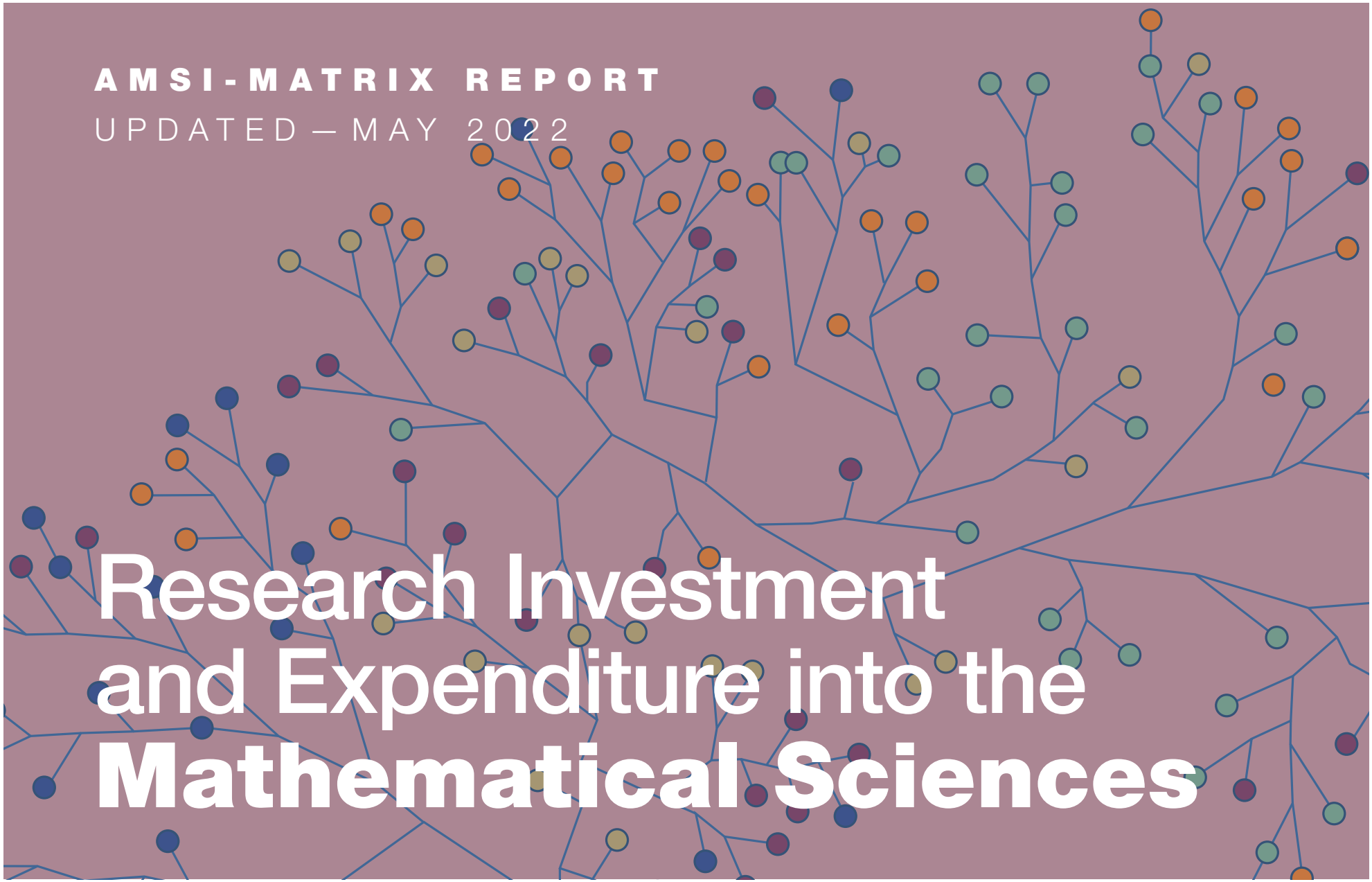
AMSI-MATRIX REPORT

UPDATED — MAY 2022



Research Investment and Expenditure into the **Mathematical Sciences**

MATRIX

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

1. Executive Summary

This report analyses research investment and expenditure in Australia to support research in the mathematical sciences over the period 2008-2021/22 using current publicly available data from the Australian Bureau of Statistics (ABS), the Australian Research Council (ARC) and the National Medical and Health Research Council (NHMRC).

Research investment and expenditure is largely facilitated through ARC and NHMRC grant schemes, and through business (BERD), government (GOVERD) and higher education expenditure (HERD) funding allocations.[1] The main observations of this report are that

1. Confirming observations by others,[2,3] across all the sciences the proportion of HERD expenditure for applied research has increased whereas that for pure basic and strategic research has decreased.

2. Higher Education investment in mathematical sciences research (pure & applied) took a $32 million hit in 2020 ($45 million in real terms).

3. In terms of grant success, ARC investment in the schemes most relevant to the Mathematical Sciences (Field of Research (FoR) code 49[4]), i.e. Discovery Projects, Discovery Early Career Awards and Future Fellowships is roughly on par with investment in other STEMM disciplines, except for a noticeable drop in DECRAs.

4. The ARC Linkage program is not well set up for supporting research in the Mathematical Sciences, only incidental grants have been awarded through this program.

5. Business and Government investment in Mathematical Sciences R&D remains minimal compared to other disciplines.

Against the background of the recent emphasis on research translation into commercialisable outcomes we note that the increased university funding for research this last decade is already mostly flowing to applied research. Fundamental research barely benefited from the funding surge earlier in the decade and declined in 2020.

Basic research should be properly funded for Australia's long-term prosperity. In addition, it is essential that research facilities in the Mathematical Sciences are well supported as National Research Infrastructure.

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1 At the time of writing of this report, full outcome statistics for ARC grants commencing in 2022 have not yet been released, with BERD and GOVERD expenditure data for 2020/21 still expected to be published by the ABS.

2 Frank Larkins, Strong research performances by Australian universities depend increasingly on unsustainable internal discretionary funding, Melbourne Centre for the Study of Higher Education, 2020.

3 Desperate, despondent, ignored': Australian science at crisis point, Liam Mannix, The Age, 20 March 2022.

4 The Mathematical Sciences two-digit Field of Research (FoR) code changed on 30 June 2020 to 49 but was 01 during most of the reference period.

2. Research Grants

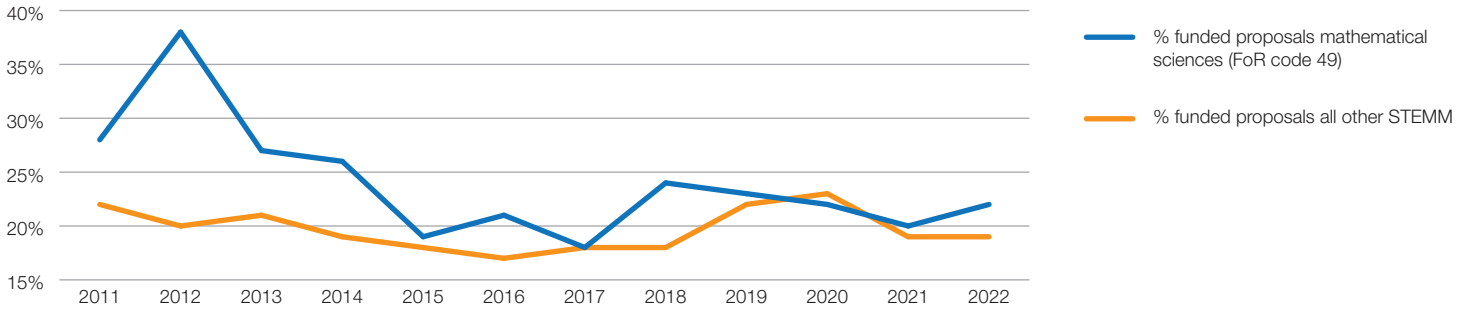
Australian Research Council (Discovery)

The largest source of research grant funding for the Mathematical Sciences (FoR 49) is provided by the Discovery funding schemes of the ARC, which is specifically targeted at supporting fundamental research. The Discovery Program supports research by individuals and teams, provides funding for research training and fosters career opportunities for Australian and international researchers.

Discovery Projects

For projects commencing in 2022 the success rate was slightly higher than that of all other STEMM codes. As an aside we note that the percentage of submitted proposals in the mathematical sciences of all STEMM submitted proposals has remained remarkably constant during the period 2011–2022, hovering around 7.5%.

Figure 1. ARC Success Rates of Discovery Project Proposals 2011–2022

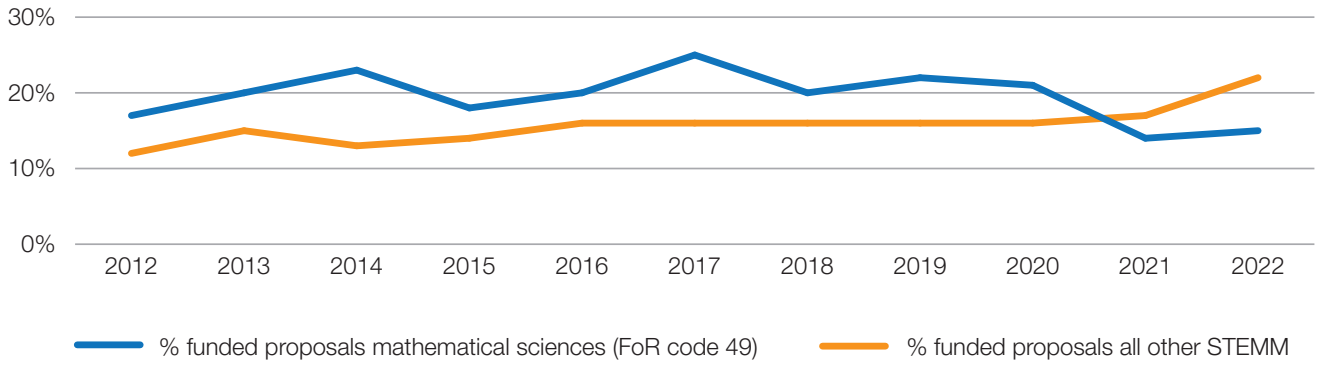


***Source**: ARC (2021)*

Discovery Early Career Awards (DECRA)

In 2021, the success rate for DECRAs in the mathematical sciences fell below that of all other STEMM codes for the first time. The success rate for 2022 barely improved, and the number of successful DECRAs in FoR 49 starting in 2022 dropped to below 50% of the average of about 11 in the previous five years. The number of successful DECRAs in other STEMM disciplines on the other hand was slightly higher than its average.

Figure 2. ARC Success Rates of Discovery Early Career Researcher Award Proposals 2012–2022

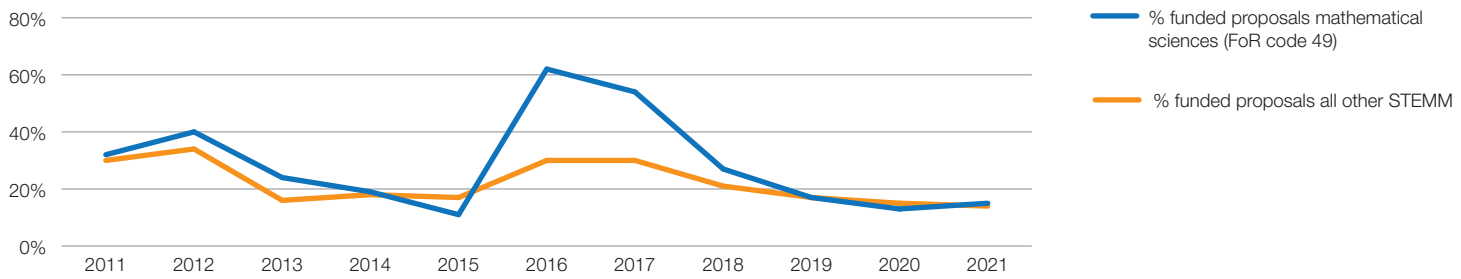


Source: *ARC (2021)*

Future Fellowships

The success rate of Future Fellowships has stabilised to about 15%, on par with other STEMM disciplines. Since 2014, on average about five Future Fellowships are awarded each year to the Mathematical Sciences.

Figure 3. ARC Success Rates of Future Fellowship Proposals 2011–2021



Source: *ARC (2021)*

Australian Laureate Fellowships

The success rate of Laureates in recent years is on par with that of other STEMM disciplines. On average about one Laureate Fellowship is awarded each year to the Mathematical Sciences, see Table 1.

Table 1. Number of Laureate Fellowships Funded

Primary 4-digit FoR Code	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total (FoR 49 Math Sci)	3	2	2	1	2	0	3	0	1	1	1
Total (FoR Other STEMM)	9	11	9	11	10	11	10	13	12	10	14

Source: *ARC (2021)*

Australian Research Council (Linkage)

The ARC's Linkage funding schemes aim to encourage and extend cooperative approaches to research and improve the use of research outcomes by strengthening links within Australia's innovation system and with innovation systems internationally. Linkage promotes national and international research partnerships between researchers and business, industry, community organisations and other publicly funded research agencies. By supporting the development of partnerships, the ARC encourages the transfer of skills, knowledge and ideas as a basis for securing commercial and other benefits of research.

Linkage Projects

Applications for funding under the Linkage Projects scheme must include at least one Partner Organisation. The success rate for Linkage Projects is generally much higher than for Discovery Projects, but the number of applications from the Mathematical Sciences in this scheme is low. With the exception of 2016, the number of applications from the Mathematical Sciences to this scheme has been below ten and has dropped to below five since 2017. Consequently, the number of funded projects is also very low as can be seen from Table 2.

Table 2. Number of Linkage Projects Funded

Primary 4-digit FoR Code	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total (FoR 49 Math Sci)	4	2	3	6	1	4	0	2	0	1
Total (FoR Other STEMM)	264	237	200	178	179	245	95	91	111	133

Source: *ARC (2021)*

Centres of Excellence

ARC Centres of Excellence are prestigious focal points of expertise through which high-quality researchers maintain and develop Australia's international standing in research areas of national priority. Through the ARC Centres of Excellence, significant collaborations occur between universities, publicly funded research organisations, other research bodies, governments and businesses in Australia and overseas, all to support outstanding research.

Table 3. Number of Centres of Excellence Funded

Primary 4-digit FoR Code	2011	2014	2017	2020
Total (FoR 49 Math Sci)	0	1	0	0
Total (FoR Other STEMM)	10	9	7	6

Source: *ARC (2021)*

The ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) commenced in 2014 and finished at the end of 2021. The ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS) was established in 2003. Before that, the Centre for Mathematical Analysis (CMA) was established in 1982 under the (then) Commonwealth Program for the Promotion of Excellence in Research. Both fall outside the reference period of this report, but are the only other known CoEs classified under Mathematical Sciences.

Industrial Transformation Training Centres

The Industrial Transformation Training Centres scheme fosters close partnerships between university-based researchers and other research end-users to provide innovative Higher Degree by Research (HDR) and postdoctoral training, for end-user focused research industries that are vital to Australia's future.

Table 4. Number of Industrial Transformation Training Centres Funded

Primary 4-digit FoR Code	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total (FoR 49 Math Sci)	0	0	0	0	0	0	1	1	0
Total (FoR Other STEMM)	4	6	5	6	9	7	5	4	6

Source: *ARC (2021)*

The ARC Industrial Transformation Training Centre in Data Analytics for Resources and Environments (DARE) commenced in 2019. The ARC Industrial Transformation Training Centre in Optimisation Technologies, Integrated Methodologies, and Applications (OPTIMA) commenced in 2020.

Linkage Infrastructure, Equipment and Facilities (LIEF)

The Linkage Infrastructure, Equipment and Facilities scheme provides funding for research infrastructure, equipment and facilities to eligible organisations. The scheme enables researchers to participate in cooperative initiatives so that expensive research infrastructure, equipment and facilities can be shared between higher education organisations and also with industry. The scheme also fosters collaboration through its support of the cooperative use of international or national research facilities. While over the last decade some LIEF grants have been awarded with a subsidiary Mathematical Sciences component, to date only one LIEF grant has been awarded with a primary FoR 49 code, to improve access to MATRIX.

Table 5. Number of Linkage Infrastructure, Equipment and Facilities Proposals Funded

Primary 4-digit FoR Code	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total (FoR 49 Math Sci)	0	0	0	0	0	0	0	0	0	0	0	1
Total (FoR Other STEMM)	73	72	65	57	64	51	43	46	31	45	42	42

Source: *ARC (2021)*

National Health and Medical Research Council (NHMRC)

While not many NHMRC grants were awarded to mathematical scientists in the period 2013–2018, there are some which have a mathematical sciences component. In 2019, a new grant program was introduced, including NHMRC Investigator and Ideas grant schemes. Mathematical Sciences related research keywords that were chosen in NHMRC grant applications between 2013–2021 included:

- Applied Statistics
- Biostatistics
- Markov chain Monte Carlo
- Mathematical modelling
- Multivariate statistics
- Statistical genetics
- Statistics

Project Grants

NHMRC Project Grants was the NHMRC's previous flagship funding program, before the introduction of the new grant program in 2019. Project Grants supported the investigation of new research ideas, and were between one and five years in length.

Table 6. NHMRC Project Grants with Mathematical Sciences Keywords

NHMRC Project Grants	2013	2014	2015	2016	2017	2018
At Least One Math. Sci. Keyword	8	8	9	5	5	9
A Primary Math. Sci. Keyword	2	2	3	1	1	2

Source: *NHMRC (2013–2021)*

Early Career Fellowships

NHMRC Early Career Fellowships provided opportunities for Australian researchers to undertake advanced training in health and medical research either in Australia or overseas, before they were included in the new grant program. A major objective of the scheme was to foster career development at the postdoctoral level by encouraging the beneficial experience of a different research environment.

Table 7. NHMRC Early Career Fellowships with Mathematical Sciences Keywords

NHMRC Early Career Fellowships	2013	2014	2015	2016	2017	2018
At Least One Math. Sci. Keyword	4	3	4	4	5	4
A Primary Math. Sci. Keyword	0	0	1	0	0	0

Source: *NHMRC (2013–2021)*

Career Development Fellowships

NHMRC Career Development Fellowships were highly competitive, four year Fellowships that recognise and provide support for the most outstanding early to mid-career health and medical researchers.

Table 8. NHMRC Career Development Fellowships with Mathematical Sciences Keywords

NHMRC Career Development Fellowships	2013	2014	2015	2016	2017	2018
At Least One Math. Sci. Keyword	2	2	3	3	1	1
A Primary Math. Sci. Keyword	0	0	0	1	0	1

Source: *NHMRC (2013–2021)*

Research Fellowships

NHMRC Research Fellowships were prestigious and highly competitive awards for high performing researchers, before the introduction of the new grant program. Research Fellowships were open to all researchers in Australia who have a sustained track record of significant and quality research output as judged relative to opportunity.

Table 9. NHMRC Research Fellowships with Mathematical Sciences Keywords

NHMRC Research Fellowship	2013	2014	2015	2016	2017	2018
At Least One Math. Sci. Keyword	0	6	2	1	2	2
A Primary Math. Sci. Keyword	0	0	1	1	0	0

Source: *NHMRC (2013–2021)*

Ideas Grants

The objective of the Ideas Grant scheme is to support innovative research projects addressing a specific question(s). The scheme provides particular opportunities for early and mid-career researchers. It is expected that the awardee will have the capability to lead the team in achieving the project aims.

Table 10. NHMRC Ideas Grants with Mathematical Sciences Keywords

NHMRC Ideas Grants	2019	2020	2021
At Least One Math. Sci. Keyword	9	10	2
A Primary Math. Sci. Keyword	1	1	0

Source: *NHMRC (2013–2021)*

Investigator Grants

Investigator Grants consolidate separate fellowship and research support into one grant scheme that provides the highest-performing researchers at all career stages with funding for their salary (if required) and a significant research support package. These grants provide the investigator with flexibility to pursue important new research directions as they arise and to form collaborations as needed, rather than being restricted to the scope of a specific research project.

Table 11. NHMRC Investigator Grants with Mathematical Sciences Keywords

NHMRC Investigator Grants	2019	2020	2021
At Least One Math. Sci. Keyword	28	7	8
A Primary Math. Sci. Keyword	5	1	3

Source: *NHMRC (2013–2021)*

3. Business, Government and Higher Education Expenditure on Research and Development

The main measures for R&D expenditure in Australia are collected every two years by the Australian Bureau of Statistics (ABS). An update that includes 2020/21 data is scheduled to be published in early May 2022.

- Business Expenditure on Research and Development (BERD) is expenditure and human resources devoted to R&D carried out by businesses in Australia.
- Government Expenditure on Research and Development (GOVERD) is expenditure and human resources devoted to R&D carried out by Commonwealth, state and territory governments.
- Private Non-Profit Expenditure on Research and Development (PNPERD) is expenditure and human resources devoted to R&D carried out by private non-profit organisations.
- Higher Education Expenditure on Research and Development (HERD) is expenditure and human resources devoted to R&D undertaken by Australian higher education institutions.

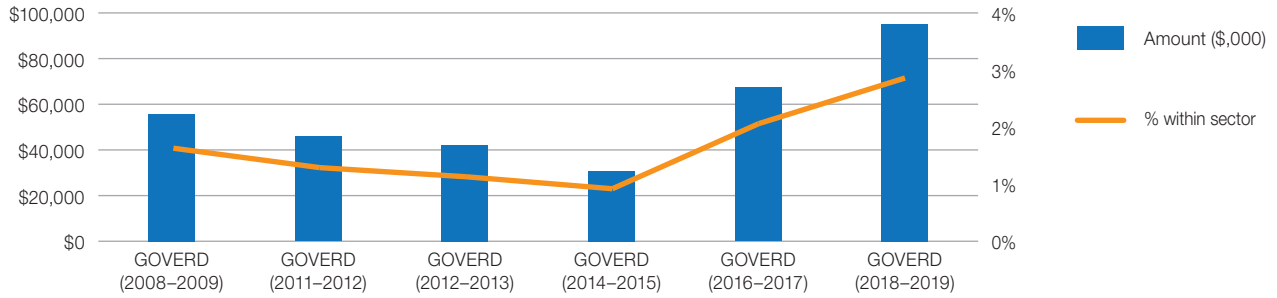
Note that these measures of R&D are expenditure measures, not measures of the source of funds. This means that GOVERD/PNPERD and HERD are mutually exclusive. Traditionally HERD is largely sourced by government funds, with block grants from the Department of Education, Skills and Employment (DESE) making up around one-third of that income.

PNPERD expenditure to research in the Mathematical Sciences is essentially non-existent. The majority of PNPERD (88%) is directed to the Socio-economic Objective of Health ($1,118 million) in 2018–19, followed by Education and Training ($39 million or 3%).

Government Expenditure on Research and Development (GOVERD)

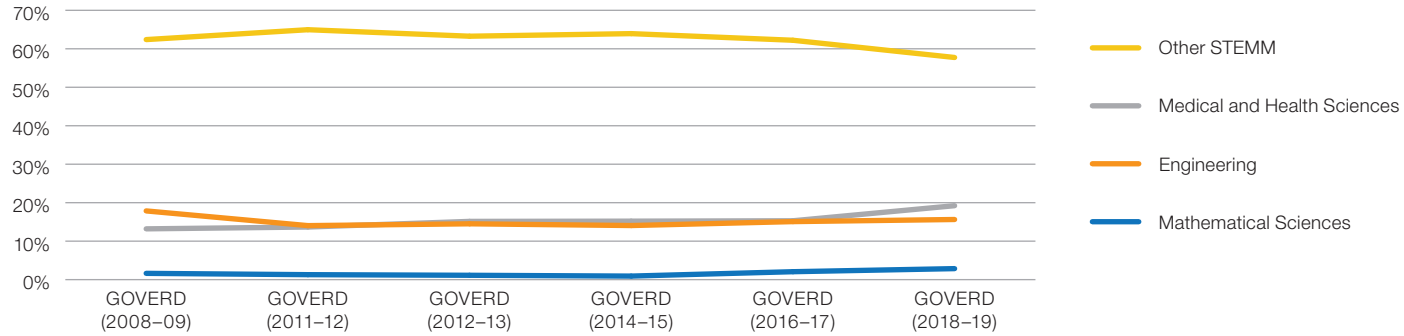
GOVERD expenditure includes expenditure and human resources devoted to Research and Experimental Development (R&D) carried out by governments.

Figure 4. Total $ and % Government Expenditure on R&D in the Mathematical Sciences



Source: *ABS (2021b)*

Figure 5. % of Total Government Expenditure on R&D by Field (2008–2019)



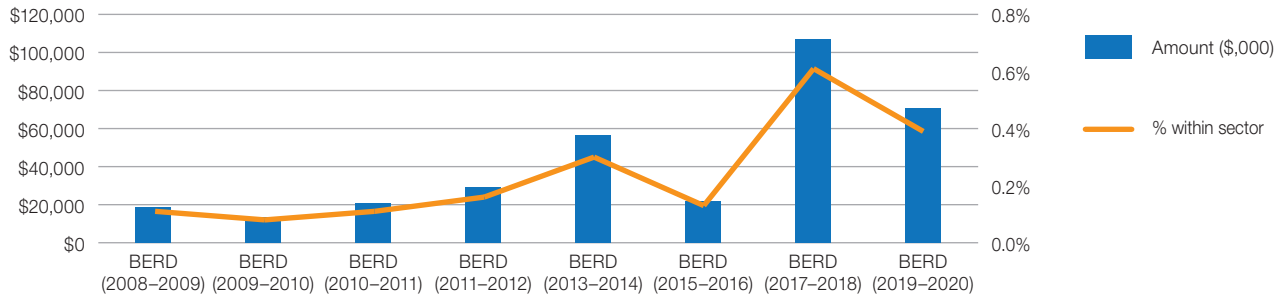
Source: *ABS (2021b)*

Comment: As a percentage of total expenditure, GOVERD expenditure to the Mathematical Sciences fluctuated between a minimum of 0.92% in 2014/15 and a maximum of 2.68% in 2018/19.

Business Expenditure on Research and Development (BERD)

Business expenditure includes expenditure and human resources devoted to Research and Experimental Development (R&D) carried out by businesses in Australia.

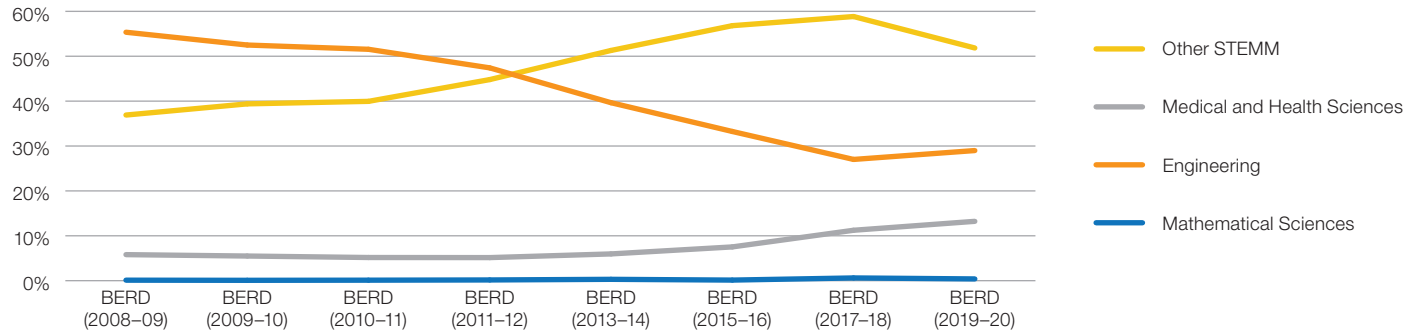
Figure 6. Total $ and % Business Expenditure on R&D in the Mathematical Sciences



Source: *ABS (2021a)*

Comment: As a percentage of total expenditure, BERD expenditure to the Mathematical Sciences fluctuated between a minimum of 0.08% in 2009/10 and a maximum of 0.61% in 2017/18, dropping to 0.39% in 2019/20.

Figure 7. % of Total Business Expenditure on R&D by Field of Research and Development



Source: *ABS (2021a)*

Higher Education Expenditure on Research and Development (HERD)

Higher Education expenditure includes funding provided by Higher Education institutions (mostly universities) to perform research and experimental development. Common funding sources to fund research are general university funds, state, local and Commonwealth funding such as block grants, as well as funding provided by business and donations and bequests.

As identified in a 2020 report by Frank Larkins[5], overall HERD expenditure increased significantly in the decade to 2018 using discretionary income resulting from exceptional growth in annual university operating revenues. Despite a decline of the percentage of total annual operating expenditure devoted to R&D, a new landmark was achieved in 2018 with universities collectively using more discretionary income to fund research and research training programs than the total funds obtained from external competitive sources. In 2020 (the first year of the pandemic), the overall HERD expenditure declined somewhat in real terms but still kept most of the gains from the previous decade. However, mathematical sciences research received $45 million less in real terms compared to 2018. Proportionally HERD funding allocated to the discipline declined significantly, from 1.86% in 2018 to 1.53% in 2020.

A key conclusion from the Larkins report identifies that 'since 2008 there has been a significant shift in the type of research reportedly undertaken by universities from basic and strategic basic research to applied research and experimental development, partly because of the 30% decline in business R&D as a percent of GDP. In 2018, only 41% of all university research was classified at the basic end, down from 50% in 2008. There are serious consequences for knowledge creation and Australia's national innovation effort if this decline is not reversed.'

In 2020, the proportion of funding to basic research declined even further to 37% - down from 41% in 2018.

Table 12. HERD Expenditure to types of research activities – for all Fields of Research (chain volume measure applied)

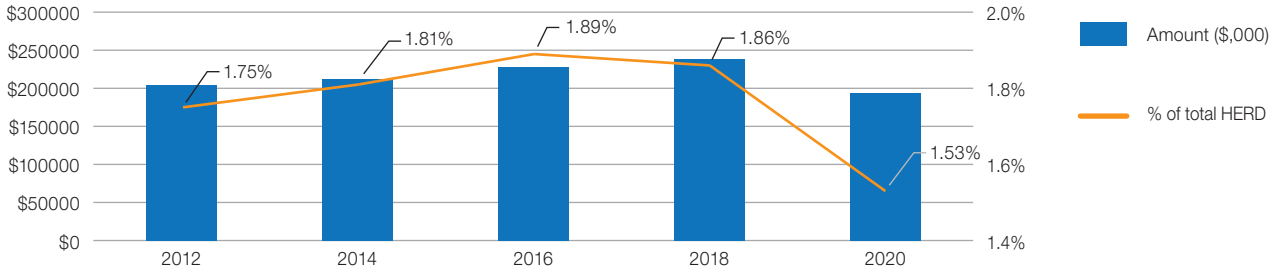
	2012	2014	2016	2018	2020
Total (Chain Volume Measures) $m	$11,670	$11,718	$12,066	$12,849	$12,668

Source: ABS (2022)

Comment: Total HERD expenditure*, in real terms, increased by 10% between 2012 and 2018, declining by 1% in 2020.

5 Frank Larkins, Strong research performances by Australian universities depend increasingly on unsustainable internal discretionary funding, Melbourne Centre for the Study of Higher Education, 2020.

Figure 8. HERD Expenditure Mathematical Sciences 2012-2020 (chain volume measure applied*)

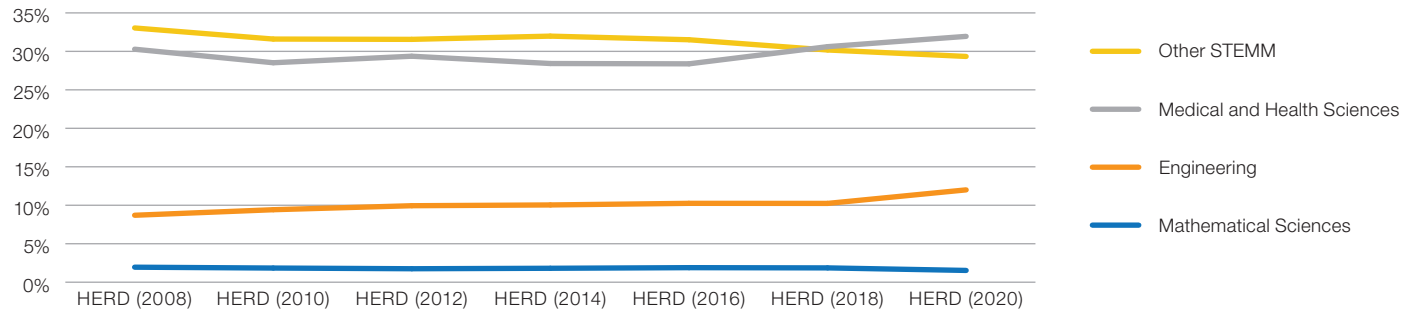


Source: *ABS (2022)*

** Chain Volume Measure (CVM): Current price values re-expressed in (i.e. based on) the prices of the previous year and linked together to form a continuous time series. The current prices values are referenced to 2020.*

Comment: As a percentage of total HERD expenditure funding for the Mathematical Sciences has fluctuated between 1.95% in 2008 and 1.75% in 2012 and in 2018 stood at 1.86% of total HERD expenditure before falling to its lowest proportion (1.53%) since at least a decade. In dollar terms, investment in mathematical sciences research (pure & applied) took a $32 million hit in 2020 ($45 million in real terms).

Figure 9. % of Total Higher Education Expenditure on R&D by Field



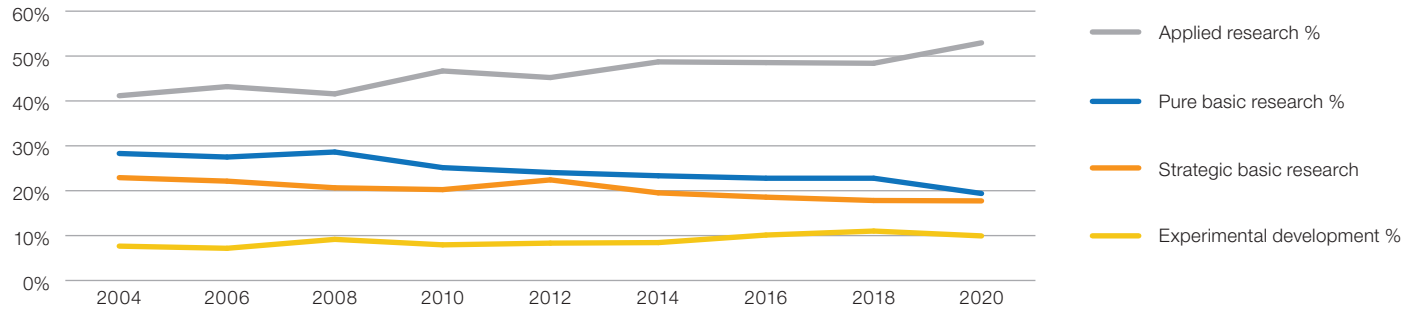
Source: *ABS (2022)*

Comments:

- When compared to 2012, in 2018 HERD funding amounts in real terms, had increased by 4% for pure basic research, and decreased by 12% for strategic basic research. In the same period HERD funding for applied research increased by 18%, and for experimental development by 46%. In 2020, only HERD funding for applied research increased by 8%. All other types of research lost funding, with pure research falling backwards by 16%.

- As a percentage of total HERD funding, the proportions of funding spent on pure basic research and strategic basic research decreased between 2012 and 2020. The proportion of HERD funding for applied research and experimental development increased – see graph below.

Figure 10. Percentage HERD Expenditure by Type of Activity 2004-2020 – All Fields of Research



Source: *ABS (2022)*

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