selective process in face-to-face graduation, the number of students who entered through a distance-learning selective process, the number of students who entered other forms of face-to-face graduation, and the number of students who entered through distance learning. distance learning. Also, it was used the number of courses that have made Enade in the last three years (a kind of exam that evaluates Brazilian higher education institutions), the number of courses with CPC in the last three years, the concept note of the undergraduate course, the grade concept of the master's degree, the concept of the doctorate, the percentage of graduates in the university total, percentage of masters in IEH (institution of education), the IGC (translated as General Index of Courses) (INEP, 2019).

CAPES - Coordination of Improvement of Higher Level Personnel – "is an agency of the federal government under the management of the Ministry of Education, responsible for the quality assured in undergraduate and graduate" (Wikipedia, 2019). The following CAPES indicators were used: number of accesses for portal (CAPES), the number of scholarships for senior national visiting professors, number of postdoctoral fellowships, number of scholarships for masters and number of scholarships for full doctorate (Coordenação de Aperfeiçoamento de Pessoa de Nível Superior, 2019).

The latest indicators were taken from the QS Ranking, the ranking, (Quacquarelli Symonds, s.d.) and the ranking from Financial Time Ranking (Financial Times, 2019).

The year of choice was the year 2010, as it was the only year in which all this information was available and of sufficient quality for analysis. The sample was composed of 328 Brazilian higher education institutions, in several states, municipalities and courses or research areas. For PLS, it is not a problem in itself the size of the sample (Falk & Miller, 1992), but the ideal is that it is above 100 (Marcoulides & Saunders , 2006).

3.2. Technique

This article is a quantitative exploratory analysis, carried out in Anonymous for double-review. It is a multivariate analysis using Partial Least Square (PLS) PATH, which allows the creation of latent (unobservable) variables, which in this case will be reflexive, that is, they represent the manifested variables and are measured through their indicators, "Reflects" in them and is expressed through them. This technique also allows the generation of second order latent variables, that is, latent variables that are generated by other latent variables (Guinot et al., 2001).

"Exploratory research is developed with the aim of providing an approximate overview of a given fact. This type of research is done especially when the theme chosen is little explored" (GIL, 2008, p.27).

The following hypotheses were tested:

Table 1.
Hypotheses

Hypothesis		Authors
H1	Incentive applied to research => Academic Performance Score	(Starovoytova, 2017)
H2	Staff => Incentive applied to research	(Cadez et al., 2017)
H3	Staff => Institution	(Duque et al., 2018) (Finch et al., 2015)
H4	Institution => Incentive applied to research	(Enero & Limjuco, 2017)
H5	Institution => Academic Performance Score	(Daraio et al.,2015)

Source: Authors.

According to a literature review present here, it was verified the existence of several indicators used in education. However, for a better explanation of the outstanding phenomenon for a university in the academic world, three major latent variables were proposed: staff (students, employees, professors), institution (quality of teaching, laboratory, number of professors, etc.), incentive applied to the research (funds, incentives for research or from government or private companies) and academic performance score (university rankings, national course evaluation notes, etc.). They are global in the sense that they can be used anywhere in the world and are universal because to use them in other countries, the researchers simply adapt this model to their indicators.

3.3. Description of the Model

After the preparation of the above hypothesis model, one software was used, SMARTPLS 3.2.8 (Ringle et al., 2019), with the option "Algorithm PLS". Due to the weakness of the weights, since not all had a value above 0.707 (Hair et al., 2014), only the following indicators were selected. The composition of the latent variables used in this article and its relevant indicators is as follows:

Table 2.
Indicators and latent variables

Symbol	Source	Latent Variable	Meaning
APS1	QS RANKING (Quacquarelli Symonds, s.d.)	Academic Performance Score	Quacquarelli Symonds world ranking
APS2	Shanghai HICI (Shanghai Ranking Consultancy, 2019)	Academic Performance Score	Number of most cited articles in Thomson Reuters
APS3	Shanghai National Rank (Shanghai Ranking Consultancy, 2019)	Academic Performance Score	Shanghai national Ranking
APS4	Shanghai PCP (Shanghai Ranking Consultancy, 2019)	Academic Performance Score	Shangai weight of the five indicators (alumni, award, hici, ns, pub) divided by the number of full-time servers
APS5	Shanghai PUB (Shanghai Ranking Consultancy, 2019)	Academic Performance Score	Shanghai number of papers in citations
APS6	Shanghai world ranking (Shanghai Ranking Consultancy, 2019)	Academic Performance Score	Shanghai world ranking
STAFF1	CAPES acesso ao portal (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, 2019)	Staff	Number of access in CAPES website

Symbol	Source	Latent Variable	Meaning
STAFF2	MEC funcionários com Doutorado (Ministério da Educação, 2019)	Staff	MEC measure for employee's doctorate degree
STAFF3	MEC funcionários com Especialização (Ministério da Educação, 2019)	Staff	MEC measure for employee's post-graduation degree
STAFF4	MEC funcionários com ensino médio (Ministério da Educação, 2019)	Staff	MEC measure for employees who completed the high school
RI1	CAPES bolsa para doutorado pleno (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, 2019)	Research Incentive	Number of scholarships for doctorate degree from CAPES
RI2	CAPES bolsa para mestrado	Research Incentive	Number of scholarships for Master of Science degree from CAPES
RI3	CAPES bolsa para pós doutorado (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, 2019)	Research Incentive	Number of scholarships for post doctorate degree
RI4	CNPq bolsa para pesquisa (INEP, 2019)	Research Incentive	Number of scholarship research from CNPq
INST1	Número de doutores no Lattes (Plataforma Lattes, 2016)	Institution	Number of doctors inside Lattes Platform
INST2	Porcentagem de doutores do total de professores no Lattes (Plataforma Lattes, 2016)	Institution	Percentage of total Doctors in Lattes
INST3	Número de pesquisadores no Lattes (Plataforma Lattes, 2016)	Institution	Number of researchers in Lattes Platform
INST4	MEC - Número de professores em Exercício (Ministério da Educação, 2019)	Institution	MEC - Number of professors in Exercise
INST5	MEC - Número de professores com doutorado (Ministério da Educação, 2019)	Institution	MEC - Number of professors with PhD degree
INST6	MEC - Número de professores com mestrado (Ministério da Educação, 2019)	Institution	MEC - Number of professors with master's degree
INST7	MEC - Número de alunos com ingresso por processo seletivo em graduação (Ministério da Educação, 2019)	Institution	MEC - Number of students with admission by selective process in graduation
INST8	MEC - Número de concluintes da graduação presencial (Ministério da Educação, 2019)	Institution	MEC - Number of graduates of the face-to-face degree
INST9	MEC - Número de cursos de graduação presencial (Ministério da Educação, 2019)	Institution	MEC - Número de cursos de graduação presencial (Ministério da Educação, 2019)
INST10	MEC - Número de matrículas no curso de graduação presencial (Ministério da Educação, 2019)	Institution	MEC - Número de matrículas no curso de graduação presencial (Ministério da Educação, 2019)
INST11	MEC - Regime de trabalho em tempo integral (Ministério da Educação, 2019)	Institution	MEC - Regime de trabalho em tempo integral (Ministério da Educação, 2019)
INST12	MEC - Regime de trabalho em tempo parcial (Ministério da Educação, 2019)	Institution	MEC - Regime de trabalho em tempo parcial (Ministério da Educação, 2019)
INST13	MEC - Número de vagas oferecidas para graduação presencial (Ministério da Educação, 2019)	Institution	MEC - Number of enrolments offered for face-to-face degree

Source: Authors.

The final format of the aforementioned model is:

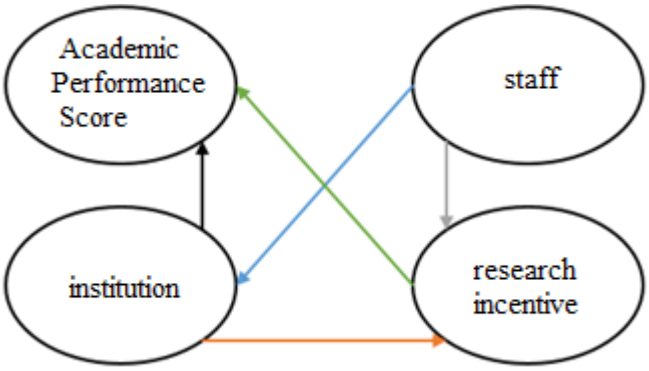

Figure 1. Model
Source: Authors, using PowerPoint ®

4. Analysis of Results and Discussion

4.1. Reliability of Items

Reliability is how much a given set of indicators of the latent variable, also called a construct, have correlation in their measurements. This test shows that these indicators are reliable to explain the latent variable to which they are related. The above indicators were chosen following only those that had a loading value greater than 0.707 (Hair et al.,2014). All others were eliminated, as shown in the table below:

Table 3.
Reliability of items

Indicator	Academic Performance Score	Staff	Research Incentive	Institution
APS1	0.840			
APS2	0.825			
APS3	0.965			
APS4	0.954			
APS4	0.954			
APS5	0.985			
APS6	0.989			
STAFF2		0.918		
STAFF3		0.961		
STAFF4		0.955		
RI1			0.988	
RI2			0.958	
RI3			0.974	
RI4			0.976	
INST4				0.983
INST5				0.931
INST6				0.880
INST7				0.942
INST8				0.930
INST9				0.909
INST10				0.827
INST11				0.978
INST12				0.834
INST13				0.962

Source: SMARTPLS 3.2.8 (Ringle et al.,2019)

4.2. Constructs Reliability

It can be measured by three indicators: the Cronbach's alpha coefficient, the Rho_a (Consistent Reliability Coefficient) and the composite reliability. The following result was found in this work:

Table 4.
Constructs Reliability

Variable	Cronbach's alpha	Rho_A	Composite Reliability
Academic Performance Score	0.967	0.973	0.974
Institution	0.971	0.986	0.972
Research Incentive	0.982	0.983	0.987
Staff	0.811	0.828	0.863

Source. SMARTPLS 3.2.8 (Ringle et al., 2019)

4.3. Convergent Validity

This test shows whether the amount of variance of the indicators and the variance of the measurement error are compatible. AVE (Average Variance Extracted) values need to be above at least 0.5 to be good. The values of this research are well above that, as shown below (Huang et al.,2013):

Table 5.
Convergent Validity

Variable	Ave
Academic Performance Score	0.863
Institution	0.731
Research Incentive	0.949
Staff	0.614

Source: SMARTPLS 3.2.8 (Ringle et al., 2019)

4.4. Discriminant validity

This test seeks to measure the degree that a construct has with itself and with the others present in the model. The ideal is that it does not have as much relation with the others and that it has much relation with itself. All constructs of this article have passed this test, as shown below (Hamid et al.,2017):

Table 6.
Discriminant Validity

	Academic Performance Score	Institution	Research Incentive	Staff
Academic Performance Score	**0.929**			
Institution	0.517	**0.855**		
Research Incentive	0.815	0.769	**0.974**	
Staff	0.582	0.779	0.731	**0.783**

Source. SMARTPLS 3.2.8 (Ringle et al.,2019)

4.5. Multicollinearity Valuation

The collinearity test seeks to prevent different indicators from measuring exactly the same thing, which can generate redundancy and possible instabilities in the model. The ideal values are that they are less than or equal to 3, although the value 5 can be accepted, depending on the case. The results of this article are in the image below and are all validated (Diamantopoulos & Siguaw, 2006):

Table 7.
Multicollinearity Valuation

	Academic Performance Score	Institution	Research Incentive	Staff
Academic Performance Score				
Institution	2.452		2.548	
Research Incentive	2.452			
Staff		1.000	2.548	

Source. SMARTPLS 3.2.8 (Ringle et al., *2019).*

4.6. Valuation of the Structural Model

4.6.1. Coefficient of Determination

The coefficient of determination, also called R^2, is a measure of how much the variable explains the model, for example, if the model is used to justify or predict some event. It is how much this variable contributes to this process. The R^2 above 0.10 already allows prediction of dependent variables in structural models (Falk & Miller, 1992). The results of the work can be seen in figure 2 below. The Institution variable contributes the most to the model, accounting for approximately 35.4%. Next, the variable of incentive applied to research contributes 29.2%. The R^2 of 70.6% of the academic performance score variable means the amount that this model can explain about it, in the case of Brazil.

The coefficients present in the connections of the variables and indicators (standardized regression coefficients) show the relations of the hypotheses. The ideal for validation is that they are at least above to or equal to 0.20, with the ideal being above 0.30 (Chin, 1998). The only hypothesis in which this was not maintained was the hypothesis in which the staff latent variable has no relation to the latent variable of research incentive, as shown below:

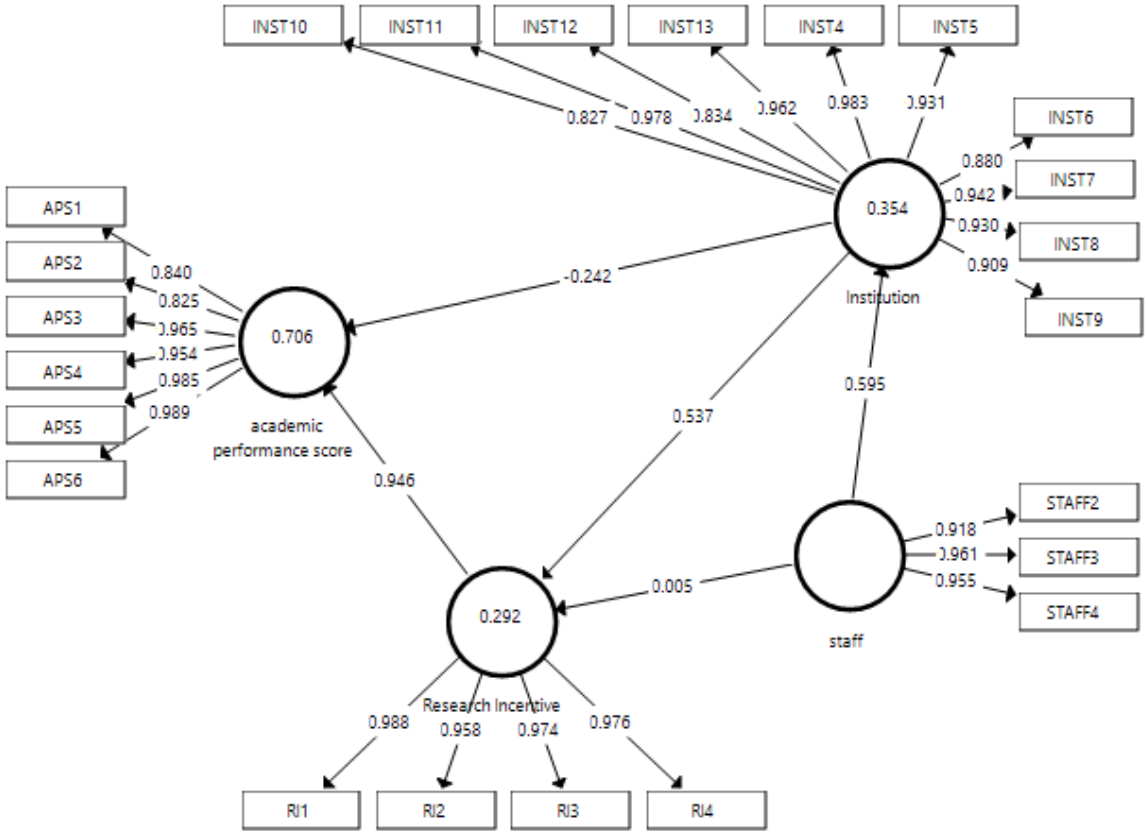

Figure 2. Model with values
Source. SMARTPLS 3.2.8 (Ringle et al., 2019)

4.6.2. Evaluation of Effects and Hypothesis Test

This test is to validate the hypotheses raised above, that is, the significance of the effects, through the bootstrapping technique, which is a random, repeated sampling, which will replace the original samples and verify if the ratios really are very different from zero. The results obtained in this article are in the table below (Hair Jr et al.,2005):

Table 8.
Hypotheses test

Hypothesis	Original Sample	Sample Mean	Standard Deviation	T-Statistic	p-Value
H1	0.94589	0.9534	0.0656	14.416	0.0000
H2	0.00536	0.0061	0.1107	0.0483	0.9615
H3	0.59510	0.5966	0.0571	10.409	0.0000
H4	0.53717	0.5569	0.1361	3.9468	0.0001
H5	**-0.24223**	**-0.281**	**0.1085**	**2.2315**	**0.0288**

Source. SMARTPLS 3.2.8 (Ringle et al., 2019)

According to the table above, the hypotheses raised at the beginning of this article had the following result:

Table 9.
Hypotheses test output

	Hypothesis	Validation
H1	Incentive applied to research => Academic Performance Score	Accepted
H2	Staff => Incentive applied to research	Rejected
H3	Staff => Institution	Accepted
H4	Institution => Incentive applied to research	Accepted
H_5	Institution => Academic Performance Score	Accepted

Source: Authors.

The criteria for judging the validity or not of these hypotheses were an alpha requirement of 0.05 and was valid for 5000 subsamples. According to the t-Student table, the value of the T statistic should be greater than 1,645, in order for the hypothesis to be classified as true, as well as to have a p-value below 0.05 (Hair et al., 2014).

Therefore, the result found was a model that supports well the explanation of how variables, indicators and hypotheses are related to each other in a form of causality, based on statistical evidence cited above for explaining the academic performance scores for higher education institutions in Brazil.

5. Conclusion

The problem presented by the study was to identify the factors responsible for the academic performance of a higher education institution and to propose a model that could be used universally to better understand the causes involved in this phenomenon and how to analyse it quantitatively as a management tool of the university itself or as a support for policies of higher education, for example, without relying only on indicators like ranking or quality such as those pointed out in the background here, in this paper.

This can have a very interesting practical application, as it allows a decision process to the managers (Duque et al., 2018). If the university has excellent technical staff of professors, students and employees, in addition to an excellent quality of teaching, perhaps what is lacking for it to have a high performance is exactly resources applied to research (Starovoytova, 2017). Not only financial sources, but motivation, dedication to research. It can be laboratories,

equipment, anything that can enrich, stimulate or increase the research ability of the institution in general.

The article suggests that the institution is determinant, in Brazil specifically, for receiving government research funds, and that the variable staff is not a relevant factor, since the hypothesis was rejected. Therefore, this may explain why the universities located in the Southeast (brown colour, in the chart below) are the ones that have the most performance in the academic world and are the ones that receive the most incentive, for example, from CAPES. The institution in this sense has a greater weight than its employees, students and professors.

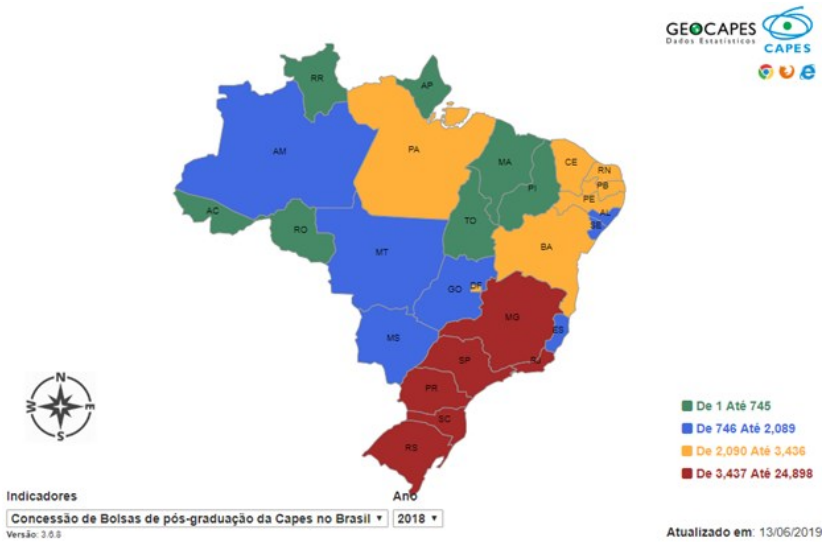

Figure 3. Brazil map of investment from CAPES applied to research
Source. https://geocapes.capes.gov.br/geocapes/

6. Final Considerations, Limitations and Future Research Lines

One limitation present here is the difficulty of finding quality in the data available for these institutions in Brazil.

It is important that new research is done, using data from other countries so that the model can be validated for other countries and universities.

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