Brazil's research indicators have improved consistently over the past two decades

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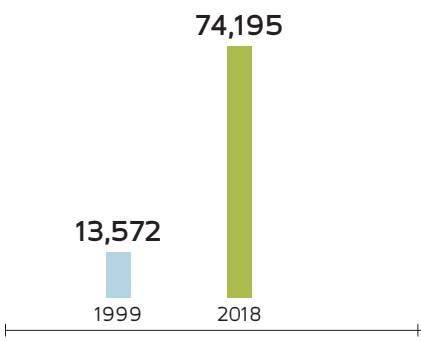
GROWTH IN NUMBERS

Papers published

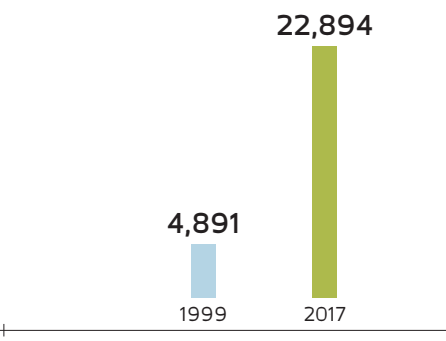
+446%



SOURCE SCOPUS

Doctoral degrees

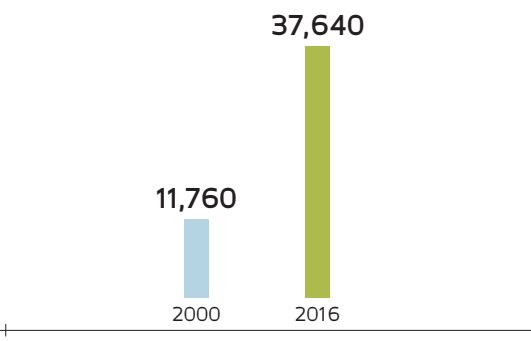
+368%



SOURCE CAPES

Research groups

+220%



SOURCE DGP/CNPQ

Brazil's research landscape has undergone profound transformation since Pesquisa FAPESP first went into circulation in 1999. Science output has grown more than fivefold—the number of Brazilian-authored papers in Scopus-indexed journals rose from 13,500 in the late 1990s to 74,000 in 2018, raising the country's publication rank from 18th to 13th. Although the Scopus database has incorporated several new Brazilian journals in recent years, preventing a like-for-like comparison, the expansion of Brazilian research is borne out by other indicators. One is the contingent of active scientists as measured by the Research Group Directory Census, an inventory of active research teams compiled by the Brazilian National Council for Scientific and Technological Development (CNPq). The number of registered groups jumped from 11,700 in 2000 to 37,600 in 2016, the most recent year for which data are available. The number of PhD researchers grew from 27,000 to 130,000, or by 380%—for comparison, Brazil's population has grown 21% over the past 20 years.

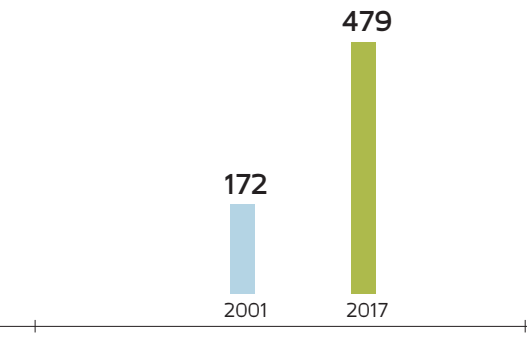
However, the transformation goes beyond just numbers. There are now as many female researchers as male; 20 years ago, 56% of researchers were men and 44% were women. The pool of newly trained talent has also expanded. The number of doctoral degrees per year grew from 4,900 in 1999 to almost 22,900 in 2018, an increase of 370%, while the number of master's degrees rose at an equally impressive rate, from 15,000 to 51,000 per year. "This testifies to the success of the graduate education model introduced in the 1960s, with its emphasis on domestically training the talent needed for research, lecturing, and other needs," says political scientist Abílio Baeta Neves, who formerly chaired the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES). This strong performance would not have been possible without substantial growth in Brazil's higher education programs, which currently train more than 900,000 undergraduates per year, compared with 350,000 at the turn of the 2000s.

Indicators of research quality have also improved. The number of graduate programs rated 6 and 7—the two top scores in CAPES assessments, denoting a high level of interaction with international research groups—grew from 172 in 2001 to 479 in the 2017 assessment, an increase of 178%. The increase is proportional to the number of active programs, which rose from 1,545 to 4,175 in the period.

Baeta Neves, who chaired CAPES in the late 1990s and then again from 2016 to 2018, underscores an important change in the concept of what constitutes a high-quality graduate program. Until the mid-1990s, the agency rated programs on a scale from A to E. "The model was clearly obsolete, with more than half of programs earning top scores of A and B," he recalls. In the 2001 assessment of the previous three years, a new scale was introduced, with ratings of 6 and 7 reserved for those programs that were deemed world-class. "By then, it had become clear from bibliometric indicators that internationalization was a key lever, as research in collaboration with foreign institutions had been shown to have a citation

Graduate programs RATED 6 AND 7

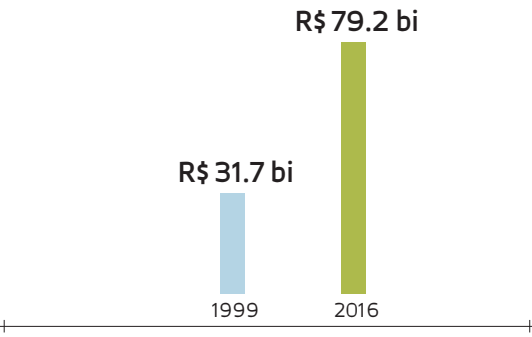
+178%



SOURCE CAPES

R&D expenditure

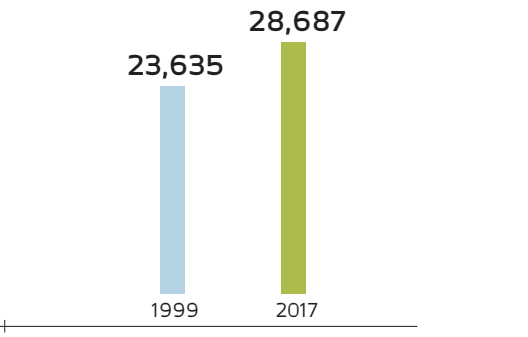
+150%



SOURCE MCTIC – VALUES CURRENT TO 2016

Patent applications in Brazil

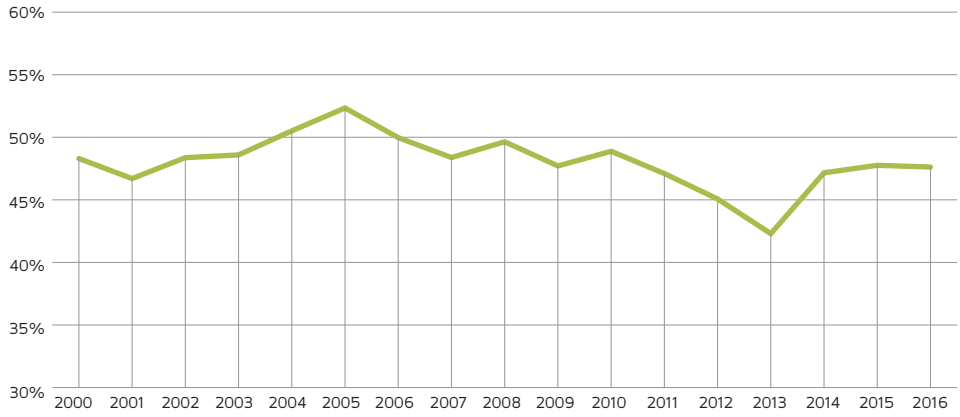
+21%



SOURCE INPI

Private effort stagnant

Corporations' share in research and development (R&D) investment in Brazil from 2000 to 2016 as a % of total expenditure



SOURCE INDICATORS/ MCTIC

impact four times greater than research done locally." Elizabeth Balbachevskyy, of the Department of Political Science at the School of Philosophy, Languages and Literature, and Humanities at the University of São Paulo (FFLCH-USP), says the expansion of public universities and graduate programs continued to follow a pattern in which institutions fall under one of two categories. "In one group are research universities with internationally connected faculty that actively engage in research networks, and in the other are regional universities, where professors are more devoted to lecturing and are less connected to research networks." She notes that the top graduate programs are largely offered by well-established universities, while younger universities are typically focused on creating cross-disciplinary programs, which are still nascent and are more difficult for CAPES to rate in a useful way. "This division is seen in many countries. But imposing a common design on all public universities would be bad policy, as it would prevent regional universities from leveraging their biggest strength, namely their responsiveness to local challenges."

The strength of a research group can be measured by its ability to work with teams across borders, and Brazil has certainly made some progress in growing its international presence: in the early 2000s, less than 30% of research in Brazil was done in collaboration with researchers from other countries; in 2017, more than 35% of Brazilian papers were coauthored with foreign colleagues. Researchers in São Paulo State have had a peculiar track record in international collaboration. They started the decade below the national average for research coauthored with foreign scientists, but they now exceed the average, having authored 40% of their papers via international collaborations.

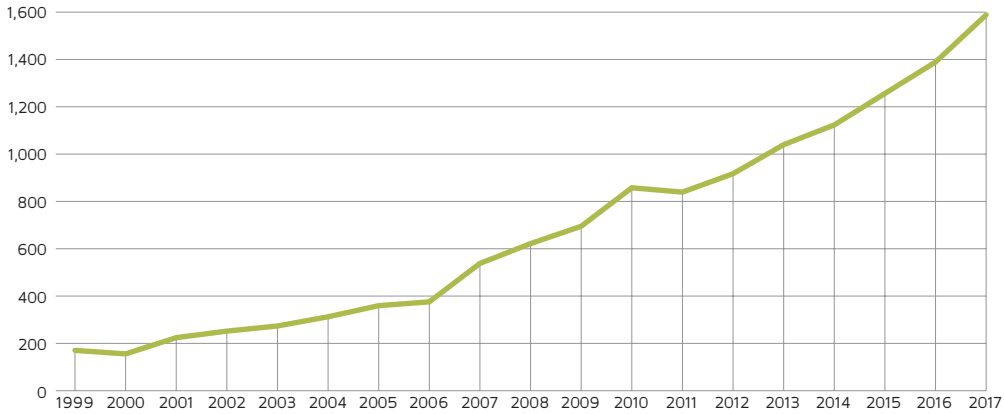
In 2017, out of the 9,500 articles they authored with foreign researchers, most (3,984) were in collaboration with researchers in the US, followed by the UK (1,683), Spain (1,356), and Germany (1,318). "FAPESP has actively supported collaborations and expanded agreements with foreign agencies and institutions, but universities in São Paulo have made a deliberate shift toward internationally collaborative, high-impact research," says physicist Carlos Henrique de Brito Cruz, FAPESP's scientific director. "The introduction of international rankings comparing university performance appears to have spurred the movement." Brazil's research impact, as measured by citations, has also improved, albeit at a slower pace than article counts. Normalized relative impact has risen from approximately 0.8 to approximately 0.9—below the world average of 1. Researchers in São Paulo also started at 0.8, but they are now at the world average.

The improvement in research indicators over the past 20 years has occurred in tandem with a reorganization of Brazil's national science, technology, and innovation landscape, notes ecologist José Galizia Tundisi, a retired professor at USP's São Carlos School of Engineering who served as president of CNPq in the late 1990s. "From a focus on grants only, CNPq funding was retargeted to also include research projects. In 2000, Millennium Institutes—networks of researchers dedicated to nationally strategic research interests—were created and later evolved into today's National Institutes of Science and Technology," says Tundisi, noting that the reorganization was strongly supported by Sectoral Science and Technology Funds.

Research infrastructure linked to the federal government has become more diversified than in the 1990s, says Tundisi. Institutes then linked to CNPq, such as the Institute for Pure and Applied Mathematics (IMPA) in Rio de Janeiro,

Academic-industry collaboration

Papers indexed on the Web of Science platform with at least one author from a Brazilian university and one coauthor linked to industry



SOURCE RESEARCH IN BRAZIL: FUNDING EXCELLENCE/ CLARIVATE ANALYTICS

Our June 2017 cover article discussed the constraints and challenges in funding research in Brazil

have since been placed under the management of social organizations, a model also adopted at the Brazilian Synchrotron Light Laboratory in Campinas. "Institutional reform has also occurred at the state level, with states such as Minas Gerais, Rio Grande do Sul, and Rio de Janeiro following São Paulo and FAPESP's lead and funneling significxant funding to science," says Tundisi.

Brito Cruz, who presided over FAPESP's Board of Directors in 1999, says the quality of research in São Paulo State has also improved, with thematic projects, for example, receiving up to six years of grant funding from the Foundation for highly ambitious initiatives. "Our thematic projects have become more robust and competitive, with more postdoctoral researchers on project teams than there were in the past," he explains. Another example is the Research, Innovation and Dissemination Centers (RIDC) program, which provides up to 11 years of funding for research consortia engaged in frontier research projects, with a mandate to invest in high-risk research without pressure to deliver short-term results. The program was launched in 2001, initially with 11 centers, and in 2013, it was renovated, with the number of centers growing to 17. This model has been used in partnerships with corporations such as Shell, Natura, and Peugeot-Citroën to implement Engineering Research Centers, in which researchers from industry and academia collaborate in a cofunding arrangement.

The transformation of Brazil's universities has increased their capacity to drive innovation and engage with industry. Counterintuitively, integration between academia and the private sector has improved remarkably. A report from Clarivate Analytics found that the number of papers coauthored by university and industry researchers had grown eightfold from approximately 200 in 1999 to 1,600 in 2017.

Patent data for 2017 show that nine universities were among the top 10 patent filers in Brazil that year—the only corporation was CNH Industrial. The makeup of Brazil's top patent performers is now very different from what it was in the early 2000s. An INPI report in 2006 listed the leading patent filers from 1999 to 2003, and only two universities made the list: the University of Campinas (UNICAMP), ranking 1st, and the Federal University of Minas Gerais (UFMG), in 10th; the remainder were all corporations, including Petrobras, Arno, Multibrás, Semeato, and Vale.

The shift highlights the importance that universities have attached to intellectual property protection, especially with the advent of Innovation Centers (Núcleos de Inovação Tecnológica, or NITs) created under the Innovation Act of 2004. These Centers have a mandate to identify and secure patent protection for potential research applications in industry. In a more recent development, universities have moved to licensing their technologies to corporations. According to Science, Technology, and Innovation Institution Policy Information Filings (FORMICT), licenses generated R$34.4 million in revenues for Brazilian universities and research institutions in 2016. Industry investment in research and development (R&D) accounted for 48.3% of total research expenditure in Brazil in 2000 and has since remained at this level, reaching at 47.6% in 2016. São Paulo is an outlier, however, with private investment accounting for 56% of total investment in 2018. "A possible explanation for this stagnation is that all these years, Brazil has never moved to open its economy and encourage local corporations to compete more in global markets," says Brito Cruz. ■