REVISTA NUPEM

Revista NUPEM, Campo Mourão, v. 12, n. 27, p. 254-276, set./dez. 2020

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The Impact of Graduate Studies and Science in Brazil: an analysis in the light of the indicators

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Artigo recebido em 14 de outubro de 2020 e aprovado para publicação em 04 de novembro de 2020.
DOI: 10.33871/nupem.2020.12.27.254-276

Abstract: The Brazilian research and graduate system has shown success, nationally and internationally, and has been strategic for the country's development. Funding agencies play a crucial role in financing and evaluating researchers and results. The establishment of a solid base of sustainable financing is fundamental, thus allowing the development of science linked to major national problems and aiming at reducing regional asymmetries. Brazilian science has been improving in quantity and quality, even though with less impact than developed countries. Universities contribute to society beyond published scientific articles. Medium and long-term public policies, with the definition of priorities, goals and precise implementation and evaluation instruments, as well as adequate financing, are necessary for the improvement of Brazil's position in the international scenario. Changes within the institutions need to increase efficiency and favour the production of relevant and impactful research.

Keywords: Relevance; Financing; Development; Innovation.

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Impacto da pós-graduação e da ciência no Brasil: uma análise à luz dos indicadores

Resumo: O sistema brasileiro de pesquisa e pós-graduação tem sucesso, nacionalmente e internacionalmente. Tem sido estratégico para o desenvolvimento do país. As agências de fomento têm um papel fundamental no financiamento, bem como na avaliação dos pesquisadores e os resultados de pesquisa. O estabelecimento de uma base sólida de financiamento sustentável é fundamental, permitindo o desenvolvimento de uma ciência articulada aos grandes problemas nacionais e visando a diminuir assimetrias regionais. A ciência brasileira tem melhorado em quantidade e qualidade, mesmo que o impacto seja abaixo do de países desenvolvidos. As universidades contribuem com a sociedade além dos artigos científicos. Políticas públicas de médio e longo prazo, com definição de prioridades, metas e instrumentos de implementação e avaliação claros, bem como financiamento adequado, são necessárias para que o Brasil avance no cenário internacional. Mudanças dentro das instituições precisam aumentar a eficiência e favorecer a produção de pesquisa de relevância e impacto.

Palavras-chave: Relevância; Fomento; Desenvolvimento; Inovação.

Impacto de los estudios de posgrado y la ciencia en Brasil: un análisis a la luz de los indicadores

Resumen: El sistema brasileño de investigación y posgrado es exitoso a nivel nacional e internacional. Ha sido estratégico para el desarrollo del país. Las agencias de financiamiento juegan un papel clave en el financiamiento, así como en la evaluación de investigadores y resultados de investigación. El establecimiento de una base financiera sólida y sostenible es fundamental, que permita el desarrollo de una ciencia vinculada a los grandes problemas nacionales y que tenga como objetivo reducir las asimetrías regionales. La ciencia brasileña ha mejorado en cantidad y calidad, aunque el impacto es menor que el de los países desarrollados. Las universidades contribuyen a la sociedad mas allá de los artículos científicos. Las políticas públicas de mediano y largo plazo, con definición de prioridades, metas e instrumentos de clara implementación y evaluación, así como un adecuado financiamiento, son necesarias para que Brasil avance en el escenario internacional. Los cambios dentro de las instituciones deben aumentar la eficiencia y favorecer la producción de investigaciones relevantes e impactantes.

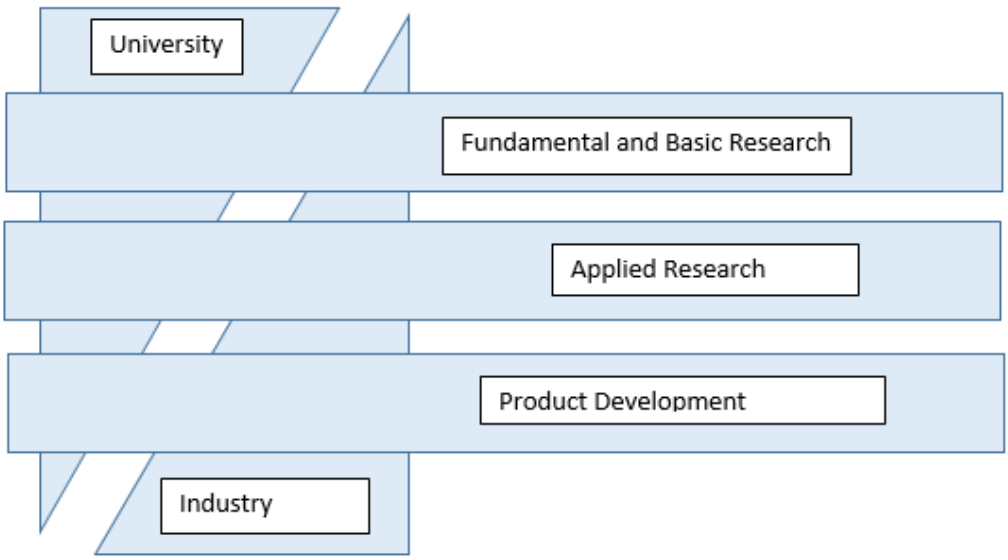
Palabras clave: Relevancia; Promoción; Desarrollo; Innovación.

Introduction

In most countries in the northern hemisphere, scientific research is one of the primary vectors for technological and innovative solutions, as a way of stimulating and boosting their economies. These activities, carried out by research groups at universities and research centres, promote the creation of technology-based companies, encourage the appearance of startups and seek solutions for public and private companies. Thus, the promotion of research and scholarship programs contribute unequivocally to the country's development, including the diversification of its economic matrix. Discussing the funding of scientific research becomes more important in the context of budgetary crisis and questions about the definition of priorities that exclude the human and social sciences.

In the knowledge society, quality in innovation is based on scientific quality. Economic development is dependent on innovation (Oliveira, 2014), alongside the existence and frequency of good results from basic research. Even the most disinteresting research can result, in the future, in a strong stimulus to innovation, be it incremental or disruptive. Each life-saving medical advance originates from basic laboratory research. The evolution of information technology, which made computers faster and smaller, with the ability to perform high-speed calculations, made it possible to send astronauts into space and helps us to better understand our planet, as a result of the work of basic scientific research. Some political sectors believe, however, that innovation can be stimulated as a process independent of the production of scientific knowledge. In reality, in the beginning, scientific ideas are transformed into applied Science, which, in turn, results in technology, that is innovation (Figure 1).

Figure 1: Knowledge Production



Source: Adapted from Trott (2012).

There is a maxim that says: knowledge is power (*Scientia potentia est*). Science is also power, development and supremacy and, above all, the country's sovereignty. Universities, in general, are training the next generations of scientists, engineers, teachers, political scientists and health professionals. These are the people who, in the future, will solve the biggest challenges of clean energy

and global sustainability, health and well-being, national security, in addition to economic opportunity and entrepreneurship, as well as teaching our children.

The Board Chairman of CBMM (Companhia Brasileira de Metalurgia e Mineração) and Itaú Bank, Pedro Moreira Salles, recently declared that

> There is no increase in productivity without an academy that combines teaching with research, working together with companies that take the risk to innovate. As in Brazil, most private third level education is not primarily dedicated to research, the solution to untie the knot of our productivity goes through autonomous and quality public universities, where ideas circulate freely and are exposed to critical thinking, without the shackles of prejudices and ideologies. […] A country that turns its back on reason and knowledge will be a poor, sick, insecure and sad country […]. Science expands our horizon and reduces our perplexity. A country that offers knowledge to the world is an honourable country (Godoy, 2019, s/p).

In an analogy, it can be said that Science is a tree, in which basic research would be the root, applied research, branches and, innovation, would be the fruits. Metaphorically, without a strong root, there is no way to harvest healthy fruits. Basic research improves our understanding of the natural world. It forms the basis of applied research in the development of commercial products and, ultimately, generates a better quality of life. There are ways to defend the Linear Innovation Model or Pasteur's Quadrant (Stokes, 1997) but, in the end, the basic sciences and applied sciences go hand in hand, as highlighted by Cantrill (2013).

At a time when public universities and Science in Brazil are under attack and at the risk of collapsing due to budget cuts, it is vital to defend the system and remember that Brazil's development owes a lot to these institutions. This defence should not, however, prevent reflection on the necessary changes in our public university system, so that it can expand its contribution in the search for solutions to the main problems faced by the country (socio-economic and cultural). This will happen when our universities project themselves internationally as a reference in the production of scientific and technological knowledge and in supporting innovation.

Reduction in funding is becoming more prevalent worldwide. Investments in Science are also being scrutinised for their ability to sustain a country's competitive advantage (such as avoiding duplicate research funding by federal agencies, in addition to funding research purely for social or economic gain). Brazil is going in this same direction. Cantrill (2013) argues that the belief that research stimulated by curiosity can, in itself, guarantee advances in technology is difficult to justify. Nevertheless, research guided by a clear mission and stimulated by society, in addition to protecting basic Science, promotes vital economic and social interests. The need for Science in networks and collaboration is also becoming more evident (OECD, 2014). Fischer, Schaeffer and Vonortas (2019) argue that the best Brazilian universities are responsible for a significant share of the country's patents, increasing over the years, and these institutions have demonstrated a progressive integration with the national innovation system.

The recent attacks and criticisms are being used to justify the budget cuts, but they do not differentiate between levels of useful contribution. They also attack lecturers and public officials whose

work reinforces the value of these institutions for local, regional and national scientific and technological development. A general budget cut compromises the positive results of the research being carried out and does not solve the real problems faced by the higher education institutions (HEIs). This became evident during the current crisis following Covid-19, as universities across the country have contributed to finding social and scientific solutions in all areas of knowledge (Souza Filho; Alves, 2020).

Only a consistent reform policy, based on a new understanding of the role and necessary commitment of public universities (as trainers of human resources and producers of knowledge) with national development, improves management in the efficiency of the use of public resources invested and increases their impacts on society. A broad diagnosis of the progress already achieved and potential achievements must be used as the basis for reform, as well as the challenges and distortions in government policies and institutional culture that have prevented the desired changes.

Diagnosis

Universities are relatively new phenomenons in Brazil, as the oldest institution is less than a century old. In general, public universities in Brazil are very new by international standards, and the official foundation of the oldest institutions date from the early 1900s. In the Northeast and Midwest, the leading universities are from the 1960s and 1970s (Federal University of Ceará, in 1975; Federal University of Maranhão, in 1966; University of Brasília, Federal University of Rio Grande do Norte and Federal University of Paraíba, in 1960). The university reform of 1968, in the context of top-down modernisation, proposed the conversion of our universities into modern institutions committed to research. They should be the dominant form of organisation for the development of higher education in Brazil (Balbachevsky, 2013), but that is not what happened. The development of higher education opened space for private initiative and public institutions became a minority in the number of enrollments (McCowan, 2007).

However, such development ensured the emergence of graduate studies and scientific and technological research in the university system (Baeta Neves, 2020). This was supported by the implementation of job stability in public universities, the full-time work regime, the valuation of formal academic degrees in terms of remuneration and constant investments in material and personnel infrastructure. The Single Legal Regime (RJU) (Brasil, 1990) strengthened the advances that enabled change in public universities. Science e technology policies and support for graduate education have complemented the picture over time.

In this process, strong associations emerged that controlled the teaching and the personnel movement, proposing the generalisation of the benefits that were associated initially with the most productive professors in research and graduate courses, for the entire faculty. Likewise, these associations defined their views on the governance model of public universities that made leaders complicit in the demands of a university community interested in defending specific privileges and benefits.

The extensive concession of the full-time exclusive dedication regime and equal pay, with the consequent reduction in teaching hours in the name of the general fiction of dedication to research, and the size of the classes in the name of the "quality of teaching", in addition to career dysfunctions in admission (selection) procedures associated with the choice of chancellors by direct election, generated an institutional culture that led to numerous distortions and compromised not only the performance of these institutions, but also the leadership role that they should exercise in the process of transforming higher education in general. Public policies fostered this scenario, as they were susceptible to the already distorted principal discussions defended by lecturers' associations. The implementation of the restructuring and expansion Program of Federal Universities (REUNI)[1], with all the investments made, did not affect the hegemony of the associations. On the contrary, their cooperative conceptions continued. The Science & Technology and graduate policies were also sensitive to principles defended by these associations. There is an extensive overlap in the offer of courses leading to inefficiency and inadequate use of teaching and research infrastructure (at the federal, state and municipal levels). The recent expansion of the federal university system did not take into account the expansion of the Federal Institutes of Science and Technology, nor the existence of state, municipal and community institutions. This lack of planning weighs heavily on the cost of higher education and leads to increased distortions that could be avoided, both systemically and within universities (Schwartzman, 2006). Government programs such as "REUNI" and "Ciência sem Fronteiras[2]" lacked strategic focus, adequate planning for their execution (McManus; Nobre, 2017), with the redistribution of research and graduate resources to supply expenses with mainly undergraduate students abroad (Science without Borders Program). For example, this program led to a cut of 75% of the funding for graduate courses in the country in 2015.

The most recent national postgraduate plans (PNPGs) aimed to expand the national research base with the creation of a system of masters and doctoral courses of national scope. Half of the graduate courses in the country were created in the last ten years, mainly in less developed regions such as the North, the Northeast and the Midwest. The production of information on the impact of published scientific articles and on international comparisons is also recent. This information enables us to analyse the situation in Brazil critically and to identify measures that can provide guidance in terms of quality and the contribution of research to national development. It is known that the problem involving scientific and technological research policies is not just the scarcity of resources. The crisis in public investment, however, does threaten to condemn the country's effort in the area into insignificance, committing it to scientific dependence and marginality.

[1] In 2003 the federal government adopted a series of measures (Reuni) to stimulate the growth of public higher education, creating financing for federal universities, so that these institutions could promote physical, academic and pedagogical expansion of the federal higher education network. The effects of the initiative can be seen in the numbers of the expansion. Reuni ended in 2012.

[2] In 2011, the Science Without Borders program was created, whose objective was to promote the consolidation, expansion and internationalization of science and technology, innovation and Brazilian competitiveness through international exchange and mobility. The initiative had resources from the Ministries of Science, Technology and Innovation (MCTI) and the Ministry of Education (MEC), through its funding agencies – CNPq and Capes –, and the Higher Education and Technological Education Secretariats of MEC. The program was expected to finance up to 101,000 scholarships in four years.

Impact of Science in Brazil

It is well known that 95% of the research carried out in Brazil is developed in graduate courses linked, mainly, to public universities (McManus et al., 2020a, in press). There are 478 institutions registered in Capes' database, of which 223 are private, 89 state, 155 federal (including universities and technological institutes) and 11 municipal. From the year 2000 to the present day, Brazil published 889,443 articles registered in Scopus®, with an increase from 15,067 articles in the year 2000 to 82,731 in 2018 (McManus; Baeta Neves; Maranhão, 2020). The increase was followed by an improvement in quality, since the Field Weighted Citation Index, increased from 0.78 in 2000 to 0.90 in 2018. The highest index in FWCI (0.95) was recorded in 2016 (slightly below the world average). It is important to remember that, in the last four years, the scientific community has faced severe financial restrictions. A high citation index is reached by publishing in open access or high impact journals, usually paid, which can be a severe limitation under the current budget restrictions (McManus et al., 2020a, in press) and an unfavourable exchange rate. Many researchers have to pay for these publications with their projects (or even from their own pockets).

In a recent report by the National Science Foundation (USA), Brazil ranks 11th in terms of article production. Another report, in a joint publication by American Clarivate Analytics with the Chinese Academy of Sciences, in 2019, Brazil appears in a list of 20 countries regarding the world leadership in Science and Technology. As expected, the USA and China lead the ranking, followed by the United Kingdom and Germany. The most important highlight of Brazil is in the biological areas, placing the country in 10th place and with a higher index than countries such as Japan, Spain, Australia and Canada. The world leadership index is based on a production index (which includes the number of important articles published and cited in the area of knowledge) and an influence index that is based on citations. The analysis was based on ten research areas and 137 research fronts established in another document (CAS, 2019). Brazil stands out in 3 research fronts ("Phosphorus loads and pollution and health risk of cyanobacterial blooms"; "Pollution and environmental risk control of heavy metals in major mineral deposits in China" and "Observations and theory researches of binary black-hole mergers"). Brazil is also the only country in Latin America with a Science & Technology cluster in the top 100 worldwide (wipo.int). The 2019 WIPO (World Intellectual Property Organization) report highlights the quality of universities in Brazil, highlighting this aspect as fundamental to the quality of innovation in the country. Thus, Brazil is in 4th place in terms of quality of innovation among middle-income countries.

The increase in international cooperation has made Brazil a partner of significant contribution to world science (Table 2). It is important to note that 30% of scientific articles published in the last five years (141.702) had foreign co-authors, mainly from North America (61.675) and Europe (82.789), with a corresponding increase in impact (4.61), almost five times greater than the world average (SciVal®). Brazilian cooperation has been seen to have a major effect on publications with international collaboration, showing that Brazilian researchers are contributing to prominent research topics worldwide, in all areas of knowledge (McManus et al., 2020b). The level of international collaboration

reached 37.4% in 2019. A 2% increase in impact with a 1% increase in international collaboration. Collaboration with Brazil in scientific and technological research is beneficial for both sides (Table 1).

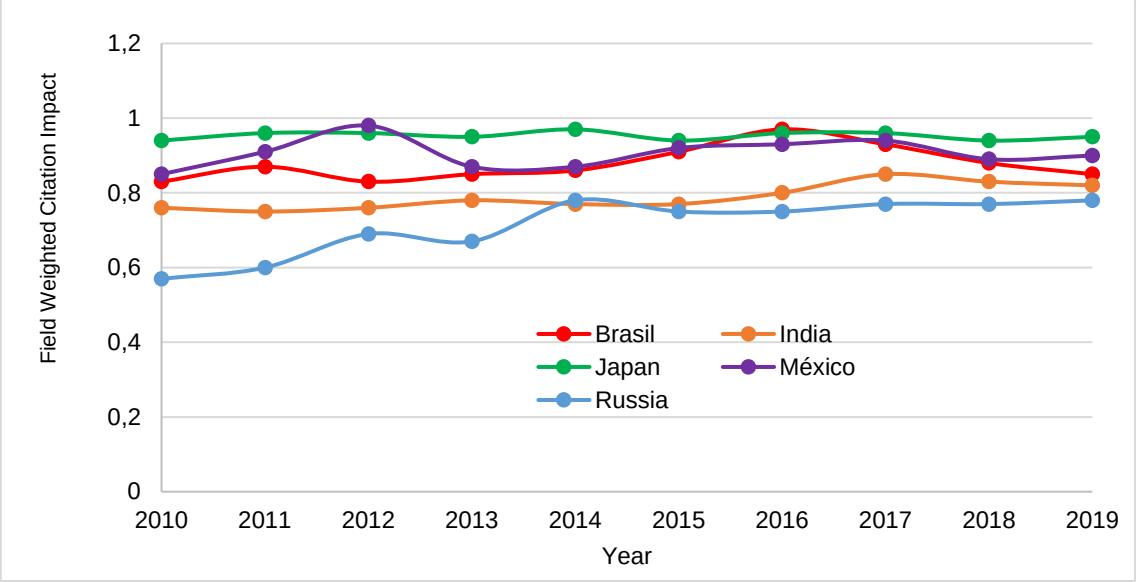
Table 1: Brazil in collaboration with the 30 countries that most publish (2014-2019) SciVal®

Country/region	Collaborative Publications	Increase in collaboration (%)	Citations per publication	Field Weighted Citation Index (FWCI)
USA	55426	47.1	16	2.26
UK	22848	67.5	23.7	3.32
France	18540	34.5	23.3	3.08
Spain	18507	46.6	22.1	3.07
Germany	18067	46.7	23.9	3.31
Italy	15168	53	24.9	3.57
Portugal	14653	72.9	14.7	2.2
Canada	13752	57.5	24.9	3.64
Australia	10580	70	32.2	4.6
Netherlands	8458	41.8	34.2	4.76
China	8072	65.1	34	4.88
Argentina	7589	23.1	20	3.02
Switzerland	7430	67.7	36.4	4.89
Colombia	6807	68.6	23.6	3.64
Chile	6096	65.5	23.1	3.64
India	6002	62.2	39.1	5.4
Mexico	5955	51.5	25.8	3.79
Sweden	5895	87.7	34.4	5.07
Japan	5886	63.4	37.6	5.43
Belgiuma	5565	52.8	33.4	4.7
Russia	5097	39.2	40.3	5.91
Poland	4688	54.2	39.6	5.79
Denmark	4351	84	39.8	5.73
Austria	4088	66.5	35	5.22
South Africa	3672	67.1	46.5	6.67
Czech Repub.	3450	55.9	34.7	5.17
Finland	3200	85.9	43.8	6.35
Turkey	3190	37.5	46.9	6.56
South Korea	3120	74.1	55.8	8.02
Greece	3084	59.9	42.9	6.11

Source: The authors, adapted from SciVal®.

When looking at the mean impact of Brazilian Science, one must remember that even developed countries, such as Japan (Figure 2), performed below or close to the world average in all areas. Russia sent a man into space; Japan is recognised for its technology, etc. All have an average FWCI <1.

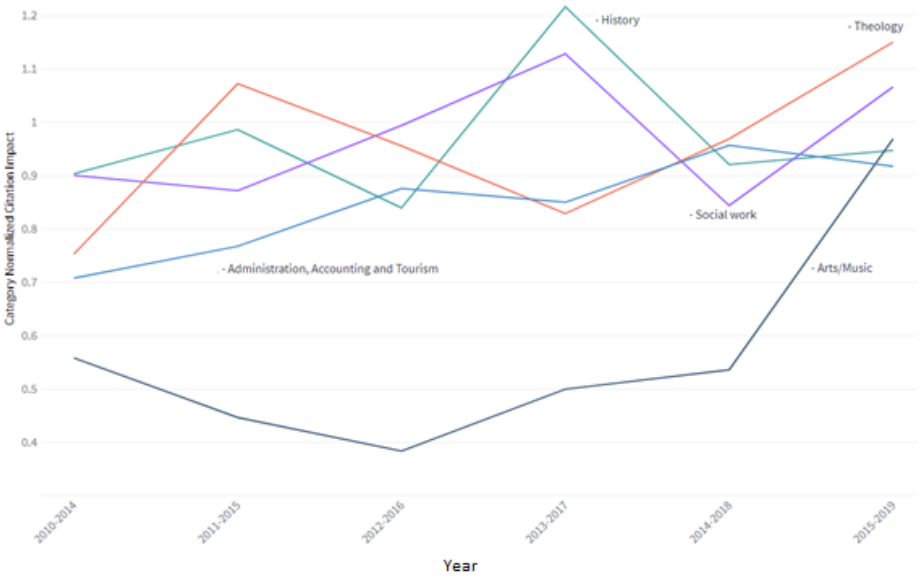
Figure 2: Field Weighted Citation Index (FWCI) of some countries



Source: The authors, adapted from SciVal®.

Brazil presents highly relevant research in several areas of knowledge (McManus; Baeta Neves; Maranhão, 2020), such as in Medicine (FWCI 2.1 x World Average), Nursing (1.85), Dentistry (1.1), Physics and Astronomy (1.8), Environmental Sciences (1.8), Geoscience (1.5), Neuroscience (1.3), among others. The research impact is less in Social and Human Sciences. These areas show, however, a substantial tangential impact that cannot be easily measured by conventional bibliometric tools, such as in the areas of culture, diplomacy and politics, in addition to the impact in practice, in areas such as studies of religion (1.1), research security (1.1), economy (1.1) and administration (1.2).

Figure 3: Impact of some areas of Social Sciences and Humanities in Brazil (InCites®)

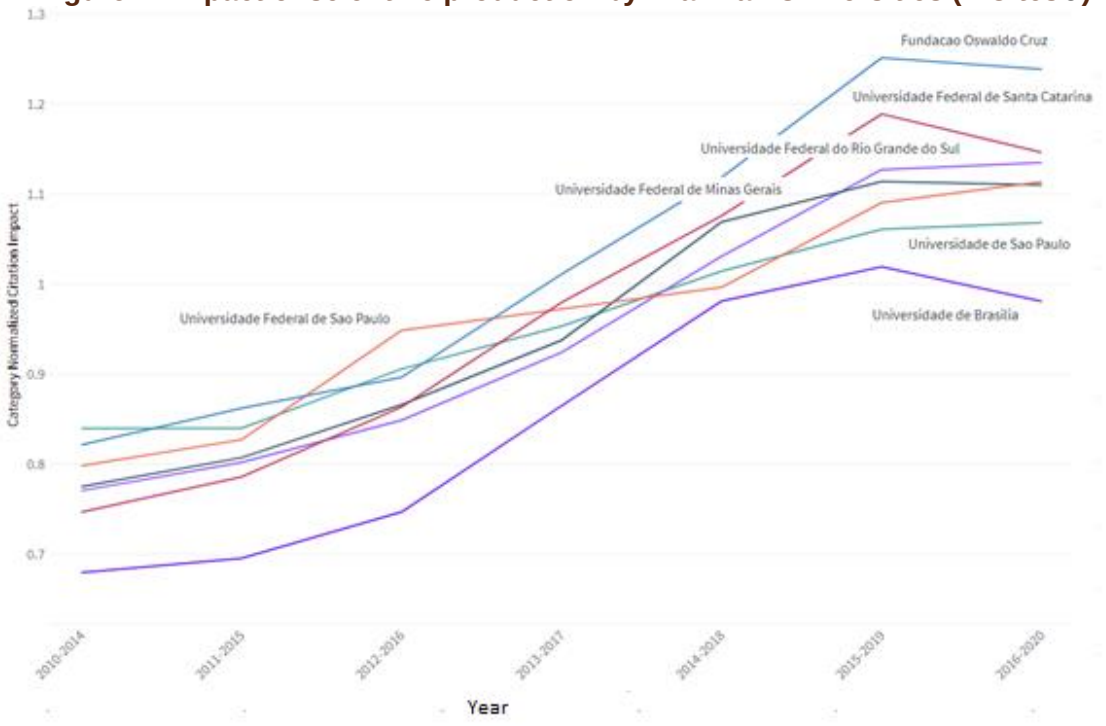


Source: The authors, adapted from InCites®.

Although the impact of research in Social and Human Sciences is lower, doctors in these areas tend to receive higher salaries than doctors in other areas (CGEE, 2016). Individual institutions also show significant impact (Figure 4).

Almost 22% of Brazilian publications in all areas of knowledge are published in national journals, second only to the USA (31.5%). The use of international indicators has been questioned for these areas. Wartburg, Teichert and Rost (2005) affirm that, when analysing individual citations, it is not possible to reveal the indicators and technological paths adopted. On the other hand, Tijssen and Winnink (2018) question the validity of the measurement methods and quantitative indicators, such as analysis of citation used to measure the excellence of R&D (Research and Development) and innovation. This is because large-scale comparative measurement or benchmarking can only reach the limits of in-depth understanding if confirmed by case studies.

Figure 4: Impact of scientific production by Brazilian Universities (InCites®)

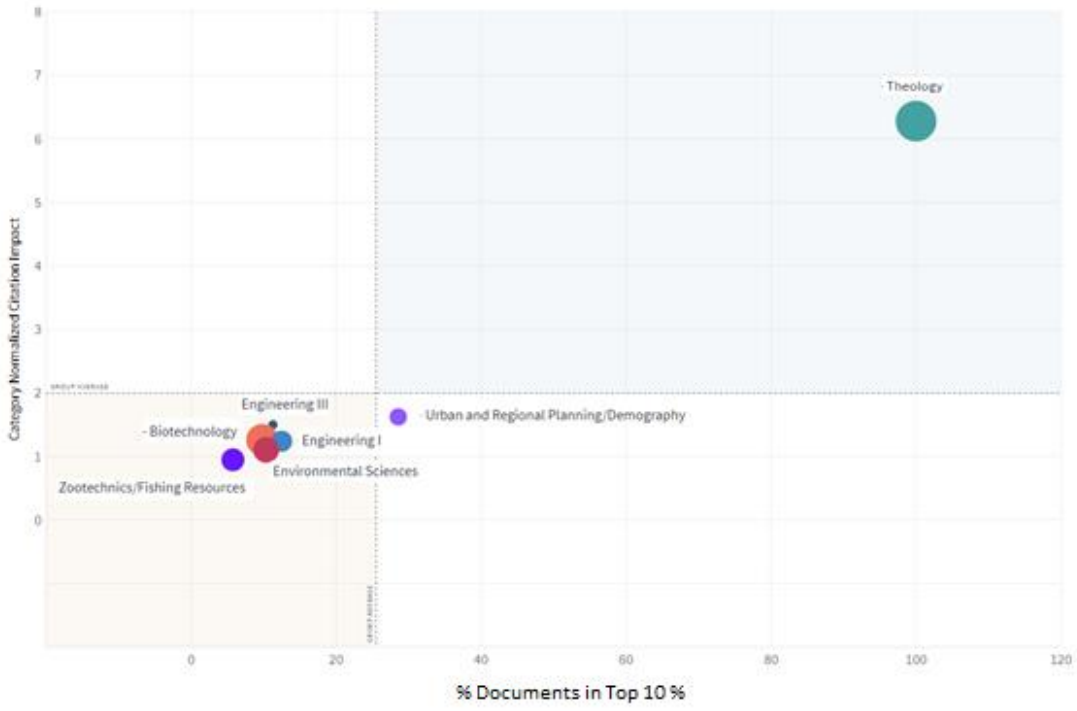


Source: The authors, adapted from InCites®.

Half of all publications in Brazil come from 14 institutions, with the University of São Paulo responsible for 18% of them. There are 86 institutions producing 90% of scientific documents, with six universities maintained by Catholic religious orders representing 2.6%, 58% of federal universities linked to the Ministry of Education, 14.5% of state universities and only 1.8% of private institutions (SciVal®). Significant impact factors are seen, especially in public institutions. Only two private hospitals and two Catholic universities, for example, appear on the list of institutions with an average impact factor greater than the world average (McManus et al., 2020a, in press). These universities train more than 60,000 masters and 21,000 doctors per year (Capes, 2018), with a 52% increase in graduate courses between 2010 (2,840 courses) and 2018 (about 4,320 courses). Most of this expansion occurred in the North

(78%), Northeast (64%) and Midwest (70%), which demonstrates an effort in terms of regional development, according to the PNPG (Capes, 2014). These institutions, newly integrated into the graduate system, cannot be expected to produce the same quality science when compared to older universities and established research institutions in other regions of the country (and which have more stable funding, as is the case of institutions in São Paulo). Still, data from InCites® show that public institutions of higher education in these regions have shown constant improvements in the quantity and quality of research over a span of 10 years (for example, Figure 5). This can be seen in the increase in the number of well-evaluated graduate courses in these regions, with two institutions in the Northeast appearing among the top 10 institutions in the "Nature Index", including the Federal University of Paraíba and the Federal University of Rio Grande do Norte.

Figure 5: Impact of different areas of knowledge at the Federal University of Mato Grosso do Sul (InCites®)



Source: The authors, adapted from InCites®.

In addition to quantity, the quality of Brazilian scientific production has also grown. Data has appeared to refute this improvement. Simplistic analyses, often based on precarious data and relating to a single point in time, are not able to capture this growth. They suggest a deliberate willingness to ignore data and modern statistical analysis resources. Analyses should take into account multiple indicators and comparisons with the group of countries in perspective. Table 2 shows the position of Brazil in relation to different indicators, having as reference the 40 countries that most invest in research worldwide, more Portuguese.

Table 2: Rank of Brazil in data from Scimago, InCites and Scival for the 40 countries that publish the most (besides Portugal)

Index	Rank Brasil
H-index	24
Citations per document	25
% International Collaboration (1990-2020)	33
% Change in International Collaboration (1990-2020)	38
Number of Citations Overall 2019	31
R&D resources invested per GDP per capita	30
Citation cost (R&D resources invested per GDP per capita/ citation)	12
Changes in the number of papers in Top 10% (2010-2020)	5
% Change in Number of Papers	10
% Change in Number of Citations	15

Source: The authors, adapted from Scimago®.

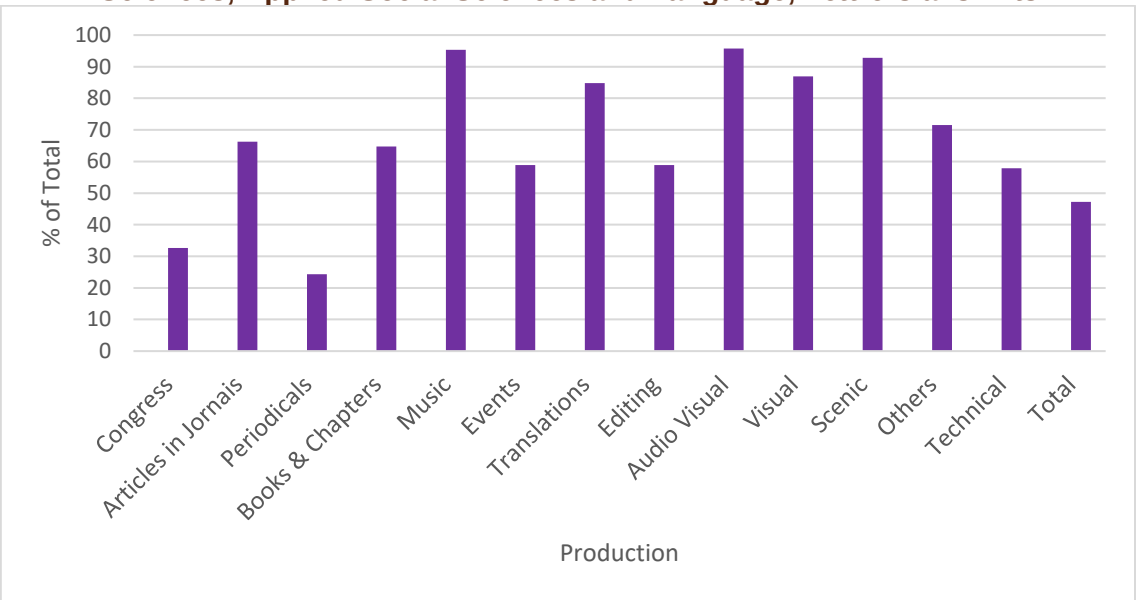
Brazil loses in terms of investments made in R&D (Research and Development) compared to other countries (Unesco, 2020), but it improves its position not only in quality but also in quantity when compared to first world countries (Table 2). As an example, a citation from Brazil costs half as much as one from Portugal and 1/12 as one from Qatar.

Postgraduate studies contribute more than Science

More than four million products were registered as a result of academic work in the 2013-2016 quadrennium (McManus; Baeta Neves, 2020a). This production involves very different profiles of academic work, depending on the area of knowledge. It reflects the intense and comprehensive activity of professors and graduate students, in addition to the knowledge production generally measured in the evaluation processes, with impacts in several areas of Science and society (ESF, 2012a, 2012b).

McManus and Baeta Neves (2020a) show that the majority of patents (more than 8700 in total between 2013 and 2016) are related to medical and multidisciplinary areas, followed by engineering, exact, biological sciences and agriculture, with 263 in other countries. There are more maps produced by humans and more computer solutions (applications) in engineering and multidisciplinary areas. Human Sciences, Applied Social Sciences, and Linguistics, Letters and Arts (LLA), also presented short courses and appeared on more TV programs and in newspapers (Figure 6), showing more significant interaction with the general public than other areas (Ochsner; Hug; Daniel, 2016). 31% of newspaper articles are in the social sciences, and this area, together with humanities, contributes more than 50% of books and chapters in books and almost 50% of technical services. The importance of these types of metrics and increased transfer of knowledge from the university to society has become increasingly important in recent years, as also seen by the growth in indicators related to altmetics (Sud; Thelwall, 2014).

Figure 6: Percentage of total production in Brazilian postgraduate courses from the Human Sciences, Applied Social Sciences and Language, Lettrers ans Arts



Source: The authors, adapted from McManus and Baeta Neves (2020a).

These areas also offered more technical services, such as evaluation, editing and composition of works and projects, participation in evaluation committees, organisation of events, among others. This also includes other types of materials, such as educational videos, and folders for the dissemination of scientific activities, etc.

While most products in the exact sciences and life sciences appear in scientific congresses and magazines, the human and social sciences (HSS) produce more books, book chapters, events, editorials and technical production. As expected, the Linguistics, Letters and Arts (LLA) area appears with the highest percentage of translations and scenic, audiovisual and visual productions. In artistic production, almost all productions took place in this area, with theatre, interpretations and presentations.

The production of full papers in events focused on the humanities, social sciences and applied engineering, while other areas had more summary papers. These areas show a substantial impact that cannot be measured by conventional bibliometric tools, such as in the areas of culture, diplomacy and politics, as well as in practice (Bulaitis, 2017). Mugnaini, Digiampetri and Mena-Chalco (2014) showed that these areas have more local impact and that bibliographic resources are more widely disseminated.

McManus and Baeta Neves (2020a) showed that most of the external technical work was based on demand from outside the university for services that are not easily measured. Although many technical works are directly linked to university, several are at the service of the community, including legal, architectural, environmental impact studies, or direct technical advice to industry or startups.

There is a range of overlaps in the applicability of each type of service offered. For example, in the health field, applications are, by their nature, internal concerning the routine of university hospitals, genetic guidance, new diagnostic techniques, external consultations of local and national scope, as well as advice to local and state governments, and in international networks in the fields of medicine, dentistry and specialised services for training professionals in new techniques, etc.

While most academic services in evaluative terms (consultant and consultancy) were related to the evaluation of courses, articles and projects, external services involved consultancy services for ministries, companies and municipalities, with the implementation of programs, development of techniques and follow-up process to ensure compliance with legislation. This also includes consultancy, reports and advice for international companies and organisations such as the World Bank, the United Nations and the OIE (World Organization for Animal Health), in addition to specific support for other corporations in various areas of knowledge.

The elaboration of projects is done by a combination of internal and external activities since they refer to the aforementioned research projects for financing, as well as activities of graduate students, urban architecture projects, projects of new laws, engineering, agriculture and environment. A large number of projects are also related to development issues in the construction and modernisation of buildings, landscaping, sewage networks and other engineering activities.

Other relevant contributions are found in the legal area in connection with the Judiciary, in addition to administrative activities at universities. In other activities, there are records of evaluation of the internal process at the university, participation in committees and commissions (scientific societies, career advancement, etc.), speakers and event organisers, among others. Scientific congresses also help to establish criteria and recognise academics among their peers, in addition to providing, in a short time, evidence in research already completed or in progress. The large production in Human and Social Sciences (HSS), in the different regions of Brazil, demonstrates their importance. The long tradition of seminars, conferences and lectures, abstracts and poster presentation is a way for researchers to receive feedback on their work, in addition to being of greater relevance in the Social and Human Sciences.

Most of the external records in this subdivision refer to lawsuits with university lecturers acting as judges and lawyers. The reviews were almost entirely academic, in congresses, scientific journals, monographs, and selection processes of funding agencies, etc. Technical reports and research purposes were also produced and intended for government agencies in all areas (municipal, state, regional, federal), including evaluation of courses and accreditation of institutions. Most of the services were internal destined for universities and federal (CAPES, CNPq) and state (FAPs) funding agencies or aimed at revising scientific articles.

The informal use of university knowledge is widespread, especially in the Human and Social Sciences (SSH). The media, including newspapers and TV influence public opinion (mass and elite public), thereby showing the influence of SSH (Coppock; Ekins; Kirby, 2018; Feldman, 2016; McCombs 2014; Olmos-Peñuela; Castro-Martínez; D'Este, 2014). Media monitoring can be an indicator of public opinion (Neresini; Lorenzet, 2014) when looking at public technical-scientific problems that are controversial and tend to polarise public opinion (Venturini, 2012; Larivière et al., 2018). Government agencies use the knowledge provided by social scientists to articulate and legitimise programs that they wish to promote.

The impact of Social and Human Sciences may be less evident than in other areas of research, since these areas are involved in the exercise of criticism, in the analysis of cultural heritage and how it is used. This does not decrease their importance or impact.

State and companies in supporting scientific, technological development and innovation

Government support for Science, technology and innovation can come from investments with resources from the national treasury or direct/indirect tax incentives. Tax incentives – for example Lei do Bem 11.196/2005 (Brasil, 2005); Law 11.774/2008 (Brasil, 2008); Informatics Law 13.674/2018 (Brasil, 2018a); Innovation Law 10.973/2004 (Brasil, 2004) and Regulatory Framework for Innovation (Brasil, 2016a) – reduce the cost of developing innovation activities and include tax deduction, reduction in credit rate, accelerated depreciation of assets, total or partial exemption from capital gains and postponement of taxation, as well as favourable treatment of dividends (European Commission, 2001). Indirect support for Science and technology from the state comes from subsidies in the form of low-interest loans such as BNDES shares (Cirani et al., 2016), as well as credit guarantee and equity investment programs and venture capital programs.

The success of direct federal funding in Brazil depends on coordination between the agencies, mainly from CNPq, FINEP and CAPES, in addition to the State Research Support Foundations (FAPs), with emphasis on their distinct and complementary profiles. CNPq's main focus is the individual researcher and his/her group while CAPES has as its primary function the improvement of higher education, something that occurs mainly in the almost 7 thousand postgraduate courses (masters and doctorates) that account for 280 thousand students. CAPES has an institutional relationship with several research centers and universities, in addition to a strong institutional cooperation program with several countries, with an emphasis on programs such as Fulbright (USA), Humboldt, DAAD and DFG (Germany), Cofecub (France), among others. FINEP has a very different objective since it does not directly relate to researchers or graduate students. It has an emphasis on institutions of the highest scientific level, supporting the creation, consolidation, maintenance and expansion of physical infrastructure (with medium and large buildings spread across the country), and academic objectives through granting resources for large equipment. Budgetary fluctuations and numerous contingencies in resources from sectoral funds and the National Fund for Scientific and Technological Development (FNDCT) have had a decisive impact on CNPq e FINEP in terms of their ability to finance research in recent years.

The Science Without Borders (Ciência sem Fronteiras) program, which initially brought new resources to the system, began, after two years, to drain resources from CNPq and CAPES for scholarships for sandwich-graduation[3] abroad (McManus; Nobre, 2017). As a consequence, this affected CNPq's true institutional identity, compromising its image and the social recognition of its work. The fact is that, over the last decade, only CAPES managed to preserve its budget and, thus, its financing

[3] A period of up to one year abroad during their undergraduate course, with the possibility of a 6 month extension to learn the language to be able to attend classes.

capacity. This was due, in large part, to the fact that CAPES was protected by the budget structure of The Ministry of Education as a whole. The unusual administrative and combative continuity of some of its leaders was also a factor. Currently, the national science and technology system is threatened, and even CAPES does not appear to be protected. The signs multiply...

The budget of the three agencies is at the lowest levels in the past decade and continues to fall. Setting a budget ceiling (Brasil, 2016b) in institutions and agencies discourages the search for extra-budgetary resources. The institutional identity of the agencies is questioned, and the willingness, at least of the government, to merge and/or extinguish some agencies increases. Administrative discontinuity in financing agencies affects programs and compromises dialogue with key partners in the academic, public and business sectors. Therefore, an unusual disposition to start from scratch prevails, making the new program a government brand. Instead of defending the objective of each agency in the face of each new challenge imposed by the globalisation of the economy, the labour market and scientific and technological research, the government adopts the posture of the new as virtuous support to the implicit conviction that what has been done to date is wrong. Nevertheless, these agencies should strengthen their mission and vision as well as incorporate funding actions that improve the impact of Science produced, together with interaction with foreign partners (McManus et al., 2020b; McManus; Baeta Neves, 2020b).

The innovation discourse is exaggeratedly highlighted at the expense of a balanced view of the necessary relationship between investments in basic and applied research and in innovation. Successive plans such as the National CT&I Plan (PNCTI), Industrial, Technological and Foreign Trade Policy (PITCE), Brasil Maior Plan (PBM), National Knowledge Platforms Program (PNPC) lack a clear definition of instruments, resources and governance for implementation, as well as continuity. A bigger problem is the inability to set priorities. According to Arbix et al. (2017), when many sectors are chosen as a priority, the ability of public agencies to react is diluted, and too many priorities are the same as none at all.

The relationship with international partners, both traditional and new, is uncertain and commitments run the risk of lack of continuity, which affects the international inclusion of Brazilian research and the country's credibility with collaborators in specific research. There are also deviations from the budget for Science, Technology and Innovation for basic education.

The most serious aspect is that there seems to be no concern with the deactivation of already consolidated laboratory structures and research infrastructure in general; they are constructions that took seven decades of constant investments, mainly of the public area, under different governments, regardless of ideology. And the most worrying is that all this happens when there are no proposals for policies and programs that (support and give meaning to such actions) point to a new vicious cycle of development of scientific and technological research in the country.

With the crisis in funding agencies, there is a risk of damaging the integrity of research, in addition to the training capacity of high-level human resources in teaching and research institutions, as well as national development.

Basic research depends to a large extent on government support. Most companies that finance applied research have specific purposes. Basic long-term research, with uncertain results, represents a high risk for companies, whose role as leaders depends on a quarterly report. The claim that companies present innovations resulting from research based on their principles may even be true in some rare exceptions. Science, in some cases, follows technology, but it is clear that this is an exception to the rule. After a successful product is developed, industry is encouraged to do more applied research to improve the product. Still, it has little incentive to discover yet another law of nature to explain this success. Apple is satisfied with the use of artificial intelligence (AI) to create a better iPhone or one of its many applications, but it leaves AI math to the academic world. According to Pedro Moreira Salles: “Agriculture without research is a subsistence farming. Mining without research is panning” (Godoy, 2019, s/p). Fonseca and Veloso (2018) state that the private Research and Development (R&D) sector in Brazil is practically isolated from the rest of the system. These authors show that countries with low national innovation performance should assign more weight to fiscal incentives, as countries with high innovation performance have more efficient financial incentives (Fonseca; Veloso, 2018).

Institutional inefficiency with University-Industry partnerships operates in the scientific scenario of inexperienced governance concerning technology transfer (TT) (Alves et al., 2015; Silva; Guimarães, 2015), in addition to substantial bureaucratic barriers in universities public institutions and research institutes (Freitas; Marques; Silva, 2013) that result in informal partnerships (Dewes; Dalmarco; Padula, 2015). Thus, researchers tend not to fully disclose their knowledge transfer activities to managers and/or administrators (Landry et al., 2010). According to Schwartzman (2002), the public sector is the leading partner and potential user of the knowledge generated by research in developing countries. Brazil cannot fail to take advantage of this.

Necessary changes

Our public universities are home to a broad and diverse scientific community. They are responsible for the formation of an expressive number of Masters and Doctors every year, with a good research infrastructure in which renowned international researchers work in their field. The best research groups tend to be integrated with highly productive international networks (McManus et al., 2020a; McManus; Baeta Neves, 2020b). Thus, there is a recognised contribution to scientific and technological research and the development of the country. Nevertheless, there is a growing feeling within universities that there is a need for change (Ranieri, 2018) and that this change should lead to an increase in the impact and relevance of the scientific and technological knowledge produced. A need for the strengthening of the communication of academic activities (teaching, research and innovation) with society is also evident (McManus; Baeta Neves; Maranhão, 2020).

For that, there is a need for: (a) greater autonomy of universities in all aspects including finance, hiring and relation with society; (b) restructuring of public financing combined with the expansion of private-sector resources in favour of investment in Science and Technology; (c) changes in the process of choosing university leaders and professionalising management activities with the improvement of

technical personnel; (d) simplification of bureaucratic procedures related to academic and research work; (e) end of salary equality and revision of full-time and exclusive dedication regimes; (f) performance assessment focused on results and impact and; (g) restructuring the teaching career and creating more flexible procedures concerning the hiring of foreign researchers; (h) clear definition of the missions of the different HEIs and strategic planning with defined objectives.

Public investment in all spheres is fundamental for the maintenance and expansion of quality higher education in Brazil. However, there has been no coordination and there is an extensive overlap in the offer of courses leading to inefficiency and inadequate use of teaching and research infrastructure (at the federal, state and municipal levels). Any new wave of expansion in public education requires planning that maximises public investment as a whole and articulates with the dynamics of community institutions defined by law as non-state public institutions. In each state of the Federation, a "consortium" of IES could be created to deal, in a cooperative regime, with the formulation of strategies for the expansion of higher education, for its financing and to combat student dropout. This consortium could also define platforms for cooperation in the use of research infrastructure.

In this process, the clear distinction between institutions must be encouraged, not only as regards the type, but especially as regards the mission and objectives concerning their relationship with society. Different regulatory and evaluation procedures and financing instruments must be adequate to strengthen the institutions' mission. The distinction between institutions leads to a more efficient and productive system and reduces overlaps and repetition. International experience shows that the indissolubility of teaching, research and extension is not a fixed rule for all higher education institutions. HEI assessment should be decentralised and conducted by independent agencies qualified for that purpose.

The organisation and governance of universities are dimensions in the exercise of university autonomy, respecting the principle of social responsibility. The process of choosing the best chancellors and directors could include a search committee indicated by the highest deliberative council of the university. The search committee should have academic representation from inside and outside the universities and qualified representation from society. It should draw up a list of names and forward it to the instance selected for the final decision. This suggestion only indicates that there are different formulas as well as the current one for choosing the university's rector and that the chancellor should not be held "hostage" by his community of voters. The objectives and indicators to be attained during the chancellor´s time in office must be established in a university development plan given the needs and demands of society. University councils must listen to society regarding strategic problems.

Conditions for the reconstruction of the public university's relations with society include a guarantee of sustainable and responsible autonomy through a global budget to enforce the provisions of article 207 of the Federal Constitution. Society should also demand results and productivity in terms of training human resources and research, stimulating the fundraising through third parties by encouraging the formation of patrimonial funds through tax incentives.

Personnel policy is the responsibility of each federal university, as long as the general principle of fiscal responsibility is respected. Admission or dismissal of academic and administrative-technical personnel should be the responsibility of each institution. The work regime, including the granting of Exclusive Dedication and stability, as well as the remuneration of teachers and civil servants, are also the responsibility of the university, as long as the general legal provisions applicable to each case are complied with. Exclusive dedication and stability must be based on merit and productivity (Teaching, Research, Extension, Administrative Technical Staff). The maintenance of Exclusive Dedication should be evaluated periodically and stability could use the tenure track system as a benchmark. For example, only 46% of all federal university lecturers supervise students in postgraduate courses (CAPES, 2018).

Remuneration should respect a minimum general floor salary for all levels in the educational system and for the career of administrative-technical personnel, with increases for productivity.

The organisation of teaching, research and extension is also the prerogative of each federal university. Each must follow a strategic plan that will define the mission and vision of the HEI, considering the impact and social relevance, in the individual actions of teaching and research, as well as in the results of extension; each federal university should be concerned explicitly with eliminating student dropout and unsatisfactory institutional performance (low number of qualified students). As seen during the Covid crisis, the incorporation of on-line teaching platforms and technologies in a hybrid model of course offering is unavoidable, as the future of education and scientific research will be a hybrid experience, where living spaces will be enriched with communication and sharing of virtual experiences. Likewise, the use of these technologies will be more intense, such as their use in national and international discussion networks, digital laboratories, language learning etc. Performance and responsibility with regard to the use of public resources must be adapted to the curriculum and the provision of classes. HEIs should incorporate graduate and post-doctoral students as research and teaching assistants in support of teaching and research projects.

In summary, there is no simple solution in the aspects that public universities are seen as inefficient, with high costs and results below expectations. The proposals for expansion of financing resources and the flexibility in the use of funds raised, stimulating the reduction of expenses with employees and charging for services performed, ends up creating a managerial vision that could solve the problems mentioned. However, these are voluntary, simplistic and compromise the invaluable contribution that these universities owe to the country.

These institutions are complex and their problems reflect a lot the problems of public policies, and not just pressure from companies. The improvement in the relationship between universities and national development requires a critical and broad reflection in the whole process of transforming public universities in their relations with society, the economy and politics.

In addition, there is a false dichotomy concerning opposing investments in universities and the demands of basic education. The real challenge is to improve the quality of education as a whole and its contribution to sustainable national development. A stronger and more socially responsible performance of our universities is also a condition for solving the general problems of education and development in

the country. And that requires public investment. However, researchers funded by public agencies need to show how their research can be of use to society (Perkman et al., 2013).

Final consideration

In the present scenario and given the above, it is evident that the most critical changes depend on initiatives in the field of legislation and the redefinition of government policies. The question is, how can this be achieved? The first step may be to deconstruct corporatism and question simplistic and voluntary solutions. This presupposes the proposition of an internal debate based on the mobilisation of segments that are committed to the proposed diagnosis (to be improved) and can contribute to the design of a new public university project. It will not be easy, but it is necessary to start, albeit in a timid way, but with persistence and willingness to change. Some defend the destruction of the public university system, just as some think that everything should be kept as it is, with more money. Therefore, any strategy must take these two lines of thought into account as a warning against naivete and voluntarism.

In summary, there is no simple solution for correction of the aspects where public universities are seen to be inefficient, with high costs and results below expectations. We need to recognize that the public university needs to show efficiency and excellence in the use of public resources and face the problems related to institutional corporativism, remembering that its survival depends on the public perception regarding its usefulness and quality of delivered products. The Brazilian public university needs to demonstrate clearly why it exists and how the consequences of not maintaining it can harm the country's future development. Change is necessary not because everything that has been done so far is wrong, but precisely because we have reached a point where the next step emerges from the constructed history, not as a disruption, but as a maturation.

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