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Government funding of cancer research in Brazil

Cecilia Ferreira da Silva [a,*], Luciana Dias de de Lima [b], Claudia Garcia Serpa Osorio-de-Castro [c]

[a] Clinical Research Division, Brazilian National Cancer Institute (INCA), 37, André Cavalcanti Street, Rio de Janeiro (RJ), 20231-050, Brazil
[b] Oswaldo Cruz Foundation, National School of Public Health Sérgio Arouca, Department of Health Administration and Planning, 1480 Leopoldo Bulhões Street, Manguinhos, Rio de Janeiro (RJ), 21041-210, Brazil
[c] Oswaldo Cruz Foundation, National School of Public Health Sérgio Arouca, Department of Medicines Policy and Pharmaceutical Services, 1480 Leopoldo Bulhões Street, Manguinhos, Rio de Janeiro (RJ), 21041-210, Brazil

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ABSTRACT

Background: Cancer research is a prominent theme on national and international development agendas. In many developed countries, funding for this area comes mainly from government sources. This article analyzes government funding of cancer research in Brazil, identifying the main funding instruments and examining the regional distribution of resources, research project and researcher profiles.
Methods: Exploratory study of government funding of cancer research in Brazil between 2007 and 2016. The primary data were federal and state funding agencies.
Results: A total of 8565 research awards were identified for the period 2007–2016. Amounting to almost US$489 million, these awards were linked to 7622 research projects and 3068 researchers. The proportion of grants awarded to women was slightly higher. It is noteworthy that just 3% of researchers received 20 % of the grants. The multiple-grant history of individual researchers seemed to be a conditioning factor for obtaining new grants/fellowships. Funding was highly concentrated in the Southeast region, accounting for 84.4 % of total awards. There was a positive correlation between number of awards and amount awarded. The most frequently studied cancers were breast (11.8 %), head and neck (9.0 %) and skin cancer (5.3 %). Studies that did not specify the type of cancer accounted for 36.8 % of grants and 45.1 % of funding.
Conclusion: The findings show a fall in the share of cancer research funding in the three largest funders. Cuts in government spending triggered by the country's political and economic crisis, highlight the vulnerability of science and technology. Greater transparency through access to information on funding, researcher, and research profiles is key to obtaining a better understanding the cancer research funding landscape in Brazil and reducing regional inequalities.
Policy summary: A more centralized management of public cancer research funding and constant investment and monitoring is needed to ensure the effective implementation of funding policy.

1. Background

Cancer is one of the leading causes of death and disability globally, with approximately 18.1 million cases and more than 9.5 million deaths in 2018 [1]. According to the International Agency for Research on Cancer (IARC), in the same year, there were 1.0 million new cancer cases and 672,758 thousand cancer deaths in the Latin America and the Caribbean region [1]. Data from Brazil's National Cancer Institute (INCA) show that there were approximately 600,000 new cases in the country in 2018 and 2019 [2].

The growing cancer burden is a human development bottleneck, especially in low and middle-income countries [3]. The rising cost of cancer treatment increases the financial pressures on health systems [4]. In Brazil, the amount spent by the country's national health service, the Unified Health System (SUS, acronym in Portuguese), on cancer treatment rose from US$316 million in 2008 to US$638 million in 2019 [5]. In 2017, the World Health Assembly recognized the need for high levels of financial investment to control cancer [6].

Cancer research is a predominant theme in both national and international development agendas. In Brazil, the Ministry of Health's National Agenda of Health Research Priorities (ANPSS) [7] and the National Cancer Prevention and Control Policy (PNPCC) [8] emphasize

* Corresponding author.
E-mail address: cecilia.silva@inca.gov.br (C.F. Silva).

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the importance of cancer research. These policy instruments reinforce the importance of disseminating knowledge on cancer while broadening the view of the disease, considering the different dimensions of health care, such as promotion, prevention, treatment, and palliative care. In addition, one of the guidelines under the PNPCC is the research network implementation for cancer prevention control [8]. In this context, all research types, like clinical trials, qualitative and prevention-oriented research, are essential to improving cancer care [9].

In countries such as Canada, the United States and United Kingdom, funding comes mainly from government sources [6,10,11]. In 2018, the Federal and provincial government organizations/programs were responsible for 73 % of cancer research investment in Canada, where a similar percentage has been the pattern since 2010. According to this survey, these programs cover 60–80 % of the overall cancer research in Canada [6,12].

In Brazil public research funding is provided by federal and state funding agencies, and the Ministry of Health's Secretariat of Science, Technology and Strategic Inputs (SCTIE) is responsible for promoting research that addresses the population's health needs [13]. The Ministry of Science, Technology, Innovation and Communication (MCTIC) is responsible for funding research and technological development through the following bodies: National Council for Scientific and Technological Development (CNPq); Funding Agency for Studies and Projects (FINEP); National Scientific and Technological Development Fund (FNDCT); and international research agreements [14]. State funding agencies (SFAs) also play an increasingly important funding role [14].

This article analyzes government funding of cancer research in Brazil, identifying the main funding instruments and examining the regional distribution of resources, research projects and researcher profiles.

2. Methods

We conducted an exploratory study of government funding of cancer research in Brazil between 2007 and 2016, focusing on resource flow between funding bodies (‘*primary funding agents*’, for example, the Ministry of Health - MoH, or ‘*intermediary agents*’ for example, funding agencies) and funding recipients (individuals or institutions). We consider specifically non-reimbursable funding. Indirect funding, such as tax exemptions and incentives, and local government sources were not assessed.

The primary data sources were state and federal funding bodies. Secondary data sources included the Lattes Platform (http://lattes.cnpq.br), funding agency databases, calls for proposals, and the Brazilian Institute of Geography and Statistics (IBGE) (to define the economy sector of institutions).

Information requests were made to the funding agencies via the Electronic System for the Citizen Information Service (e-SIC), for data on research projects with the following keywords in the title or abstract: cancer (s), tumor (s), neoplasm (s), carcinoma (s), oncology, and cancerology from the period 2007–2016. The MoH's health research information system, *Pesquisa Saúde,* was used as a source in cases where SFA data were not available.

Selection of research projects followed inclusion criteria: (1) studies on cancer in humans; (2) grants awarded between 2007 and 2016; (3) funding operated by funding bodies (CNPq, FINEP, SFAs[1] and MoH's Department of Science and Technology – DECIT), and (4) complete information on: researcher's/institution's name, city or state, amount of funding awarded, funding period, and project/research title. Exclusion criteria were: (1) insufficient information to determine the type of cancer or research theme; (2) funding for publications or scientific events, (3) reimbursable funding, (4) awards linked to canceled calls for proposals, and (5) duplicate entries.

The data were organized into three profiles: funding, researcher, and research project. The amount of funding was inflation-adjusted to December 2018 using the IBGE Extended National Consumer Price Index (IPCA). Data from the São Paulo state funding agency (FAPESP) were adjusted using the consumer price index published by the Institute of Economic Research Foundation, University of São Paulo (IPC/FIFE).

Amounts were converted to US dollars using the average exchange rate for the year to 31 December 2018 (R$3.8821 to US$1.00) published by the Institute of Applied Economic Research (IPEA) (available at http://www.ipeadata.gov.br).

The data were analyzed using descriptive statistics and hypothesis testing (Student's t-test), adopting a 5% significance level. Statistical analysis was performed using Stata (StataCorp LLC, version 14).

3. Results

A total of 18,097 research projects were retrieved from the country's funding agencies. After screening and the application of the eligibility criteria, we identified 259 projects with one or more funding instruments. These cases were broken down into the respective funding bodies and added to the dataset, resulting in a final sample of 8565 funded projects (Fig. 1).

3.1. Funding

The total amount of funding for the 8565 grants awarded between 2007 and 2016 was almost US$489 million. The grants were linked to 7622 research projects, 393 proponent institutions, 431 executing institutions, and 3068 researchers. Average grant duration was 2.77 years $\pm$ 1.97 [1 - 9 years][2] . The number of grants was unevenly distributed across funding agencies as follows: SFAs –6,088, CNPQ – 2,084, DECIT– 310, and FINEP – 83.

The distribution of financial resources across country regions was highly uneven. Funding was concentrated in the Southeast region, with 7226 awards (84.4 %), followed by the Northeast with 533 (6.2 %), South with 437 (5.1 %), Center-West with 156 (1.8 %), and the North with 79 (0.9 %). The funding landscape of the North was incomplete because Roraima does not have a SFA and the projects returned by the Amapá State funding agency were not eligible.

The agencies that provided most funding for cancer research were FAPESP, FAPERJ, CNPQ, and DECIT. FINEP awarded a limited number of grants but accounted for a significant proportion (11 %) of overall funding. Rondônia's state funding agency awarded only one grant (Table 1).

Three types of research funding instruments were identified: (a) fellowships/scholarships in Brazil (n = 4866) and abroad (n = 408), (b) grants/research aid (n = 3267) and (c) economic incentives[3] (n = 24). All regions received funds for fellowships/scholarships; however, research conducted abroad was awarded mainly for institutions/researchers in the Southeast (66.6 %). Economic incentives were not provided in the North and Northeast.

Fellowships/scholarships were provided mainly to graduate (44.8 %) and undergraduate students (25.7 %). Doctoral awards were 934 (39 %) and 86.6 % were concentrated in the Southeast. Post-doctoral scholarships were 732 (31 %). Grants/research aid comprised 3119 awards for projects (95 %) and 148 for facilities (5%), concentrated in the Southeast (90.5 % of total funding). The North was the only region that did not receive support for facilities.

Grant amounts varied from US$422.37 to US$5,126,091.55, with a

[1] All Brazilian states except Roraima have a state funding agency (SFA).

[2] The grant end date was not shown in 14% (n = 1,212) of the projects, meaning that these calculations include only 7,353 grants.

[3] Non-reimbursable financial resources granted to companies to carry out research, development, and innovation activities.

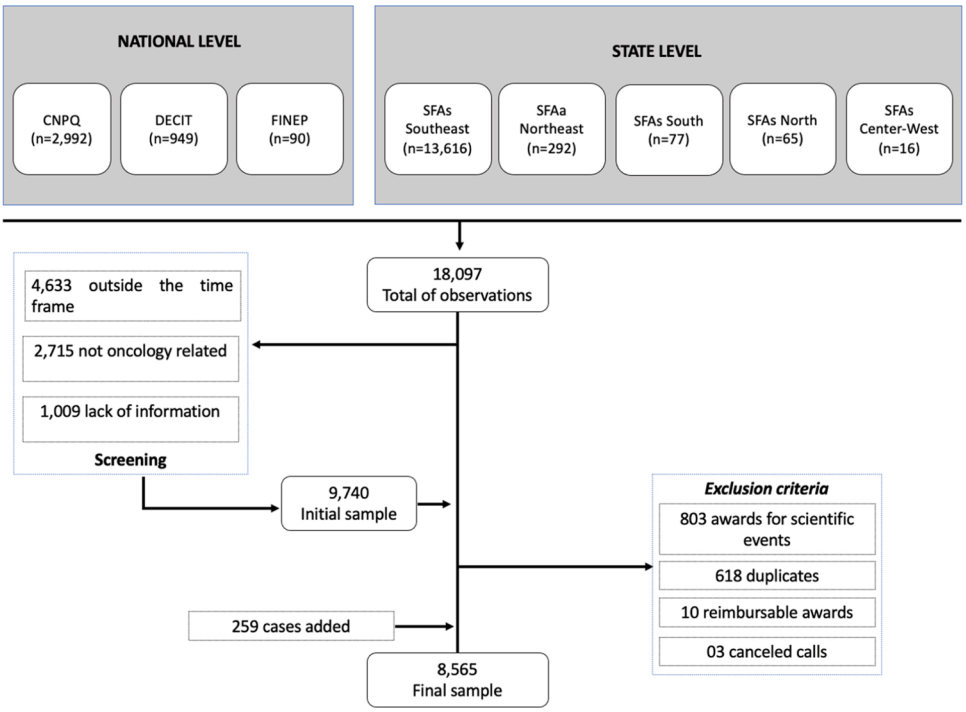

Fig. 1. Cancer research funding project eligibility flowchart, 2007 – 2016.
Legend: Female (F), Male (M)
Notes (1): Inflation-adjusted amounts to December 2018. (2): Data include 242 foreign institutions. (3): 83 researchers did not have data on sex and 242 researchers were outside the country.

Table 1
Distribution of cancer research grant numbers and amounts by funding agency. Brazil, 2007 -2016.

Funding Agencies	Awards		Grant amount		Fellowship/scholarship amount		Total ($)	Percentage (%)
	Number	Percentage (%)	Median (US$)	Subtotal (US$)	Median (US$)	Subtotal (US$)		
National Level								
FINEP	83	1.0%	507,457.30	52,167,513,46	66,974.06	1,167,293.35	53,334,806.81	10.9 %
CNPQ	2084	24.3%	13,284.47	27,753,739,47	14,840.35	23,781,526.49	51,535,265.96	10.6 %
DECIT	310	3.6%	32,456.66	22,879,822,78	4,000.06	1,138,361.71	24,018,184.49	4.9 %
National level Subtotal	2477	28.9%		102,801,075,71		26,087,181.55	128,888,257.26	26.4 %
State level								
FAPESP (SP)	4457	52.0%	87,323.87	191,763,608,36	20,417.66	126,045,124.03	317,808,732.39	65.1 %
FAPERJ (RJ)	1114	13.0%	10,563.18	21,962,780,97	7,617.35	8,987,396.51	30,950,177.48	6.3 %
FAPEMIG (MG)	259	3.0%	14,114.51	5,216,719,82	1,672.92	161,037.34	5,377,757.16	1.1 %
FAPES (ES)	21	0.2%	15,027.47	153,255,26	8,586.88	127,397.47	280,652.73	0.1 %
Southeast subtotal	5851	68.3%		219,096,364,40		135,320,955.35	354,417,319.76	72.6 %
FUNCAP (CE)	31	0.4%	27,819.99	1,543,459,85	6,376.55	78,570.38	1,622,030.24	0.3 %
FACEPE (PE)	31	0.4%	18,593.83	378,621,72	24,915.74	481,576.47	860,198.19	0.2 %
FAPEMA (MA)	96	1.1%	3,617.65	154,878,03	141,432.47	16,105.79	170,983.82	0.0 %
FAPEAL (AL)	10	0.1%	15,122.30	126,754,15	9,811.87	19,623.74	146,377.89	0.0 %
FAPITEC (SE)	3	0.0%	,	,	12,308.20	35,167.80	35,167.80	0.0 %
FAPESB (BA)	3	0.0%	75,474.61	206,983,30	,	,	206,983.30	0.0 %
Northeast subtotal	174	2.0%		2,410,697,06	,	631,044.18	3,041,741.24	0.6 %
FAPESC (SC)	12	0.1%	45,336.29	546,906,18	,	,	546,906.18	0.1 %
FAPERGS (RS)	17	0.2%	17,230.88	476,844,68	3,394.38	12,165.71	489,010.39	0.1 %
FA (PR)	14	0.2%	16,529.71	276,434,92	3,394.38	3,394.38	279,829.30	0.1 %
South subtotal	43	0.5%		1,300,185,79		15,560.09	1,315,745.87	0.3 %
FAPEAM (AM)	9	0.1%	20,209.35	419,233,18	,	,	419,233.18	0.1 %
FAPAC (AC)	2	0.0%	12,670.57	12,670,57	1,272.89	1,272.89	13,943.46	0.0 %
FAPRO (RO)	1	0.0%	,	,	2,688.48	2,688.48	2,688.48	0.0 %
North subtotal	12	0.1%		431,903,75		3,961.37	435,865.12	0.1 %
FUNDECT (MS)	8	0.1%	9,931.20	69,775,51	28,077.59	28,003.61	97,779.12	0.0 %
Center-West subtotal	8	0.1%		69,775,51		28,003.61	97,779.12	0.0 %
State level subtotal	6088	71.1%		223,308,926,51		135,999,524.60	359,308,451.11	73.6 %
Total	**8565**	**100.0%**		**326,110,002.21**		**162,086,706.15**	**488,196,708.36**	**100.0 %**

Notes: (1) FAPESP (SP- São Paulo), FAPERJ (RJ – Rio de Janeiro), FAPEMIG (MG – Minas Gerais), FAPES (ES- Espírito Santo), FUNCAP (CE - Ceará), FACEPE (PE - Pernambuco), FAPEMA (MA - Maranhão), FAPEAL (AL - Alagoas), FAPITEC (SE - Sergipe), FAPESB (BA - Bahia), FAPESC (SC – Santa Catarina), FAPERGS (RS – Rio Grande do Sul), FA (PR- Paraná), FAPEAM (AM - Amazonas), FAPAC (AC - Acre), FAPRO (RO - Rondônia), FUNDECT (MS – Mato Grosso do Sul); (2) During the study period, FAPITEC and FAPRO did not fund cancer studies, and FAPESC, FAPESB, and FAPEAM did not award fellowships.

median of US$31,168.70. Across regions medians were similar, except for the Southeast, which showed higher values. Research fellowships/scholarships ranged from US$112.02 to US$708,379.49, with a median of US$14,939.35. Across regions the highest values were also in the Southeast region, while the lowest values were in the Northeast.

Across regions, CNPQ was the major provider of funding in the

Northeast, Center-West, and South regions (Fig. 2), while DECIT was the largest provider in the North.

The findings show steady growth in funding between 2007 and 2010, followed by a marked decrease in 2011. Funding began to rise again in 2012, reaching a peak in 2013 and dropping off once more in 2015 (Fig. 3). Since 2013 no positive correlation between the total number of awards and the total funded amount was observed.

Most recipient institutions were educational (80.5 %), followed by health care management organizations (13.5 %). We were unable to characterize 43 institutions (0.3 %) due to lack of data.

International partners were 376 (134 proponent and 242 executing institutions), representing 4% of the sample. Institutions were mainly located in the United States (43.9 %) and the United Kingdom (10.9 %).

3.2. Researchers

A total of 3068 researchers and 83 institutions were identified. Female researchers received 4420 (51.6 %) of the 8482 individual grants, and males 4062 (47.4 %). Yearly distribution of awards by funding instrument was generally even and slightly higher for women.

The average number of grants per researcher was 2.8. It is noteworthy that 2990 (97 %) received 80 % of the grants (group A), while 78 researchers (3%) received 20 % of the grants (group B). Although overall funding in group A was higher, minimum, maximum and median values were higher for group B (Fig. 4). Difference in the mean values between the groups was statistically significant (p-value = 0.00).

Most of the grants (80 %) went to 27 institutions, while 108 institutions accounted for 15 %, and 258 accounted for a mere 5%. The distribution across executive institutions was similar.

3.3. Research projects

The Health Sciences field encompassed 36.3 % of 7622 projects, while 32.4 % were included in the Biological Sciences category. Information sources flaws missed 'field of knowledge' in 17 % of the sample.

Among the Health Sciences medicine (59.3 %), pharmacy (14.5 %), and dentistry (11.4 %) were dominant. Main areas in Biological Sciences were biochemistry (32.4 %), genetics (20.9 %), morphology (13.8 %), and immunology (11.3 %).

The most frequently studied cancers were breast (11.8 %), head and neck (9.0 %), skin (5.3 %), central nervous system (4.1 %), prostate (3.3 %), and cervical (3.1 %). A large number of projects, 3151 (36.8 %) did not specify the type of cancer and 7.4 % (n = 630) involved multiple cancers.

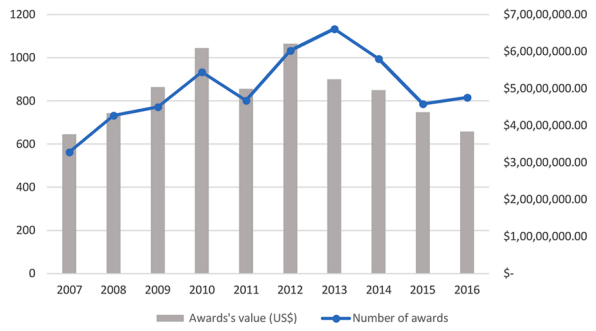

Fig. 3. Distribution of cancer research funding (absolute number of grants and total amount of funding provided). Brazil, 2007 to 2016.

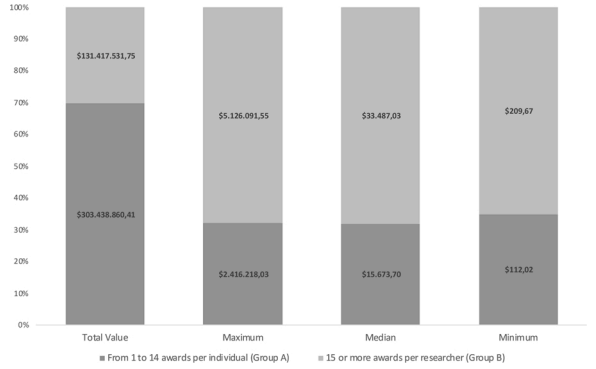

Fig. 4. Distribution of total, minimum and maximum funding grouped by number of awards per researcher (Groups A and B). Brazil, 2006-2017.
Note: Inflation-adjusted amounts (to December 2018).

The distribution of cancer type among researcher groups (A and B) was similar. Both studied mostly non-specific cancers (68 %), followed by breast (23 %), head and neck (19 %), and skin (12 %). Testicular cancer accounted for the lowest proportion of funding (0.03 %) and the smallest number of awards (0.02 %).

The types of cancer with the highest number of awards also received the highest amounts of funding (Fig. 5).

Funding for the most common cancers (according to 2016 estimates) was highly concentrated in the Southeast (82.2 % of grants). The

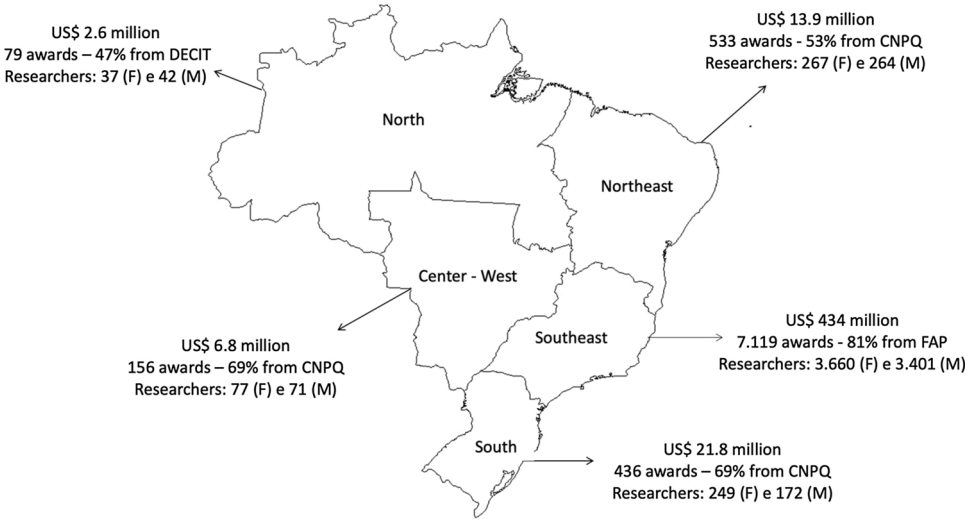

Fig. 2. Map of major providers of government funding of cancer research by region, Brazil, 2007 - 2016.
Note: Amounts were inflation-adjusted to December 2018.

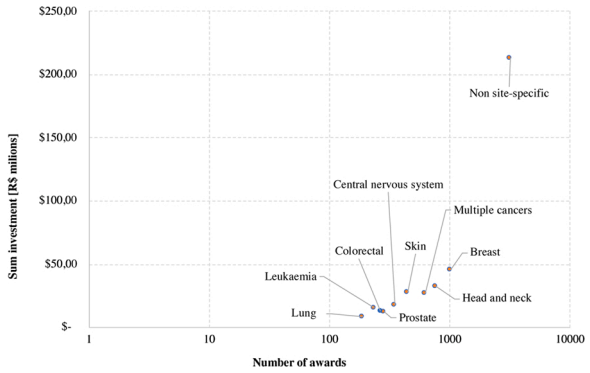

Fig. 5. Distribution of grants and total funding by most studied types of cancer. Brazil, 2007-2016.

number of grants was lowest in the Center-West and North (1.5 % of all grants).

4. Discussion

Information on research funding in Brazil is spread across funding bodies. Public access to this information is restricted, posing enormous research challenges. This study used multiple data sources, allowing for a more comprehensive analysis and offering a broader country picture.

Cancer research funding in Brazil is operated mainly by SFAs, a result of the decentralized science and technology policy initiated in the 1980s, leading to the reallocation of federal funding to states [15].

Although 25 of Brazil's 26 states and Federal District received funding for cancer research, distribution was uneven, being heavily concentrated in the Southeast (84.4 %). This regional domination [16,17] is credited to the high concentration of research facilities, researchers and graduate scholarships in the Southeast, which leads the country's technical and scientific capacity [18]. Historically, the Southeast has been the largest recipient of research funding. Between 2003 and 2005, the region received 72.5 % of MoH funding for research and development (US$76 million) [17]. An assessment of National Clinical Research Network (RNPC) funding and projects showed that the Southeast received 51 % of the resources provided through public calls for proposals, amounting around to US$7.1 million between 2007 and 2011 [18].

FAPESP played a major role in the provision of cancer research funding in the Southeast (52 % of total). This reflects the organization's long history of research funding, dating back to the 1960s. Part of the agency's success is due to its annual revenue, which includes 1% of the tax revenues collected by the State of São Paulo, the country's richest state. In 2016, these transfers from the state treasury represented 78 % of the agency's total revenue [19]. This development policy represents a sustainability strategy, making research funding less susceptible to changing national priorities and external vulnerabilities.

A solution found by some foreign countries to counterbalance regional disparities in research funding was to centralize the management of funds and funding information, enabling a more collaborative environment among funding organizations, thus promoting effective decision making about cancer research funding and avoiding gaps and excesses [20]. The Brazilian government has made efforts to expand funding to all regions through national funding agencies [21], which is evident in the distribution of grants by agency. The large share of funding provided by DECIT in the North is a result of MoH policies introduced in 2004, to reduce regional inequalities in science and technology and promote innovation in health and health equity [22]. CNPQ's role in the Northeast, Center-West, and South regions is also worth mentioning.

Although CNPQ has been a key funding agency since 1951, the country's socioeconomic policies have had a substantial impact on its budget, directly affecting both researchers and research. The development of research should be seen as a medium to long-term process requiring the constant maintenance of financial contributions.

Although the absolute number of awards and overall amount of funding vary by region, median award amounts were similar across regions, because grant amounts in public calls are standard, an apparent strategy to promote equity in public funding.

On the other hand, the multiple-grant history of individual researchers seems to be a conditioning factor for obtaining higher-than-average new grants/fellowships. Another factor that seems to contribute to the funding imbalance is that 80 % of the grants are concentrated in only 27 proponent institutions, which is equivalent to 6.8 % of the country's research organizations. Strategies to encourage research in other institutions should be developed to strengthen research at the national level and reduce inequality.

Cancer research is a core element of national cancer control plans, and research funding is essential to make plans happen [23]. The creation of the National Policy for Science, Technology, and Innovation in Health in 2004 had a positive impact on health research funding, contributing to the increase in cancer research funding between 2004–2010, observed by this study [24]. However, cuts in government spending triggered by the country's political and economic crisis highlight the vulnerability of science and technology.

Our findings show a fall in the share of cancer research funding in the country's three largest agencies. Cancer research expenditures by FAPESP, FINEP and CNPQ as a proportion of overall funding between 2007 and 2016 fell from 15 % to 10 %, 22 % to 1%, and 2% to 1%, respectively [19,25–29].

Researcher gender was not shown to be a conditioning factor for funding. The substantial representation of women in the sample reflects the historical struggle of women in science. The proportion of women among researchers and inventors has increased over time in various countries [30]. Moreover, women are strongly represented in health and biological sciences [30].

Due to the complexities of cancer, many of the studies focused on basic research, examining general biological and molecular phenomena rather than specific types of cancer. In our sample, non-specific cancer studies (36.8 %) received 45.1 % of total funding. These findings are corroborated by the literature. In the United Kingdom, 43.8 % (n = 1883) of cancer research did not specify type of cancer [10]. Data from the National Cancer Research Institute (NCRI) shows that over half of the £580 million spent by its partners on cancer research between 2015 and 2016 was not specific to a particular cancer type [31]. Furthermore, studies on biological development are important for cancer prevention strategies, while research on DNA repair processes, epigenetic events, and mutational profiles play a crucial role in cancer control [32].

As the study results, the breast, prostate, skin, central nervous system, and head and neck cancer were the most studied types of cancers in the UK survey between 2000 and 2013 [10]. However, the most commonly occurring cancers in Brazil in 2016 [33] accounted for less than 50 % of grants and 34 % of total funding. It would be expected that these cancers would have been more strongly represented in the sample.

In Brazil, breast has been the most incident cancer among women since 2007 [2,34]. Breast cancer accounted for the largest proportion of resources (9.7 %) among studies. It is worth mentioning that women's health remained prominent on the country's health research agendas between 2004 and 2018, which may have influenced the results. However, cervical cancer, which is the third most commonly occurring cancer among Brazilian women [2] did not fare as well, receiving only a small number of grants (3.1 %) and small proportion of overall funding (2.3 %). A possible explanation for this is the relatively low cervical cancer mortality rate in comparison to the high incidence rate [33].

Despite the high concentration of research in the Southeast region, many studies had a broad geographic scope, and may have a national impact. Though an interesting area for future research, the uneven

regional distribution of funding does not necessarily mean that the results and benefits of research are restricted to specific regions. Besides, the cancer funding distribution should be positively correlated with Brazil's incidence and mortality rates.

Brazil has adopted a decentralized funding model, bringing diversity and versatility to the research funding process. However, this model can impose barriers, restricting a more comprehensive view of the country's cancer research investments, due to the multiplicity of sources and funding mechanisms. Producing an overview of the cancer research funding landscape in Brazil was a major challenge. Promoting greater transparency through access to information on funding, researcher, and research profiles is key for better understanding this landscape and reducing regional inequalities in research funding. Access to information is vital to the formulation of effective public policies, definition of research priorities, goals and methodology, and identification of investment and knowledge gaps.

In conclusion, there is no isolated solution. In order to succeed in cancer research investments, Brazil should focus on data management in respect to data access, transparency, and monitoring to support the decisions at researcher and funding (agencies/bodies) levels. Moreover, special attention must be centered on stable and sustained finances for this research area.

5. Policy summary

A more centralized approach to the management of public cancer research funding combined with ongoing investment and monitoring, is needed to ensure the effective implementation of funding policy.

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Disclosure

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