

A scanning electron micrograph (SEM) of various bacteria. The top half of the image is dominated by a dense cluster of red, spherical bacteria. The bottom half features several purple, rod-shaped bacteria and a network of yellow, filamentous structures. The background is dark, highlighting the intricate details of the microbial life.

Office of the Queensland Chief Scientist

Health of Queensland Science *Review*

November 2014



Queensland
Government

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Cover page: Buggz by Darren Brown. Part of the Institute for Molecular Bioscience's Ångström Art™ Collection. A scanning electron microscope image of 2 different types of bacteria on the surface of macrophages. Macrophages attack and ingest the bacteria as part of the immune response. **Page 4 and back cover:** MCF7 by John Griffin. Part of the Institute for Molecular Bioscience's Ångström Art™ Collection. Many of the cells used by researchers in molecular biology have been derived from human cancers of one sort or another. These cells may be used in cancer-related research or in research entirely unrelated to cancer. This cell line was derived from an invasive, and ultimately fatal, breast cancer and has been used to understand the mechanisms whereby cancerous cells leave their native locale and invade other tissues in the body. **Page 5:** Image courtesy of Marina Matthews Photography. **Page 7:** Image courtesy of Simtars. **Page 8:** Image courtesy of QIMR Berghofer Medical Research Institute.

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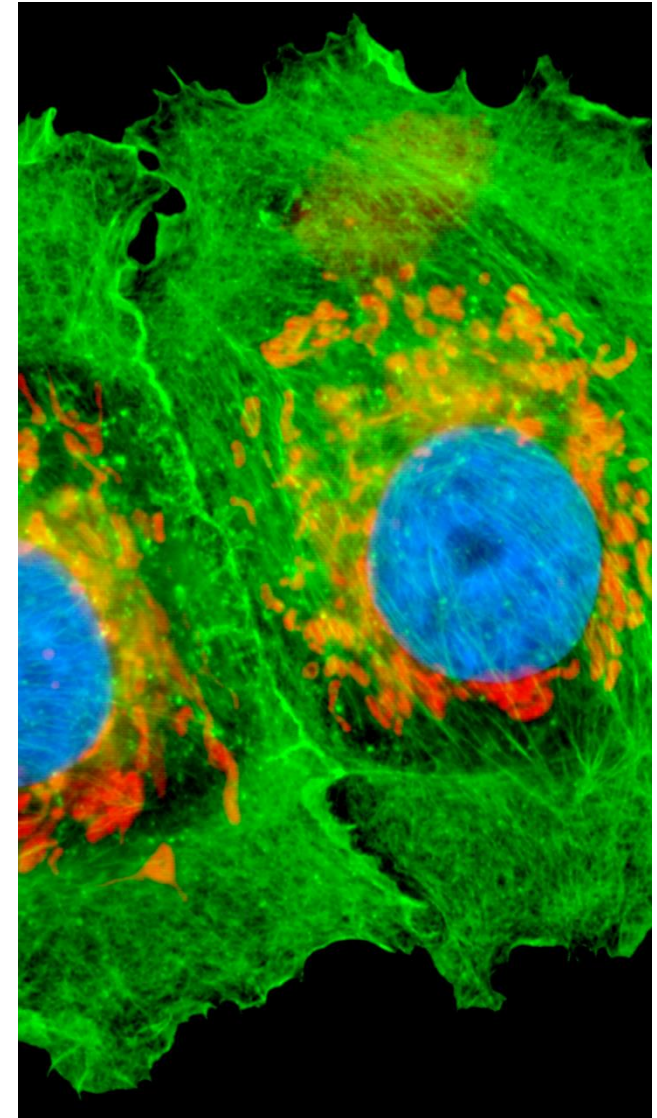
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Key observations and recommendations

1. Over the past decade, the Queensland Government has invested significantly into research and development (R&D). We must continue to build on this investment to facilitate innovation and help drive economic growth. Our array of world-class research infrastructure should be used to continue to attract and retain top researchers who can help address our opportunities and challenges.
2. Further investment in R&D will help unleash the potential of science and assist us to leverage other funding sources. Queensland's businesses, universities and governments must all play a role. To address our comparably low R&D investments, we should consider investing a higher percentage of our Gross State Product (GSP). Compared to other states, we leverage less commonwealth R&D funding – this is something we need to address. Attracting business investment to our research and development will be crucial in producing outcomes from this work.
3. Talented and passionate people are vital to effective research and application. Over the past decade there has been strong growth in Queensland's Science, Technology, Engineering and Mathematics (STEM) skilled workforce. Conversely, STEM subjects at Queensland high school and universities are seeing declining enrolments. Critical to address this is student and teacher engagement in these subjects. We must ensure we have the quantity and quality of STEM skills Queensland requires to underpin a strong economy and quality of life.
4. We must continue to learn from and partner with others. Here in Queensland we have a relatively strong - and growing - international collaborative base, but we must increase our partnering with emerging scientific powerhouses – like China and India. This is imperative given the scale and complexity of future scientific challenges.



Key observations and recommendations



The Translational Research Institute

5. We need to greatly improve our linkages between R&D and the frontline - businesses, healthcare providers or government policy makers - where our quality research can be applied and have impact. We need to be passionate around translating our great ideas into great outcomes, with a focus on: taking our research from laboratory to market; ensuring our universities and institutes are working closely with industry; and collaborating with our international counterparts to identify areas to which good science can be applied.
6. Recognising the need to ensure our quality research is no longer lost in translation and not effectively applied benefit Queensland, we have developed a set of Decision Rules for Investment to ensure the government partners with Queensland's universities and research institutions in order to deliver practical research to unlock the state's potential and enable Queenslanders to share in the full benefits of successful resource use. We need to invest in a range of areas with designated scale for maximum impact.
7. Bringing together these points, good progress has been made in the past 18 months. The *30 year Queensland Plan*, and vision for the state has emphasised the education imperative, with innovation as a key element in the government response. The *Science and Innovation Action Plan* (SIAP)¹ has galvanised attention on the people side, and on the criticality of maintaining momentum, as well as the battle for effective translation through emphasising collaboration and knowledge exchange. Corresponding funding through the *Accelerate Programs*² - hopefully increasing substantially for the next three years - is underpinning these thrusts, in line with the focus obtained through a new set of state research priorities. The visionary objective of the \$500 million *Entrepreneurial and Innovation Fund*³, as outlined in the state's forward plan 'Stronger, Smarter Choices' will add much needed impetus in an increasingly competitive international environment.

Sources: 1. SIAP <http://www.qld.gov.au/dsita/assets/documents/science-innovation-action-plan.pdf>; 2. Accelerate Programs <http://www.business.qld.gov.au/industry/science/grants>; 3. THE STRONGEST & SMARTEST CHOICE Queensland's plan for secure finances and a strong economy <http://www.strongchoices.qld.gov.au/TheStrongestSmartestChoice-Web.pdf>

Introduction

Introduction and background



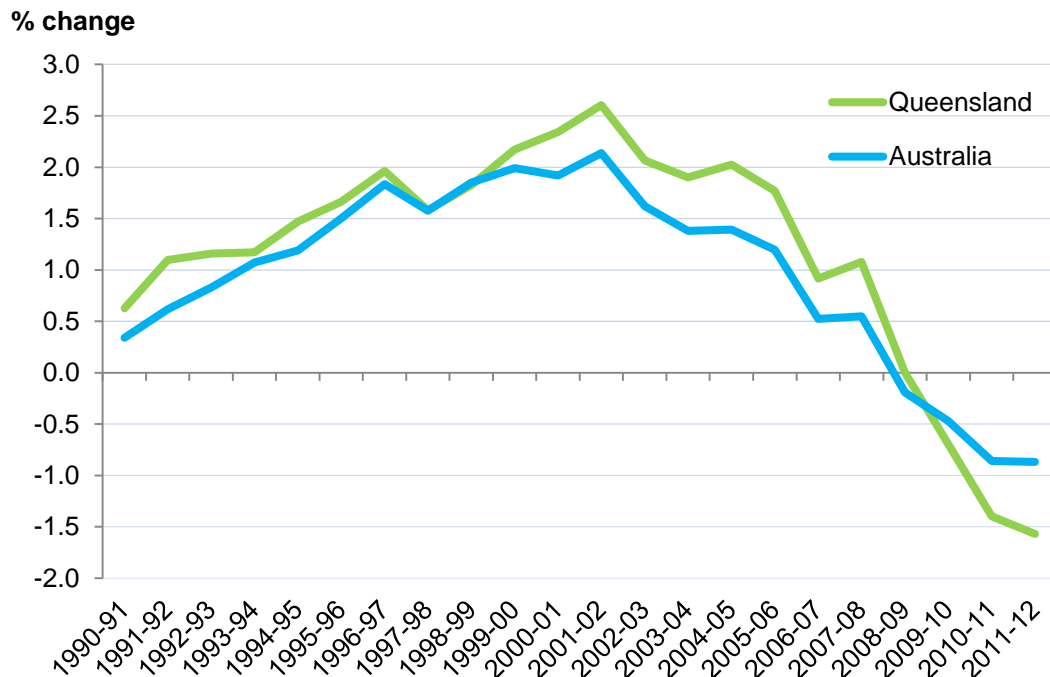
Advances in science are changing our lives. And we know that most people don't recognise the vital role science plays at almost all levels of our lives, at almost every minute of the day.

Science Minister, Mr Ian Walker

- Between 1998 and 2014, the Queensland Government invested \$5 billion on science, innovation and skills; leveraging an additional \$4 billion to provide an overall investment of \$9 billion.
- To drive employment and economic growth, the Queensland Government has identified agriculture, construction, resources and tourism as the 'four pillars' of the Queensland economy.
- Support for this will be seen through 'The Strong Choices Investment Package' which will establish ongoing support for a broad range of public infrastructure projects over the next six years including the 'Entrepreneurial Innovation Fund (EIF) worth \$500 million'.
- The EIF would be used to reinvigorate research and innovation across Queensland, once again placing Queensland at the forefront of technological breakthroughs, focusing on growing our four pillar economy and providing jobs and opportunity for all Queenslanders. This fund will help create and maintain highly skilled jobs for future generations of Queenslanders; it's an investment in our future.
- In addition, the Science and Innovation Action Plan which outlines four specific areas we want to concentrate on: maintain momentum; deliver innovative government; help businesses grow; collaborate and share knowledge.

Our productivity challenge

Multifactor productivity¹ annual per cent change, five year rolling average



It can be said without exaggeration that in the long run probably nothing is as important for economic welfare as the rate of productivity growth.

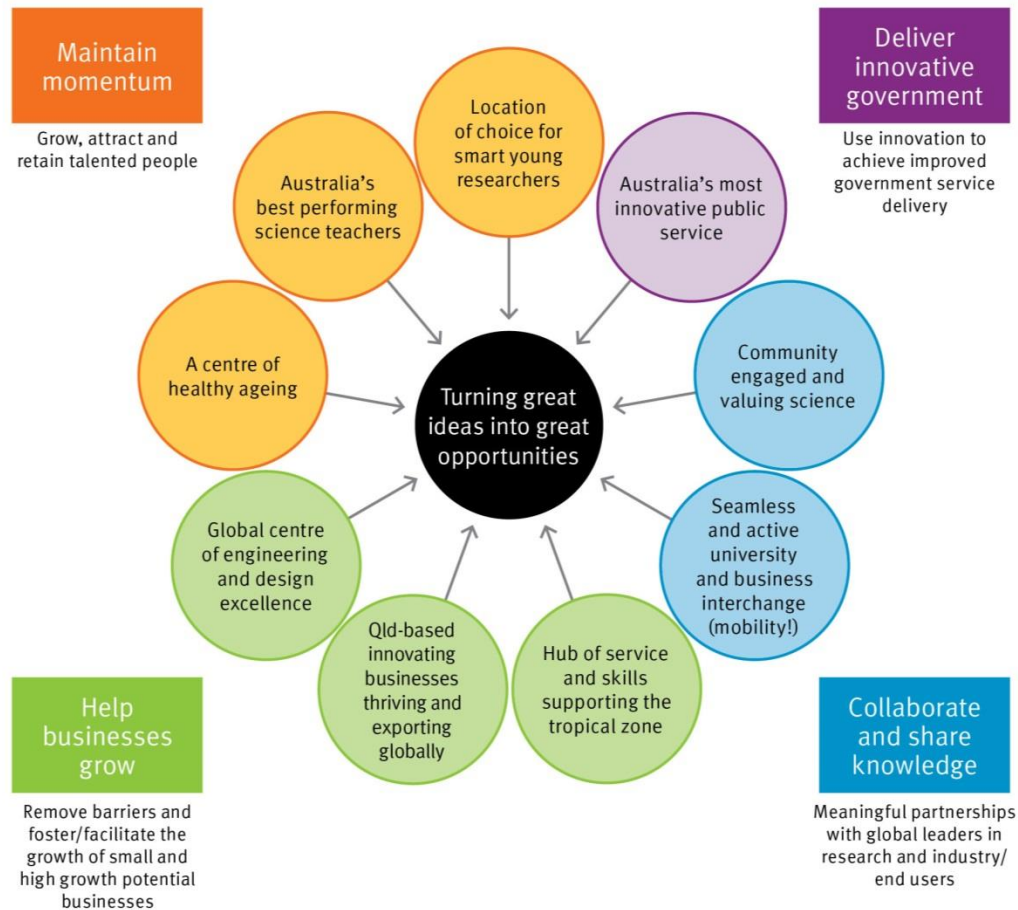
William J. Baumol, Princeton University; Sue Anne Blackman and Edward N Wolff, New York University

- In the long run, productivity will principally drive the prosperity of Queensland and the nation. However, Queensland's multifactor productivity has been in decline for a number of years.
- Australia ranks second last (out of 51 countries)² for total factor productivity growth – the lowest it has ever been while our labour productivity ranks 51 out of 60.
- The Productivity Commission has estimated that more than 60% of Australia's economic growth between 1994-95 to 2005-06 was due to growth in multifactor productivity and investment in innovation³.

Sources: 1. OESR, 2014. <http://www.qgso.qld.gov.au/products/publications/estimates-qld-productivity-performance/index.php>; 2. Eslake S (2011) The Australian Economy in the 2000s <http://www.rba.gov.au/publications/confs/2011/pdf/eslake.pdf>; 3. Barnes P & McClure A (2009) Investments in Intangible Assets and Australia's Productivity Growth, Productivity Commission Staff Working Paper, Canberra. Cited in DIISR (2011) Australian Innovation System Report, Department of Innovation, Industry, Science and Research, Canberra.

Science and Innovation Action Plan¹

Vision, goals and key action areas



Source: Science and Innovation Action Plan (2013) <http://www.qld.gov.au/dsita/initiatives/science-innovation-action-plan/>

The Queensland Government's vision is to use applied science, technology and innovation in 'turning great ideas into great opportunities'.

To realise these goals, the Queensland Government has identified a suite of departmental actions under four key action areas:

- maintain momentum
- collaborate and share knowledge
- help businesses grow
- deliver innovative government.

Science and innovation underpins our growing knowledge-intensive industries including aviation, aerospace, biofuels, defence, life sciences, ICT, and health.

They maintain the momentum from the state's strong base of research infrastructure and world class institutions to continue to attract the best and the brightest researchers in the world.

They are primary drivers of productivity growth - critical for Australia's prosperity, economic growth, and social wellbeing.

They will contribute to a more efficient and productive public sector, as identified in the Commission of Audit.

The vision for the future

Queensland transformed into a world leading centre of creativity, productivity, and knowledge through first-class research, entrepreneurship, and innovation that generates jobs, fosters our four pillar economy, and provides opportunities for all Queenslanders.

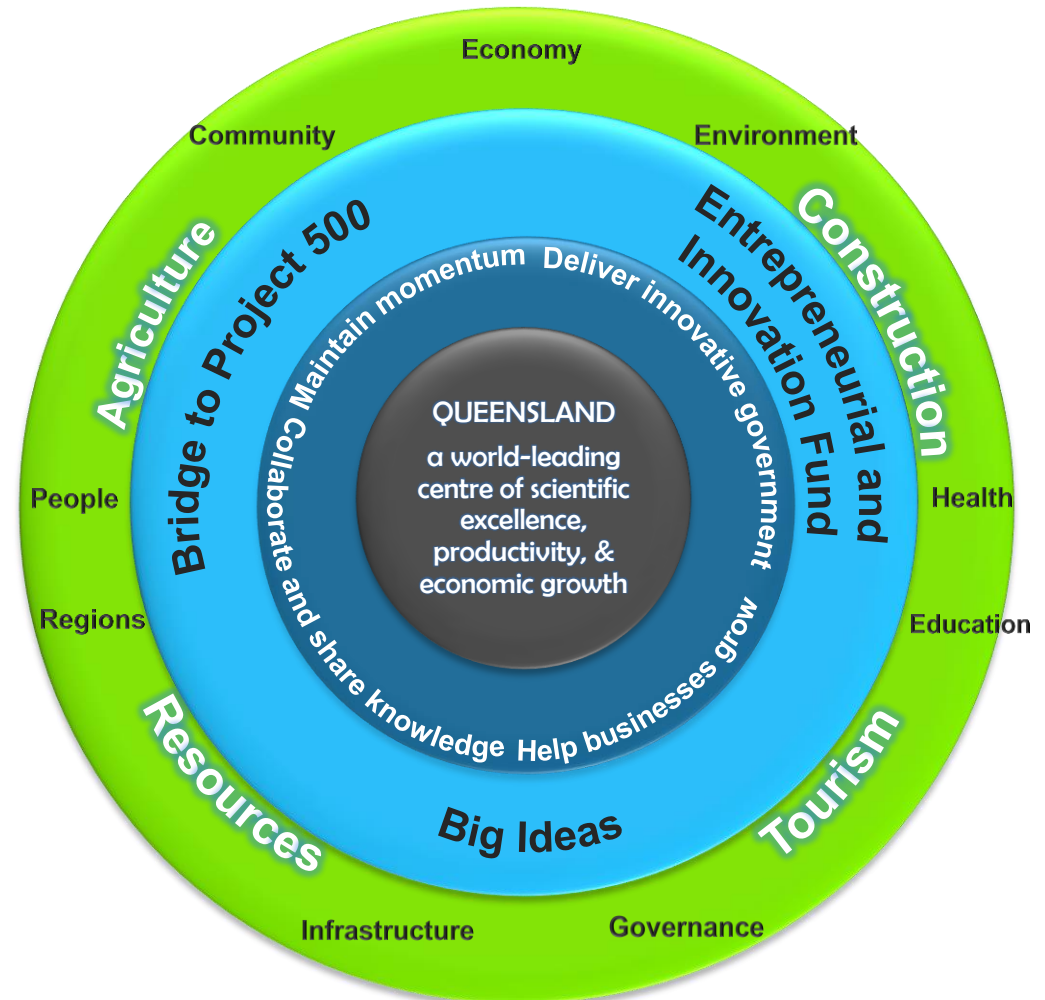
Turbocharge the Queensland economy through accelerated innovation - the leaders of China have three priorities: innovate, innovate, and innovate.

Translate great science and great business ideas into commercial value – make sure that our entrepreneurs and innovative businesses have the skills, information, connections, digital infrastructure, and opportunities to successfully cross the ‘valley of death’ and then (and most importantly for Queensland) to scale up and generate high-value jobs.

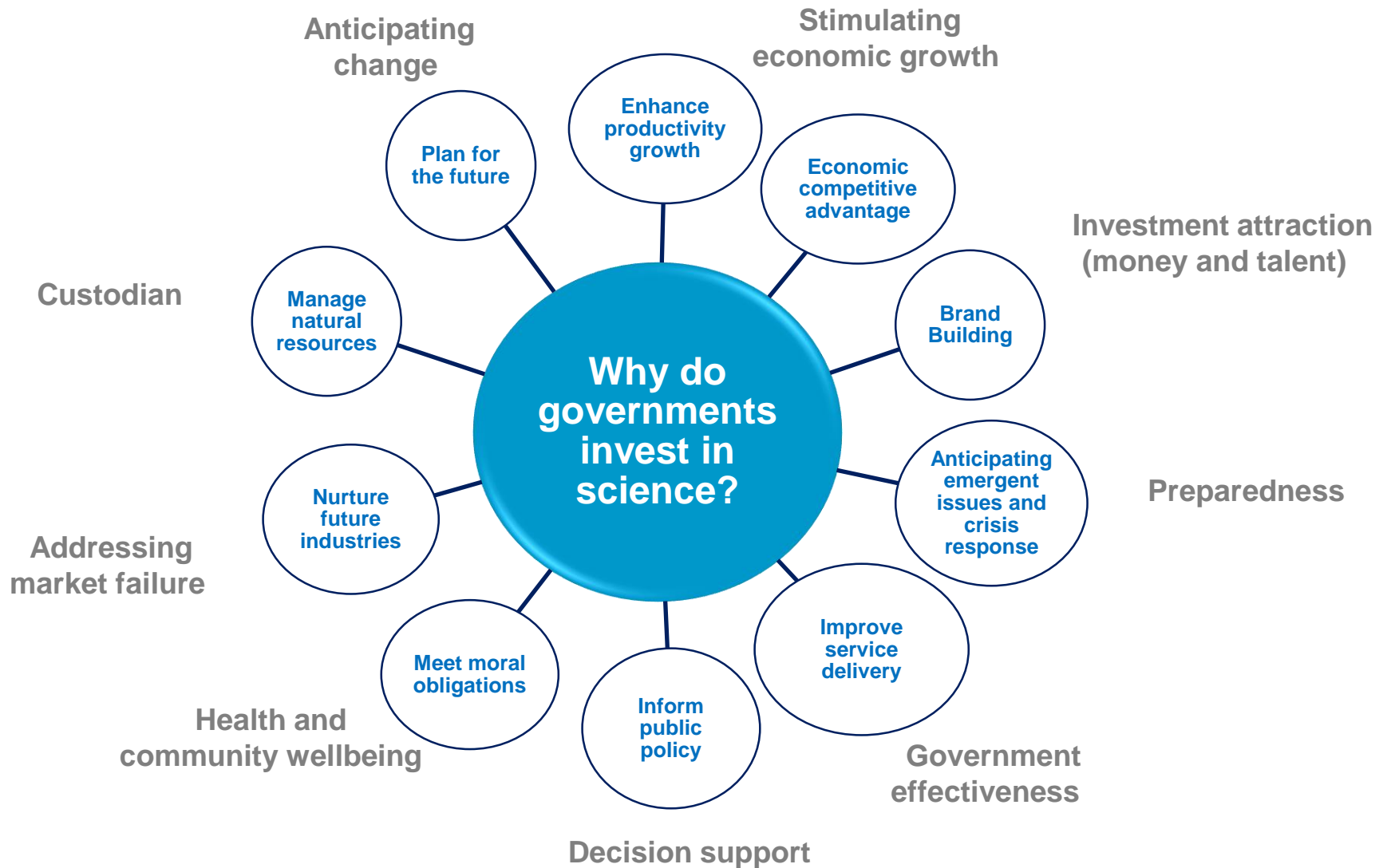
Maintain momentum by scaling up the *Accelerate* program, including a challenges component.

Strengthen **collaboration** between business and publicly funded research bodies to significantly enhance innovation.

Grow the skills base by attracting world-class researchers to Queensland and nurturing the future talent base by boosting school and university programs in STEM.



Why governments invest in science



Entrepreneurial and Innovation Fund

The EIF is an initiative proposed under *Queensland's Plan for Secure Finances and a Strong Economy*.

Objectives

The EIF seeks to drive innovation and turbocharge the Queensland economy by using brains and smart technology to generate jobs, build globally competitive, high-growth, entrepreneurial businesses across our four pillar economy and provide tangible benefits for Queenslanders right across the state.

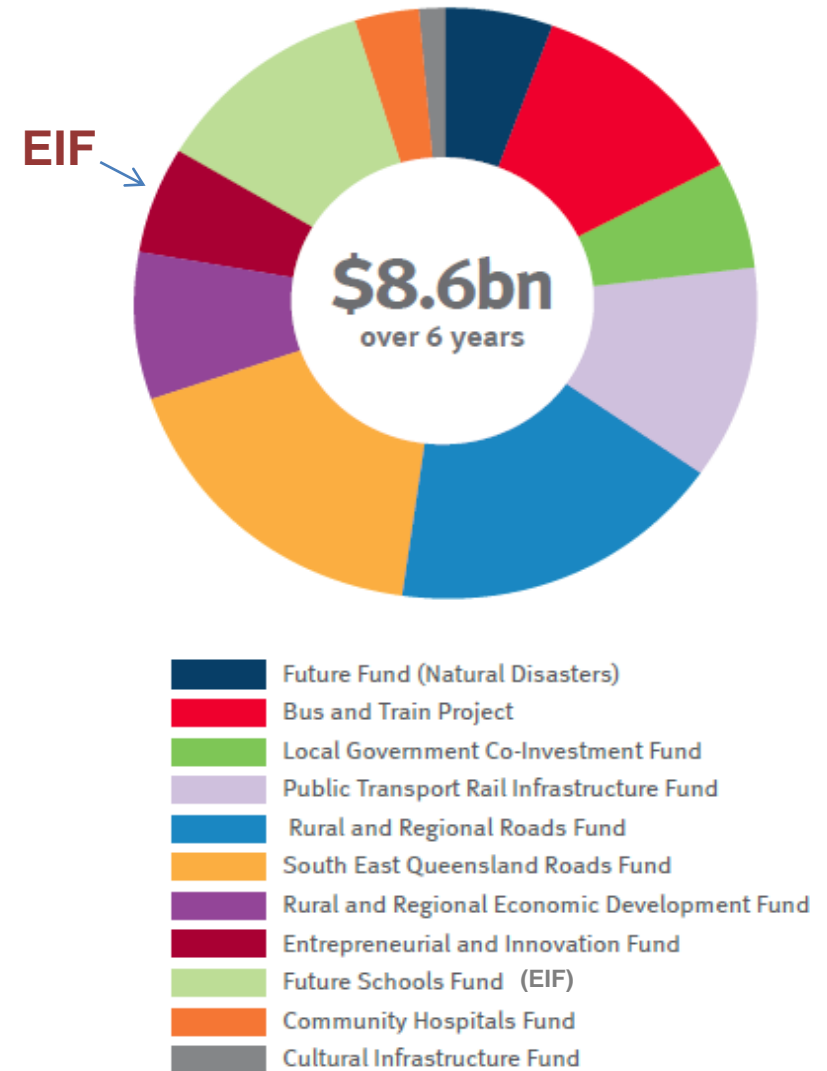
Priority investment areas

The EIF will support the Science and Innovation Action Plan, turning great ideas into great opportunities by maintaining momentum, collaborating and sharing knowledge, helping business grow, and delivering innovative government. The EIF will direct funding towards meeting Queensland challenges and opportunities, including harnessing big data, smarter transport, and northern agriculture. It will attract and foster world-class talent and strengthen collaboration and industry buy-in. The program will assist in translating excellent science and great business ideas into economic value and help develop high-value products and services for a global market.

What success will look like

Innovation improves productivity growth and creates jobs. Success will include:

- \$500 million leveraged into at least \$1 billion, directing more federal funding into *Queensland* priorities
- increased productivity and living standards in Queensland and more efficient Queensland Government services
- greater collaboration, especially between industry and universities, to increase impact from our research.



Source: Queensland Government (2014) Queensland's plan for secure finances and a strong economy. <http://www.strongchoices.qld.gov.au/>

People and skills

Education and skills¹

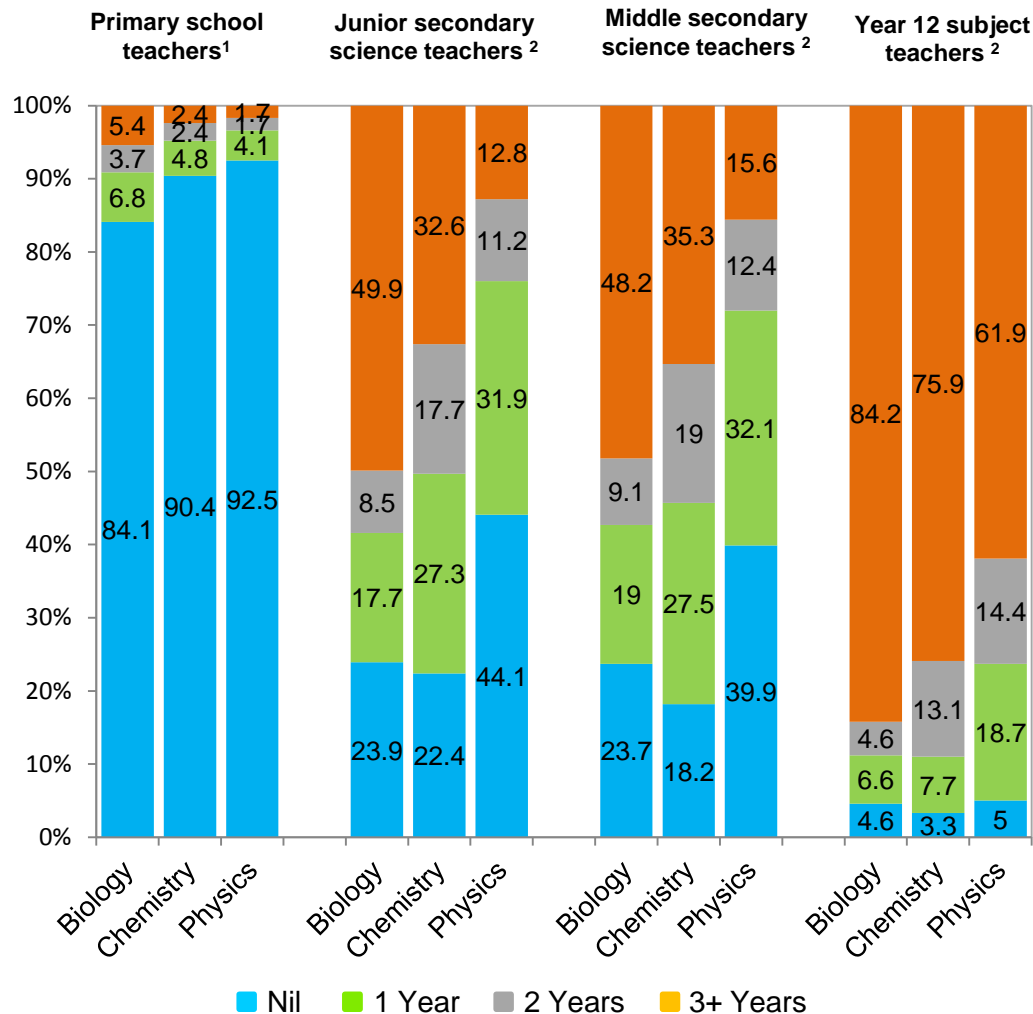
- Australians need to have the education and skills required to take advantage of innovation and thereby improve productivity.
- The majority of jobs being created in the modern economy require not only high-school completion, but some post-secondary education, whether at university, in the vocational education and training sector, or through apprenticeships and traineeships.
- Australia has made good progress in increasing school completion rates and participation in post-secondary education and training. Nevertheless, substantial challenges remain and a number of recent developments raise serious concerns about our future capacity for successful innovation. These include:
 - Slow progress towards the goal of universal high school completion. At 74%, Australia's secondary school completion rate ranks 22 of 40 OECD countries².
 - The reliance of the higher education system on income from overseas students who may go elsewhere (17.5% of total income, compared to 11.7% from HECS-HELP³).
 - Funding cuts in the TAFE system at the State level, which threaten the most vulnerable students⁴.
 - Chronic difficulties in the apprenticeship and trainee system, reflected in low completion rates and highly variable outcomes⁵.

Sources: 1. Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE), 2012, Australian Innovation System Report 2012; 2. OECD Country Note – Education at a Glance:OECD Indicators 2012; 3. DIISRTE, 2012, Higher Education Base Funding Review, Final Report; 4. The Courier, 2012, Ballarat education expert warns on TAFE cuts. <http://www.thecourier.com.au/story/143367/ballarat-education-expert-warns-on-tafe-cuts/>; 5. Australian Government, 2012, Apprenticeships for the 21st Century, Final Report of the Expert Panel.



Education Lab at QIMR Berghoffer

STEM teaching in Australia

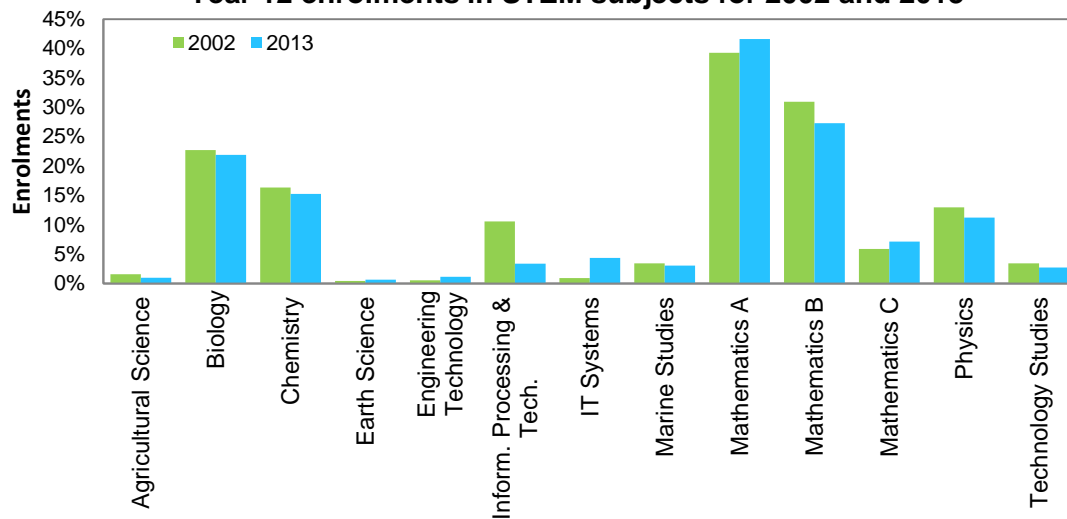


- Australian teachers' formal tertiary science qualifications increase from primary school (where teachers need to be generalists) to secondary school (where teachers can specialise more).
- By year 12, students are more likely to be taught by teachers with some years of tertiary science education. Students at this level need highly skilled teachers with strong content knowledge, however, as most students have opted out of STEM subjects by then, the full value of these resources for the broader school community is missed.
- There is a more fundamental challenge to science and maths teaching. Currently, the only entry requirement for an education degree is Year 12 or equivalent sound achievement for English and Maths, resulting in graduates teaching subjects such as science in which they have no formal education³.
- Recognising this at the Queensland level, from 2016, entry into Queensland teaching degrees will require a sound achievement in a science subject as well as English and Maths. This policy will take some time to have an impact, but is likely to create a fundamental shift in teaching standards in science in the future.

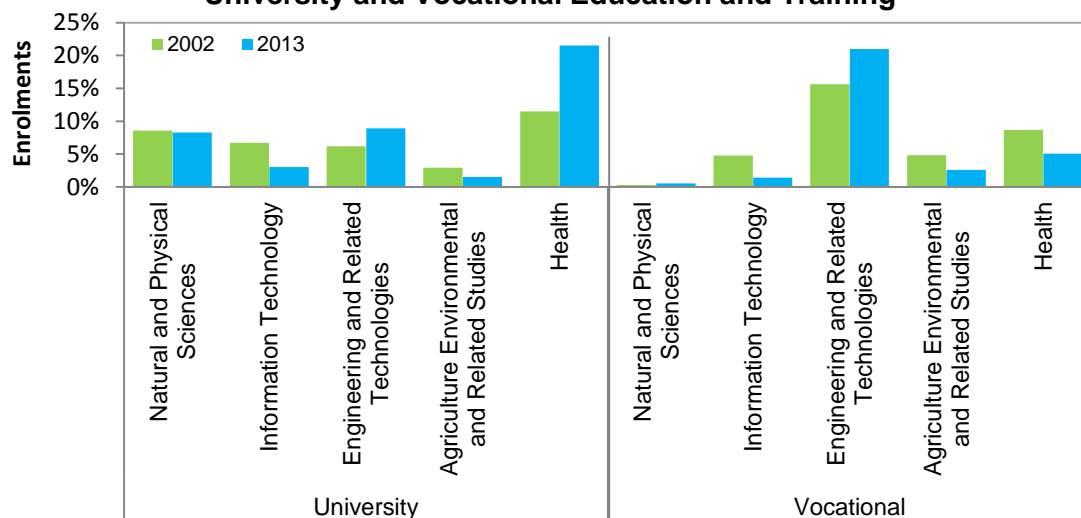
Sources: 1. Staff In Australia's Schools 2010: Main Report On The Survey. Australian Council for Educational Research (2011); 2. Who's Teaching Science? Meeting the demand for qualified science teachers in Australian secondary schools. Australian Council of Deans of Science (2005). 3. Queensland College of Teachers: Teacher Education <https://www.qct.edu.au/Education/index.html>

Secondary, vocational and tertiary science and maths enrolments

Year 12 enrolments in STEM subjects for 2002 and 2013



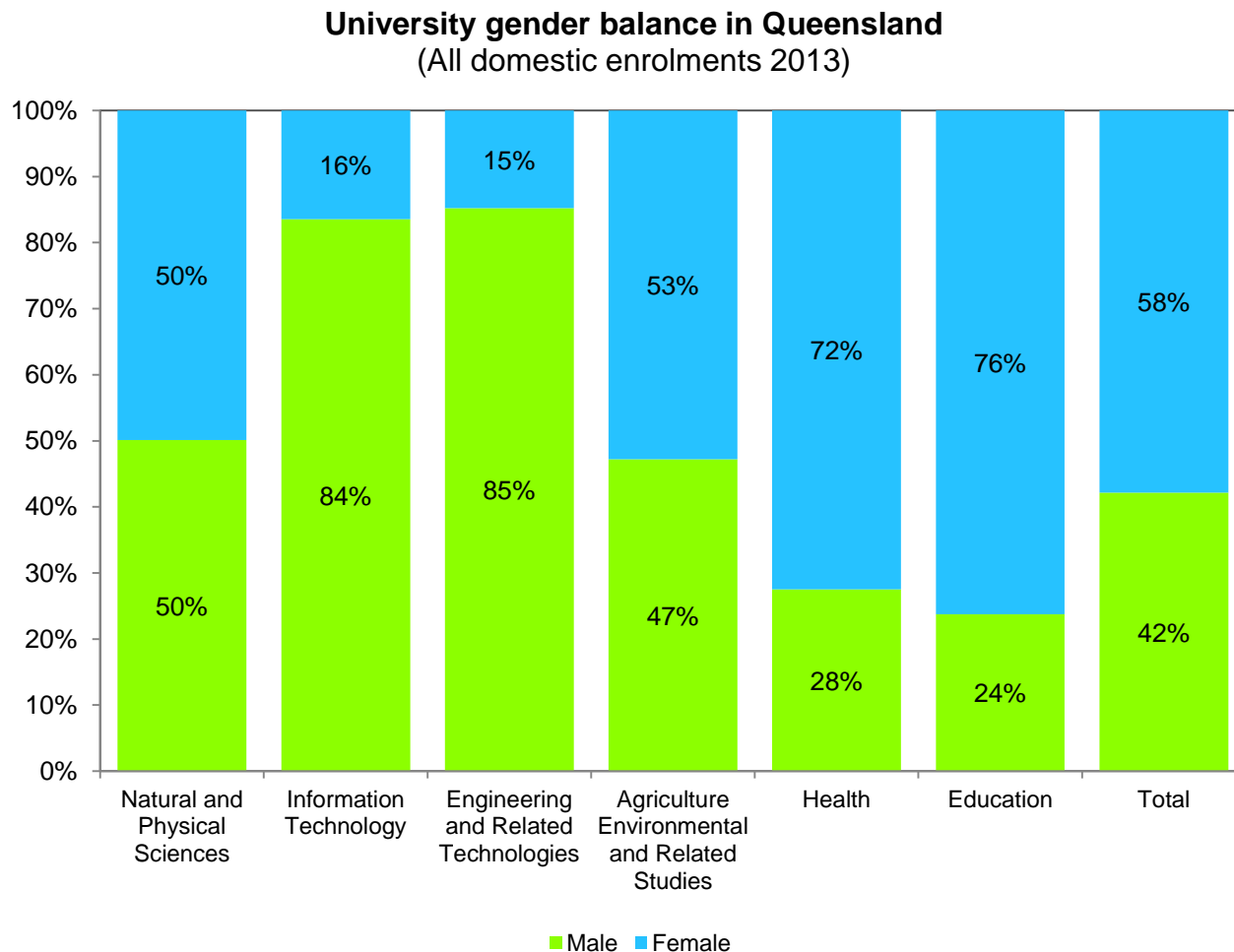
Enrolments in science-related subjects 2002 and 2013 - University and Vocational Education and Training



- The proportion of all Queensland 17-year-olds studying the major science subjects in year 12 has been in decline since the early 1990s.
- Between 2002 and 2013 enrolments by year 12 students in information processing and technology have declined by more than half (5598 in 2002 to 2168 in 2013). In addition, technology studies enrolments have also dropped slightly (1813 in 2002 to 1741 in 2013).¹
- University and vocational enrolments in information technology have decreased by at least 50 per cent over the last 11 years. This trend is echoed in agriculture, environmental and related studies, where tertiary and vocational education and training areas have seen a drop in enrolments as well.
- The drop in information technology enrolments is a concern as computer skills graduates make up only 2 per cent of our annual domestic graduates.² We are already seeing a decline in STEM graduates. Reports suggest that over the past decade an estimated 100,000 new jobs were created in Australia's technology sector, with only 49,500 new domestic students graduating during that time.³
- This contrasts with strong increases in enrolments in engineering and related technologies (both tertiary and vocational) and in health (tertiary only), driven perhaps by students' response to economic signals.

*Note: Total Year 12 enrolments in 2002 = 38,441; in 2013 = 48,205
Total university enrolments in 2002 = 137,445; in 2013 = 180,524
Total vocational enrolments in 2002 = 401,800; in 2013 = 357,259.*

University STEM gender balance

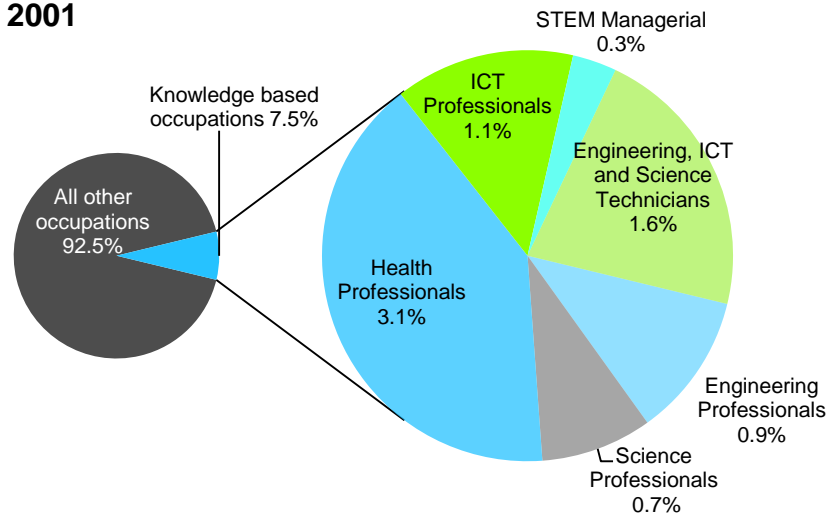


- In 2013, 58 per cent of Queensland's domestic university students were female compared to 56 per cent in 2001.
- Men are heavily over-represented in engineering and information technology and have been since 2001.
- Women are slightly over-represented in natural and physical sciences (science) and agriculture and environmental courses.
- Men are strongly under-represented in health and education courses and there is no evidence of any countervailing trend. For example, in 2002 respective enrolments in health were 27 per cent for males and 73 per cent for females. In 2013, male enrolments in health are still at 27 per cent and females have remained at 73 per cent.

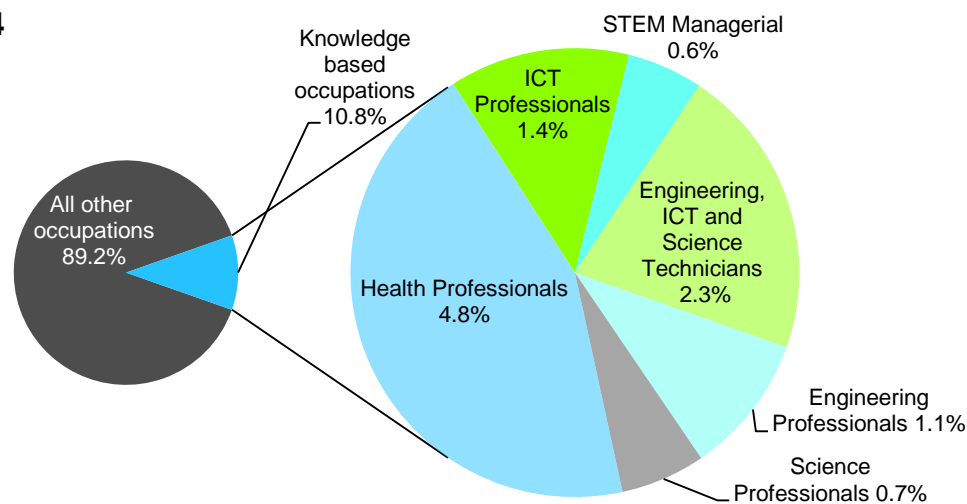
Source: Department of Industry, Innovation, Science, Research and Tertiary Education, uCube, available at <http://www.highereducationstatistics.deewr.gov.au/>

Queensland's knowledge-based workforce

May 2001



May 2014



- In May 2014, more than 250,000 Queenslanders were clearly and directly employed in knowledge-based occupations*.
- That represents approximately 10.8 per cent of the total workforce – up from 7.5 per cent in May 2001. By comparison the national average has risen from 9.4 to 11.1 per cent.
- The total Queensland labour force grew at an average of 3 per cent per annum between 2001 and 2014, but STEM employment grew at more than twice this rate (7.4 per cent per annum on average).
- “More new jobs have been created over the last five years in these ‘knowledge economy’ professions than in mining, accommodation and food, or in construction. In recent years, new job creation has, to a large extent, depended on us exploiting our relatively high level of skills. This has been made possible because in decades past we have made investments in education and skills”.

**Note: The knowledge based workforce was defined here by the following occupation categories and codes: Engineering Professionals (233), Natural and Physical Science Professionals (234) [also including Actuaries, Mathematicians and Statisticians (2241)], Health Professionals (25), ICT Professionals (26), STEM Managers [encompassing Research and Development Managers (1325), Engineering Managers (1332), ICT Managers (1351)], Engineering, ICT and Science Technicians (31). STEM skills are also relevant in other occupations not captured under this definition.*

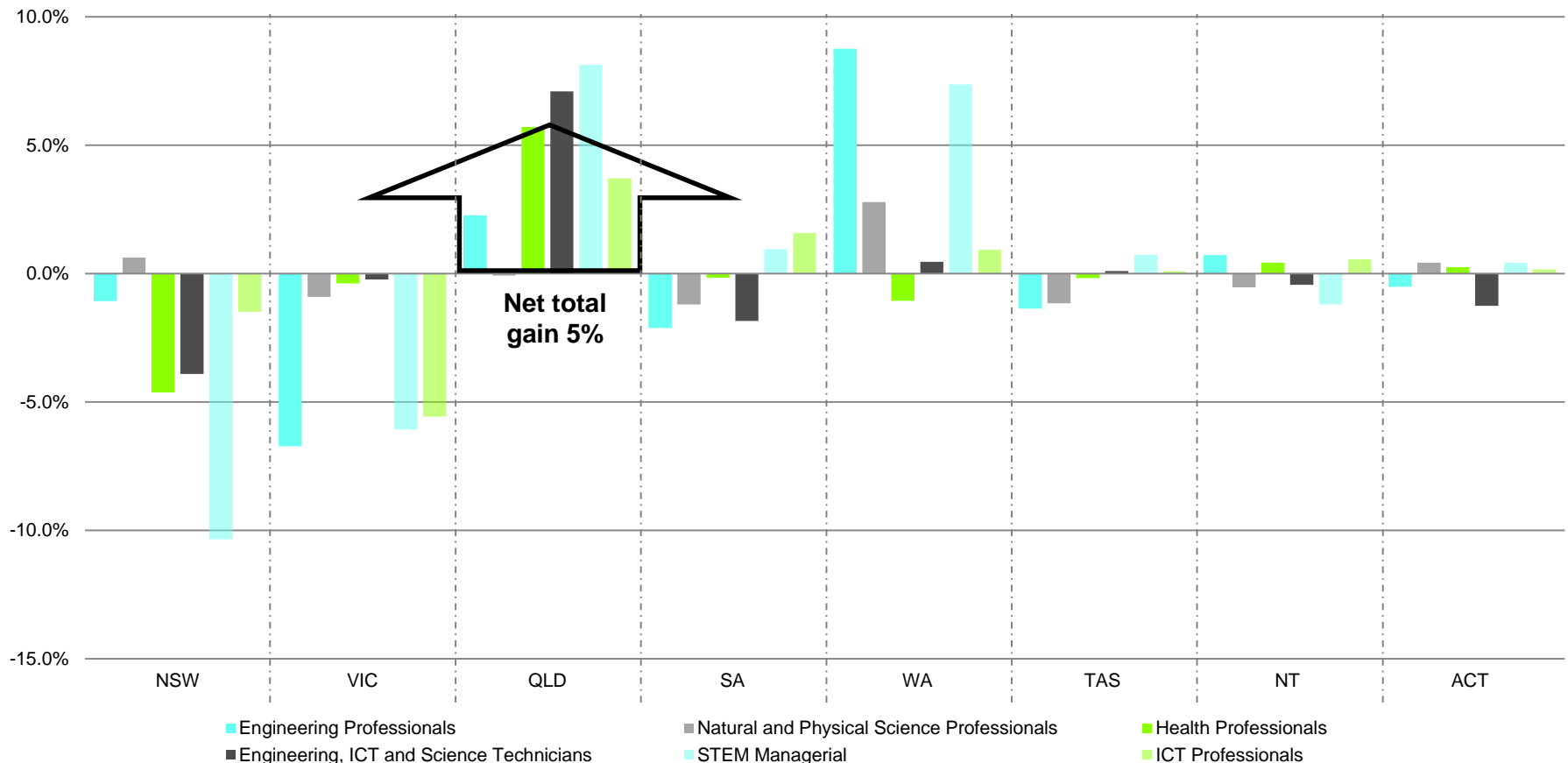
¹Australian Academy of Science (2014) Australia's Innovation System Submission 112. Submission to the senate economics references committee inquiry into Australia's innovation system from the Australian Academy of Science/July 2014.

Australia's shifting knowledge-based workforce

Between May 2001 and 2014 there have been significant shifts in where our knowledge-based workforce is located. The graph below shows that Queensland and, to a lesser extent, Western Australia are emerging as increasingly important nodes for the Australian knowledge economy – with net gains across the full spectrum of knowledge-based

careers. New South Wales and Victoria still dominate the landscape with over 56 per cent of all jobs but the future could be quite different, particularly if the resources sector continues to expand with its accompanying demand for skilled labour to maintain global competitiveness.

Net gains and losses of knowledge workers – 2001-2014

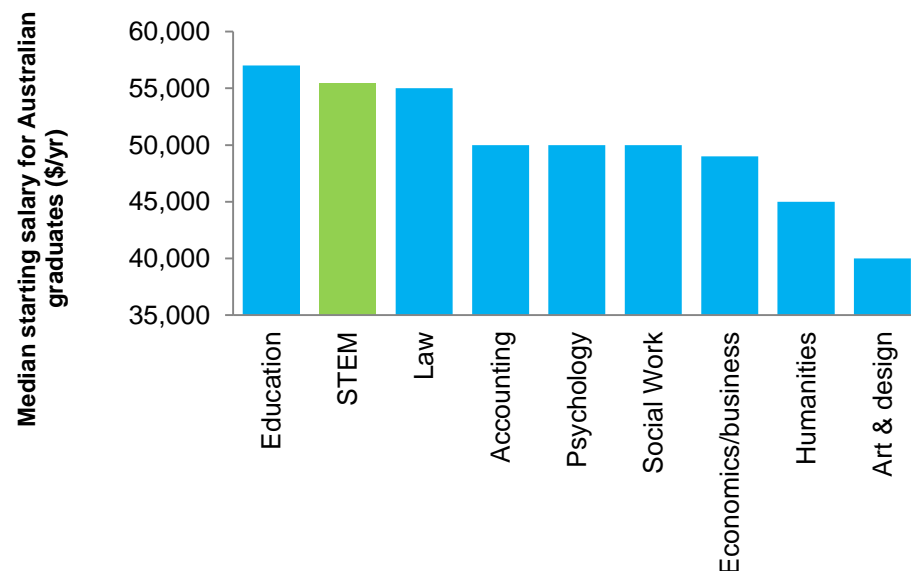


Source: ABS Labour Force, Australia Catalogue # 6202.0

Sciences employment and salaries

Region	Source	Year	Average Annual Wage (AU\$)
Queensland	Current Survey	2011	\$66,965
Australia	ABS	2011	\$74,750
New Zealand	New Zealand Statistics	2011	\$46,536
USA	United States Dept. of Labor	2010	\$69,447
Canada	Statistics Canada	2011	\$60,638
Sweden	Statistics Sweden	2010	\$67,114

- In the area of life sciences, the average annual wage for Queensland employees is \$66,965. This is \$10,000 below the average Australian wage for scientific, education, health-related categories, although comparable to several other member countries of the OECD¹ including New Zealand and Canada.
- The median annual starting salary for Australian STEM graduates aged under 25 years in full time employment compares favourably with the starting salary for bachelor degree graduates in other disciplines.²
- The median annual starting salary for STEM graduates aged less than 25 years and in their first full-time employment in Australia (\$55,500) was higher than the median graduate starting salary for all bachelor degree graduates (\$52,500).²



Sources: 1. Silvey, P. and Proctor, L. (2011) Queensland life sciences industry report 2012. VenturePro. Report commissioned by the Queensland Department of Science, Information Technology, Innovation and the Arts. <http://www.qld.gov.au/dsitia/assets/documents/qld-life-sciences-industry-report-2012.pdf>. 2. According to the ABS, across all industries, the average annual salary for Australian and Queensland employees in 2011 was \$71,568 and \$69,945, respectively. Employment and expenditure medians from the current survey suggest an average annual salary of \$66,965 for QLS employees in 2011. As a cross-check, a measure of the typical Australian Life Sciences wage in 2011 was determined by taking a simple average of three ABS salary data reporting categories (Scientific, Education, Health-related) to arrive at \$74,750.

People and skills: Observations and recommendations

- People with education, skills and experience in STEM areas are important to economic growth and general social advancement. We must nurture the STEM pipeline to deliver the quality and quantity of talent that will drive our future economy.
 - The number of students studying STEM subjects at school has continued to decline, although the trend is mixed – steady enrolments in mathematics contrasting with slight drops in core science subjects and wide variations in more applied science subjects. The introduction of sound achievements in science and maths as prerequisites for entry into teaching degrees from 2016 is a vital step in lifting long-term teacher capability in these critical fields.
 - Since 2001, the number of people employed in STEM-related occupations in Queensland has increased by one and a half times the rate of the total labour market growth, reflecting strong sustained demand for STEM skills and training. This is being seen in the makeup of the state's workforce with knowledge workers now comprising almost 11 per cent, up from under 7.5 per cent in 2001.
 - We are also drawing on interstate talent, with Queensland enjoying a net gain between 2001 and 2014 compared to losses in Victoria and New South Wales. We need to maintain and build on this momentum to achieve critical mass in our priority areas.
 - In contrast with general enrolment rates, female participation in many secondary and tertiary level STEM subjects remains low, particularly in the engineering and information technology fields.
- This can have a 'chilling effect' on future enrolments. We need to engage female students early on and provide strong role models.
- We are one of three countries in the OECD that do not have a national STEM strategy – and as a result we lack a coordinated plan of action. Of the Queensland Department of Education, Training and Employment's draft *STEM Education Strategy* will help inform future state school action, but a more inclusive policy document that takes into account independent schools and the vocational sector is needed for a fully integrated approach.
 - Undergraduate, PhD and early to mid career researchers need to have access to continuous professional development opportunities outside their specific scientific expertise to inculcate a collaborative and flexible approach from the start of their careers. For example, quality time spent in industry would allow some researchers to aid research translation and contribute their generic analytical and creative skills and training in other endeavours.
 - We must take full advantage of the plethora of existing programs offered by organisations to improve students' engagement in STEM education.
 - Student engagement is also enhanced by programs that provide specialised training and support for both primary and secondary teachers. Professional development for teachers and educators is essential as is enhancing access to resources for teachers and students. For example, the former (and very successful) Science Spark program.

Investment and infrastructure

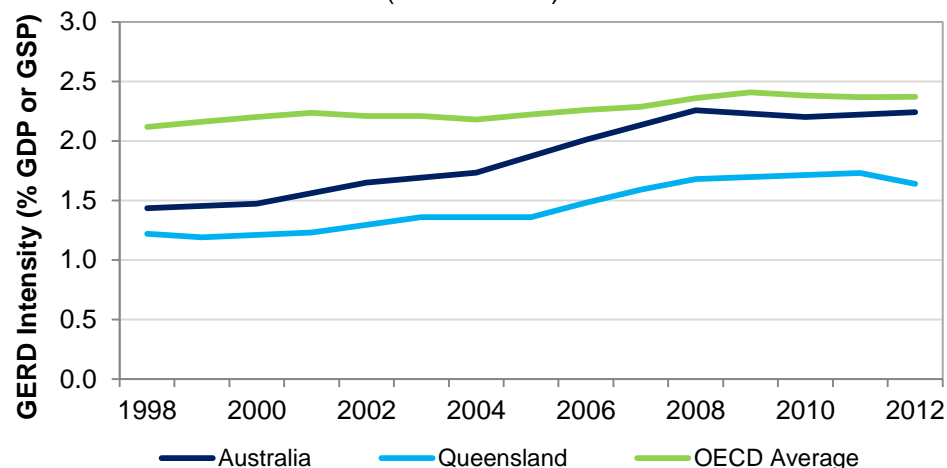
Overview of the Queensland R&D landscape

- In 2011-12, Queensland's Gross Expenditure on R&D (GERD) was estimated to be \$4.6 billion.¹ This is just 14 per cent of Australia's GERD when our share of both the economy and population is nearly 20 per cent.
- Australia's share of world R&D expenditure in 2012 was approximately 1.6 per cent², Queensland's share of Australia's R&D expenditure in 2011-12 was 14 per cent.¹ Thus Queensland R&D spend is approximately 0.22 per cent of the world R&D spend.
- 54 per cent of the total spend in Queensland was by the business sector (\$2.5 billion) and 35 per cent was by the higher education sector (\$1.6 billion)¹ (estimated). The Organisation for Economic Co-operation and Development (OECD) average for business and higher education as a percentage of GERD is 68 per cent and 18 per cent respectively.
- The Australian Government's support for science, research and innovation in 2013-14 was \$9 billion.⁵ By comparison, Toyota Motor Corporation's R&D spend in 2012 was US\$9.8 billion and Novartis AG, a diversified healthcare company, spent US\$9.3 billion.⁶

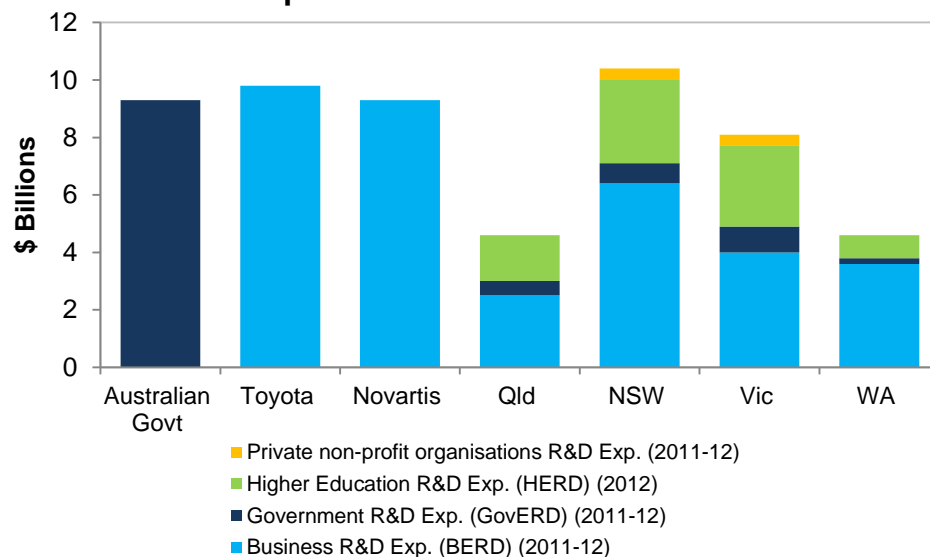
Note: GERD values are an estimate only for 2011-12 for Queensland and Australia using published ABS datasets as listed below

Sources: 1. ABS, Research and Experimental Development, Businesses, Australia, 2011-12 Cat # 81040DO121-20111, ABS, Research and Experimental Development, Higher Education Organisation, Australia, 2012 Cat # 81110DO001_2012, ABS, Research and Experimental Development, Government and Private non-profit organisations, Australia, 2012-13 Cat # 81090DO005_20122013, 2. Battelle, 2012 Global R&D Funding Forecast; 3. Queensland Chief Scientist Annual Report 2011, 4. Queensland Government R&D expenditure report 2011-12, Office of the Queensland Chief Scientist. DSITIA; 5. The Australian Government's 2013-14 Science, Research and Innovation Budget Tables; 6. Booz and Co's '2013 Global Innovation 1000 Study'; 7. OECD, Main Science and Technology Indicators

GERD Intensity over time^{1,6}
(1995 - 2012)



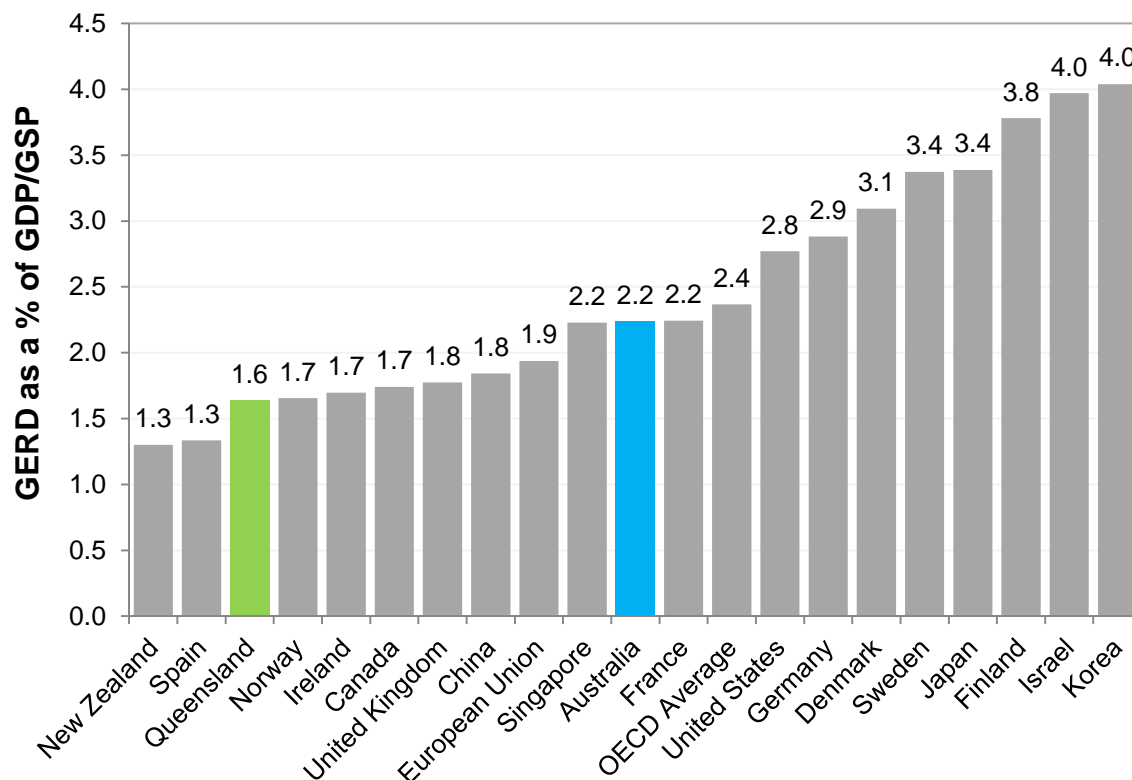
Comparison of R&D Investment^{1,4,5}



Overview of the Queensland R&D landscape

R&D Intensity^{1,2}

(2011 - latest data available and estimate for Qld and Australia)



- 'GERD Intensity' is the total GERD spend expressed as a proportion of GSP/GDP. In 2011, Queensland's GERD intensity was estimated to be 1.6 per cent.¹
- While Queensland GERD intensity has grown by more than 50 per cent in the last two decades¹, our investment is still low by national and international standards.
- Queensland is well behind world leaders such as Finland (3.8 per cent), Sweden (3.4 per cent), Japan (3.4 per cent) and the USA (2.8 per cent).²
- For Queensland to meet the national and OECD averages, it is estimated it would have required an additional spend of \$2 billion and \$2.4 billion respectively in 2011-2012. To become a national leader in 2011-12 would have required an additional \$3.1 billion investment.

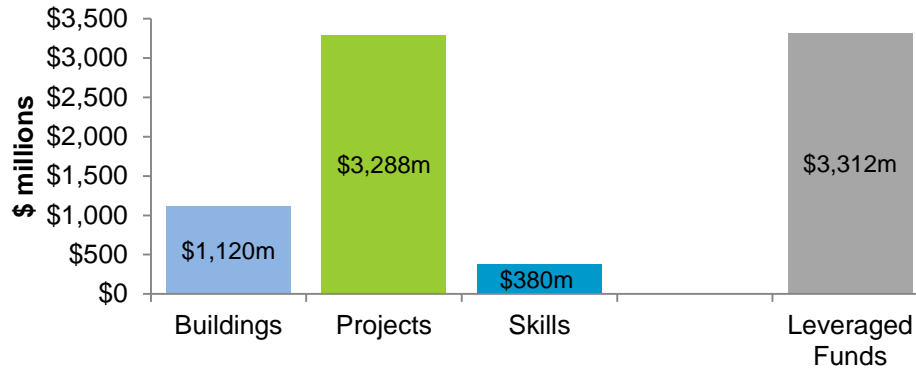
Note: GERD values are an estimate only for 2011-12 for Queensland and Australia using published ABS datasets as listed below

Sources: 1. ABS, Research and Experimental Development, Businesses, Australia, 2011-12 Cat # 81040DO121-20111, ABS, Research and Experimental Development, Higher Education Organisation, Australia, 2012 Cat # 81110DO001_2012, ABS, Research and Experimental Development, Government and Private non-profit organisations, Australia, 2012-13 Cat # 81090DO005_20122013; 2. OECD, Main Science and Technology Indicators

Smart State investment 1998-2011

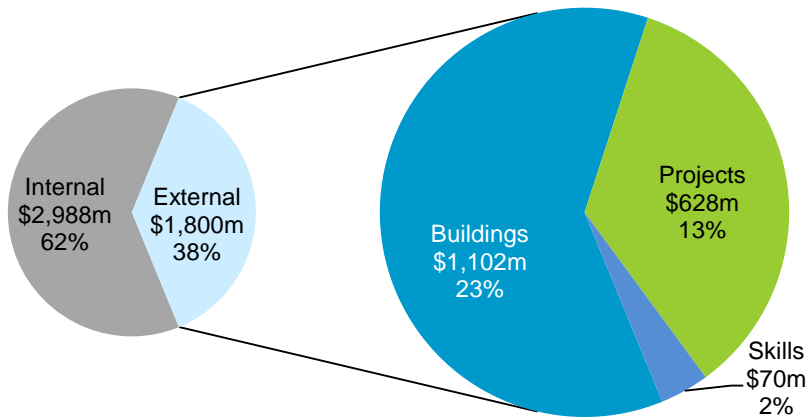
Total Smart State investment 1998-2011*

(* excludes \$100m of new commitments in 2011)



External Smart State investment 1998-2011*

(* excludes \$100m of new commitments in 2011)



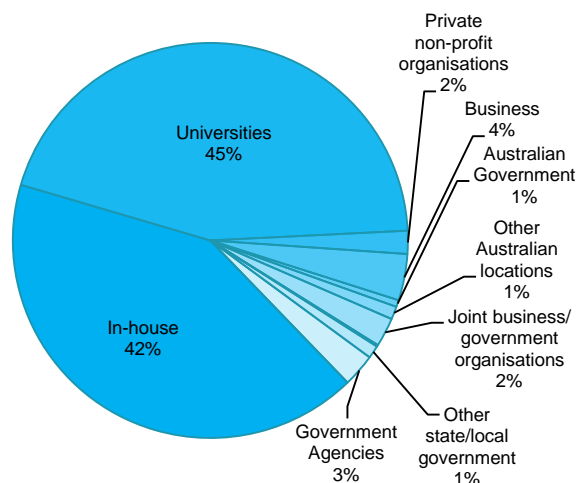
- Between 1998 and 2011, the Queensland Government invested approximately \$4.9 billion under the 'Smart State' banner.¹ Twenty four per cent of this was used for buildings (infrastructure), 68 per cent funded projects, and 8 per cent went to education and skills programs.¹
- Much of the funding went to support in-house Queensland Government R&D (nearly \$3 billion) while the remainder was disbursed to external organisations, mainly to support major infrastructure projects.¹
- A further \$3.3 billion was leveraged with these investments to give a total investment of approximately \$8.2 billion.¹
- The Smart State Investment supported 45 new institutes or research facilities and 230 fellowships and scholarships.²
- During the Smart State program, the number of publications authored by Queensland researchers grew by 140 per cent - well above the growth rate for Australia as a whole (105 per cent).³

Sources: 1. Queensland Government R&D Expenditure Report 2010-11, Office of the Queensland Chief Scientist; 2. Audit of Science Investment and Funding Programs, DSITIA (2013); 3. Analysis from the Web of Science (Thomson Reuters) publication database

Queensland Government R&D expenditure

Where was the R&D undertaken?

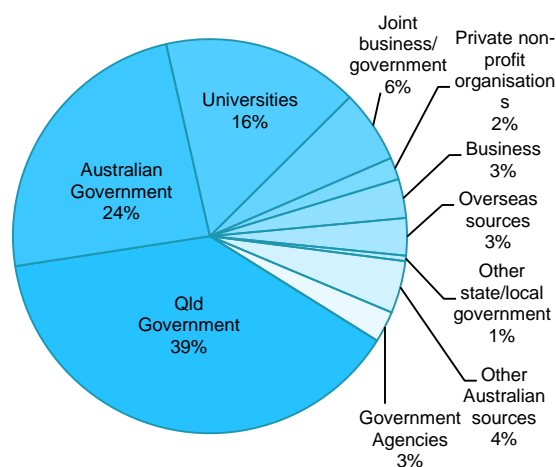
Total Qld Government R&D Expenditure (\$523m)
Location (2012-13) (including QIMR leveraged funds of \$91.5m)



In 2012-13, the Queensland Government funded \$203 million worth of R&D. An additional \$228 million was leveraged from external sources, resulting in total R&D expenditure of \$431 million (compared with \$634 million in 2011-12)¹. In addition QIMR leveraged an additional \$91.5 million which is captured in the chart above.

Who Paid for the R&D?

Total Qld Government R&D expenditure (\$523m) by Funding Source (2012-13) (including QIMR leveraged funds of \$91.5m)

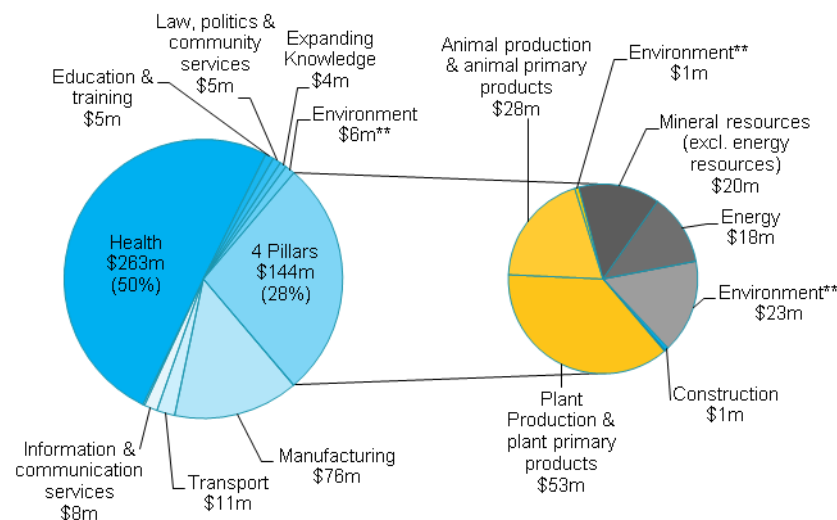


Of the R&D performed with the Queensland Government, the Universities paid for 15 per cent, the Australian Government paid for 24 per cent and the Queensland Government paid for 39 per cent. The business sector only funded 6% of total research.

Fifty per cent of funding goes towards health research and it is performed across a number of departments and government bodies including QIMR Berghofer. Four Pillars research investment has decreased.

In what areas will the R&D benefit Queensland?

Total Qld Government R&D Expenditure (\$523m) by Socio-Economic objective (SEO) (i.e. the outcome of the research) and alignment to the Four Economic Pillars



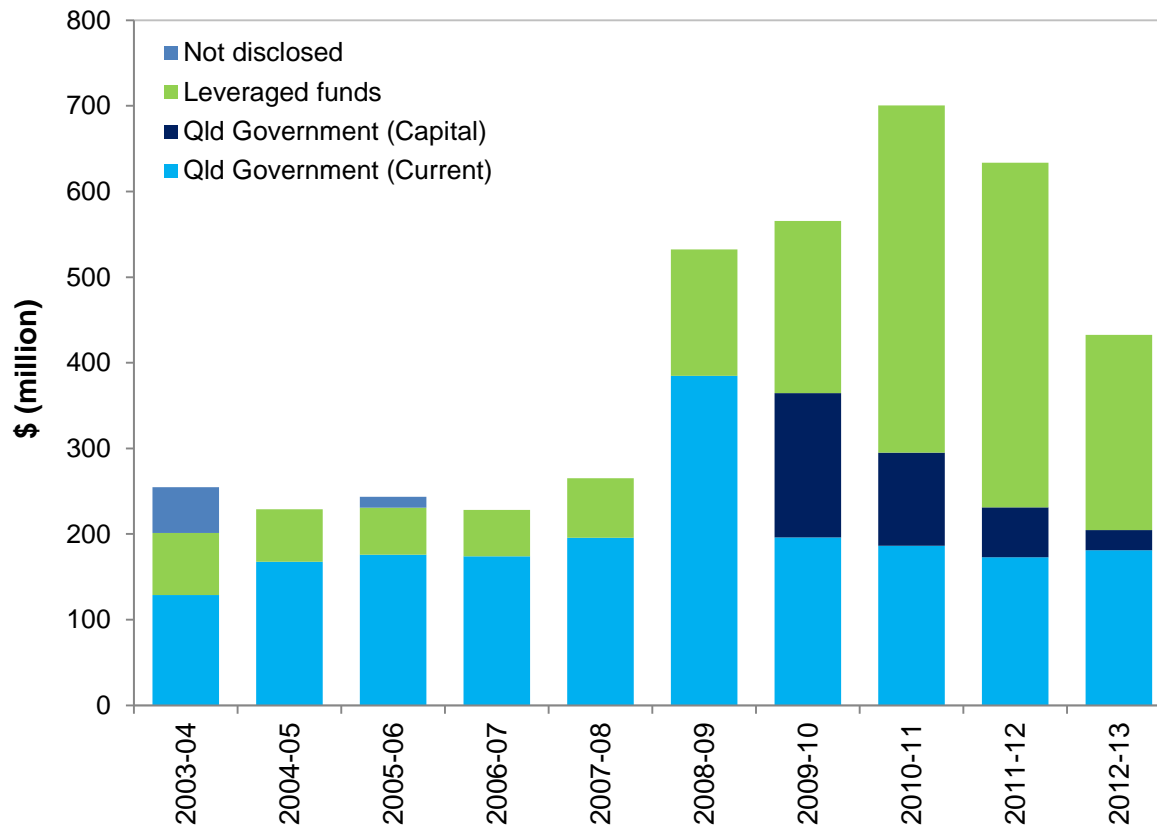
Socio-economic objectives that align to the economic pillars have been separated into a smaller pie chart. These are: **Agriculture (yellow)**: animal production and animal primary products, plant production and plant primary products, and projects aligned to agriculture and environment. **Construction (blue)**: construction. **Resources (grey)**: mineral resources; energy; and projects aligned to resources and the environment and **Tourism** (no expenditure using ABS definitions).

**The Environment SEO has been split into three sections: Environment research that aligns directly to Agriculture, Environment projects that align to the Resources sector, and the remaining Environment research that is not aligned to the Four Economic Pillars (in the larger pie chart).

Source: Queensland Government Research & Development Expenditure Report 2012-13, Office of the Queensland Chief Scientist

Queensland Government R&D expenditure

**Queensland Government R&D Expenditure and Leveraged funds
2003-04 to 2012-13**



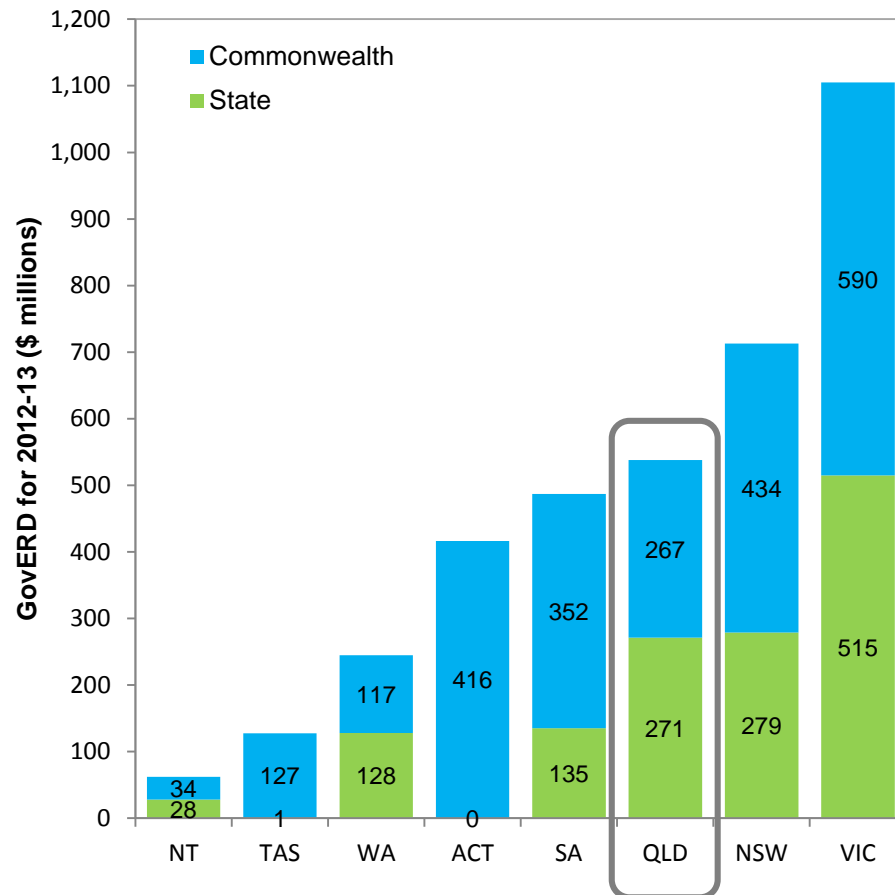
**Note: the categorisation of expenditure into current and capital was only implemented from 2009-10.*

Source: Queensland Government Research & Development Expenditure Report 2012-13, Office of the Queensland Chief Scientist

- Queensland Government expenditure on R&D has been in decline for several years.
- Total Queensland Government expenditure decreased by 32% in 2012-13 from the previous year.
- Queensland Government current spend has remained relatively the same across the last four years but Queensland Government capital spend has decreased by more than half in 2012-13.
- Leverage on Queensland Government funds has reduced again in 2012-13 to only \$1.12 for every \$1.00 spent, compared to \$1.74 leveraged in 2011-12.
- This decrease is due to infrastructure commitments coming to an end - in the past infrastructure projects have attracted high levels of investment (leverage) from universities, federal research agencies and philanthropy.
- Business sector investment in R&D performed or linked to government is very low and it is important for government to grow our business sector commitments if we are to encourage greater collaboration with industry and strengthen our R&D portfolio.

Federal R&D expenditure

Federal Government and State government R&D expenditure for 2012-13

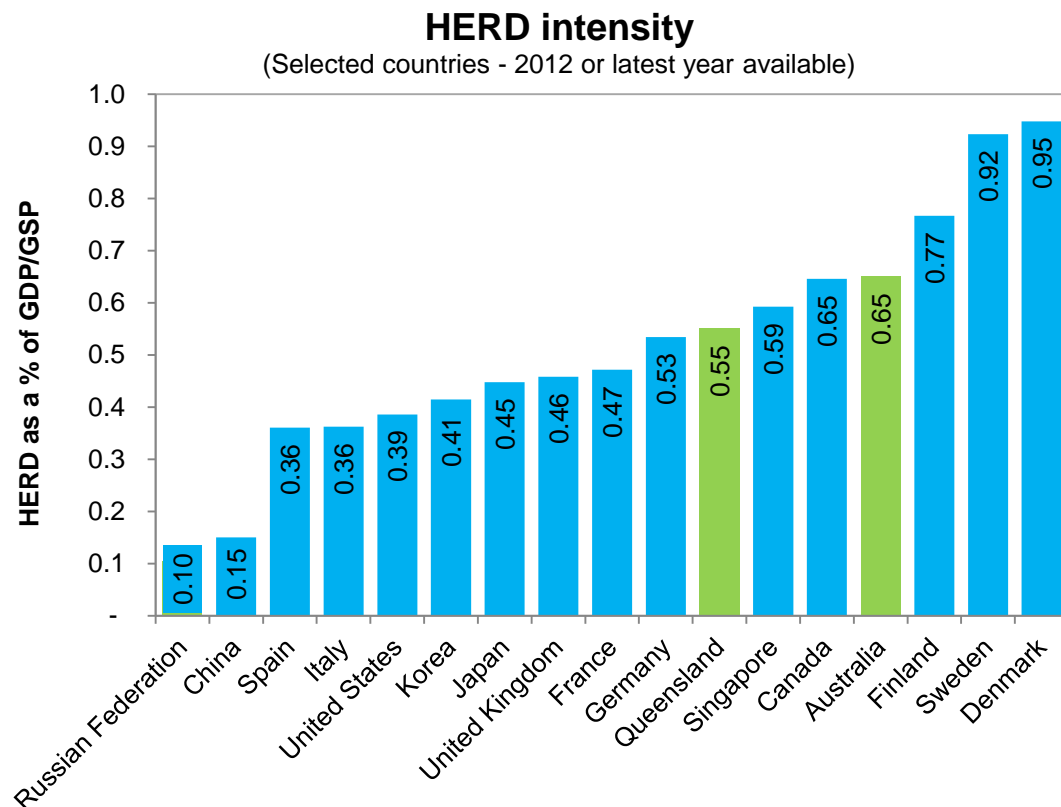


- The Australian Government is a major funder of science, research and innovation. The latest state-related data from the ABS¹ shows that in 2008-09 direct federal government expenditure on R&D amounted to \$3.73 billion*.
- \$267 million (or 11 per cent) of commonwealth GovERD was spent in Queensland.
- In 2012-13, the total ABS recorded GovERD (commonwealth and state R&D expenditure) in Queensland was \$539 million, with the state government providing nearly 50 per cent of the total.
- Queensland's leverage of commonwealth money, dollar for dollar, is not comparable to other states.
- New South Wales is able to leverage 60 per cent more in commonwealth dollars than Queensland. South Australia, which puts in half the dollars Queensland does, leverages 30 per cent more Commonwealth funding than Queensland.

**Note – The Commonwealth GovERD figure does not include substantial federal funding (at least \$2.4 billion in 2010) expended through universities and which is recorded under Higher Education on R&D (HERD).*

Source: ABS, Research and Experimental Development, Government and Private Non-Profit Organisations, Australia, 2012-13, Cat # 8109

Higher education R&D

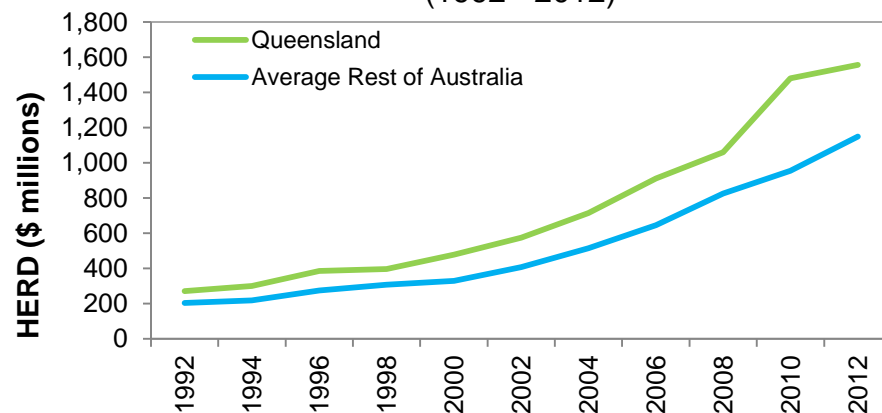


- In 2012, Queensland's HERD spend was \$1.56 billion or 0.55 per cent of Gross State Product (GSP) – well below the Australian national level at 0.65 per cent of Gross Domestic Product (GDP).¹
- In international terms, Queensland is well below the world leaders, typically Northern European countries such as Finland, Sweden and Denmark² and Australia is still not in the leading countries.

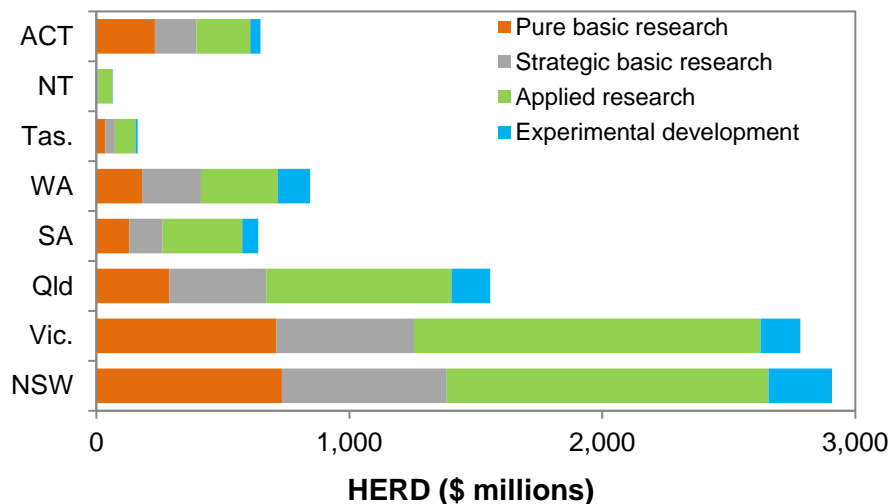
Sources: 1. ABS Research and Experimental Development, Higher Education Organisations Australia, 2010 Cat # 8111.0; 2. OECD, Main Science and Technology Indicators (HERD as a percentage of GDP)

Higher education R&D

HERD Expenditure
(1992 - 2012)



HERD expenditure in 2012 for the states



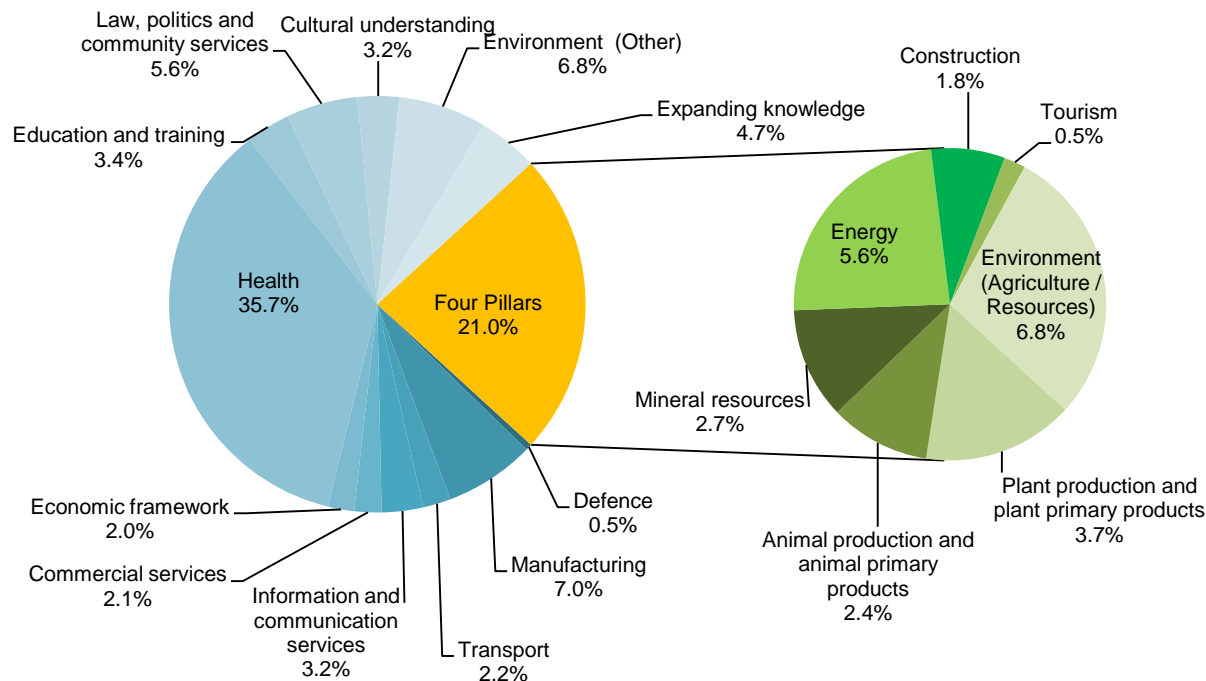
- Queensland's portion of research spent on Higher Education is low in comparison to the rest of Australia, and the gap is widening over time.¹
- Queensland's basic research spend of 19 per cent is low in comparison to many other states and territories and when compared to the Australian average (25 per cent).
- Conversely, strategic basic research, applied research and experimental development are performed in Queensland at higher proportions than the national average and most other states.¹
- Over the last two decades, Queensland's applied and experimental research has moved from 43 per cent to 57 per cent of the total activity.
- This suggests Queensland has a strong focus on the practical application of HERD, as do many other states and territories. This is consistent with the state government's policy objective.

Source: ABS Research and Experimental Development, Higher Education Organisations Australia, 2012 Cat # 8111.0

Higher education R&D

HERD by Socio-Economic Objective

(Total = \$1.56B, 2012)



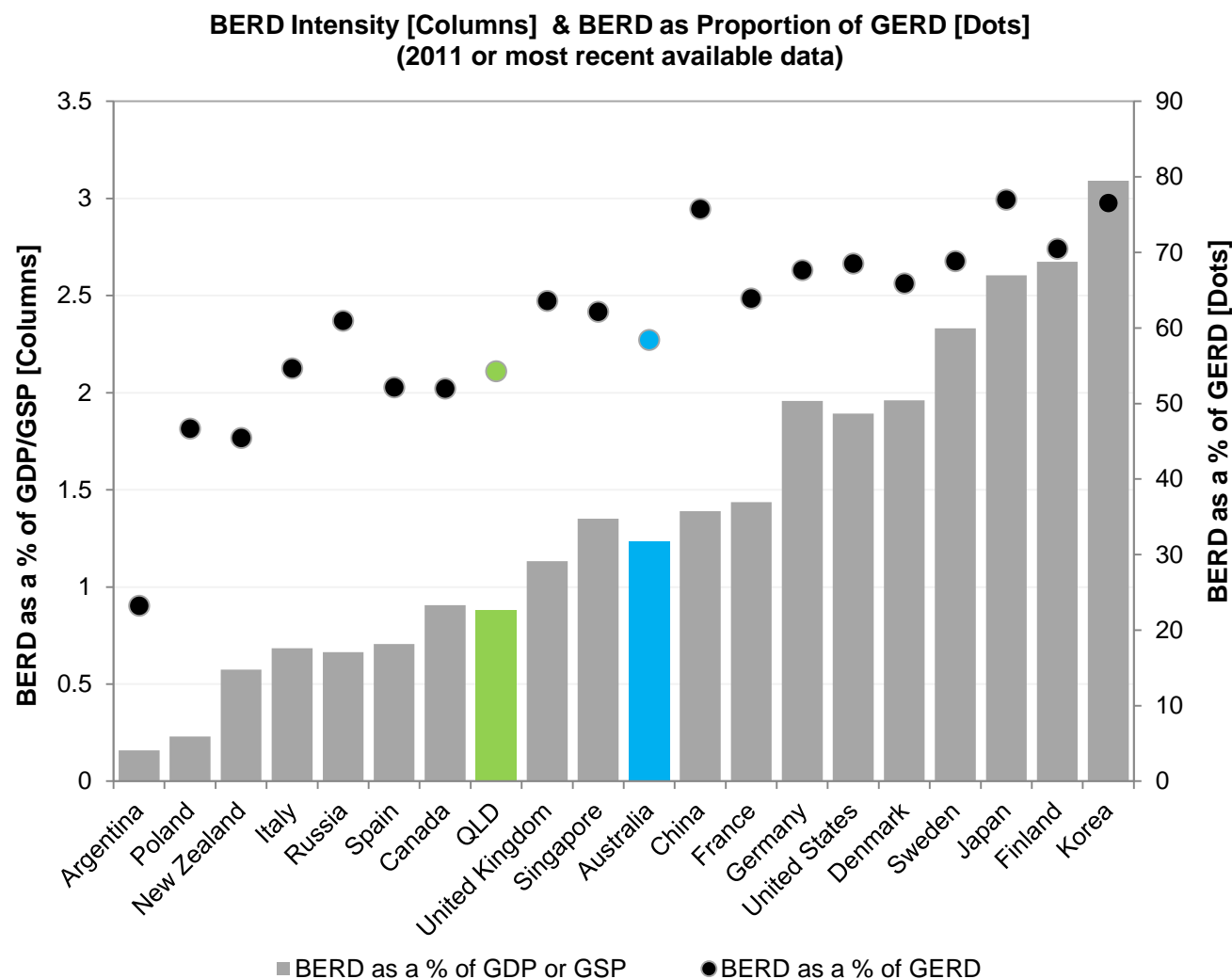
Notes:

1. An estimated 50 per cent of environmental R&D supports the agriculture and resources pillars.
2. The 'commercial services and tourism' domain set out in the ABS data has been allocated as 80 per cent (commercial services) and 20 per cent (tourism).

- Socio-Economic Objective (SEO)¹ reflects the purpose of the HERD as perceived by the data provider. The SEO classification system consists of discrete economic, social, technological or scientific domains.
- In Queensland, the top two SEOs were Health (31 per cent), and the Environment, with 13 per cent (split across traditional and four pillar research areas - see note).
- SEOs that align most directly with the Four Pillar Economy account for 24 per cent of HERD overall, with agriculture and resources accounting for 6.8 per cent, construction for 1.8 per cent and tourism 0.5 per cent.

Source: ABS Research and Experimental Development, Higher Education Organisations Australia, 2012 Cat # 8111.0

Business expenditure on R&D

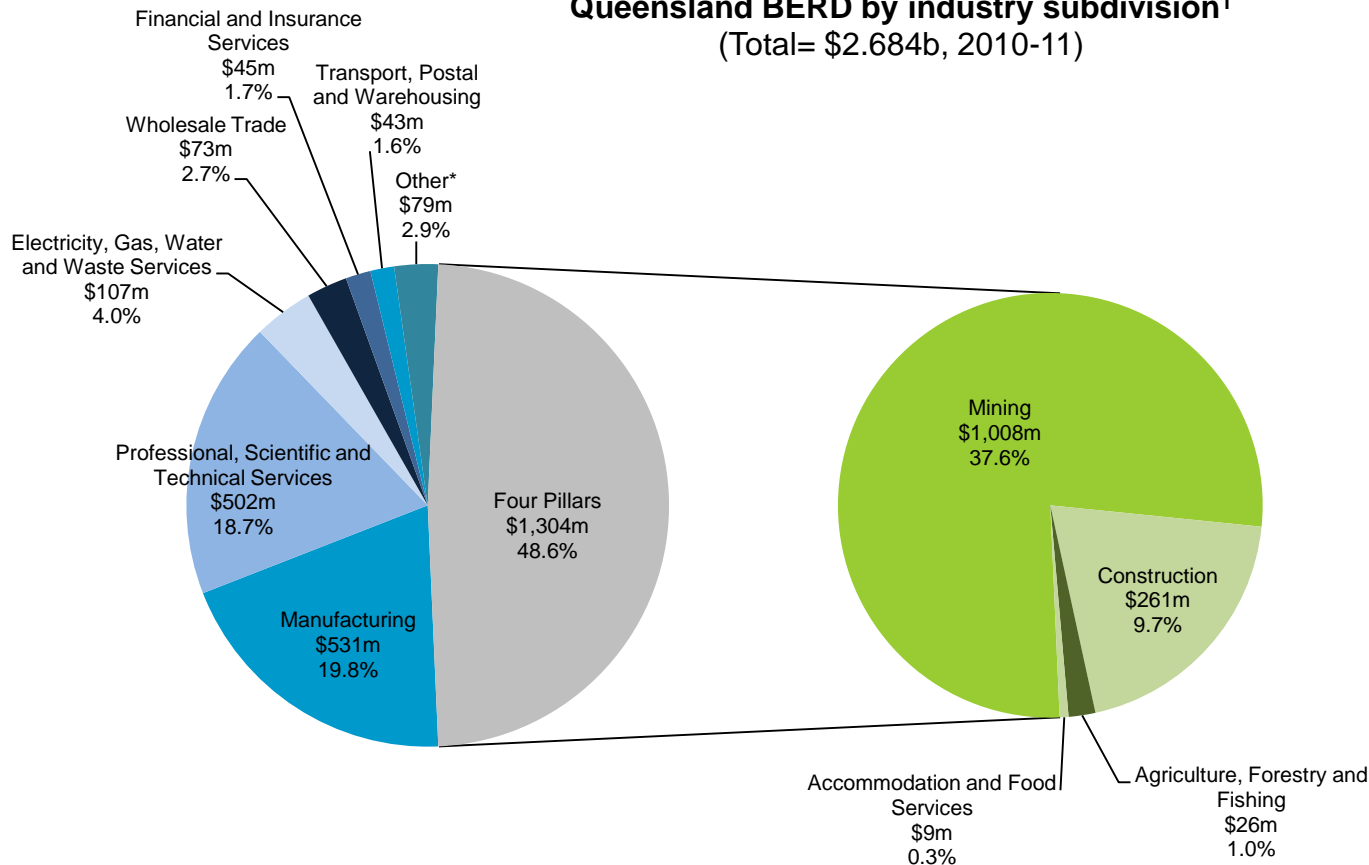


- At approximately 54 per cent, Queensland's business share of R&D is similar to global R&D leaders.
- However, Queensland's BERD intensity (BERD as proportion of GSP/GDP) at 0.88 per cent is low compared to the Australian average (1.2 per cent) and is below most OECD nations^{1,2}.
- Korean and Finnish businesses invest proportionally three times more than Queensland, while the United States and Germany spend more than twice as much².
- The ratio of research to development in Australian business is estimated to be about 40:60 (compared with 30:70 in the 1990s)³.

Sources: 1. ABS Research and Experimental Development, Businesses, Australia, 2011-12 Cat # 81040; 2. OECD, Main Science and Technology Indicators (BERD as proportion of GDP and GERD); 3. Australian Research: Strategies for Turbulent Times (2011), Dr Thomas Barlow

Business expenditure on R&D

Queensland BERD by industry subdivision¹
(Total= \$2.684b, 2010-11)



- In 2010-11 Queensland businesses spent \$2.7 billion on R&D¹.
- The bulk of spending was made by the mining (37.6 per cent), manufacturing (19.8 per cent), professional, science and technical service (18.7 per cent) and construction (9.7 per cent) sectors¹.
- The mining and construction industries account for a much greater fraction of Queensland BERD than the national average¹.
- Together, the sectors of Queensland's Four Pillar Economy account for nearly half the R&D spend of Queensland businesses.

Note: 'Other' includes Administrative and Support Services; Information Media and Telecommunications; Retail Trade; Rental; Hiring and Real Estate Services; Health Care and Social Assistance; Education and Training; Other Services.

Source: ABS, Research and Experimental Development, Businesses, Australia, 2010-11 Cat # 8104.0

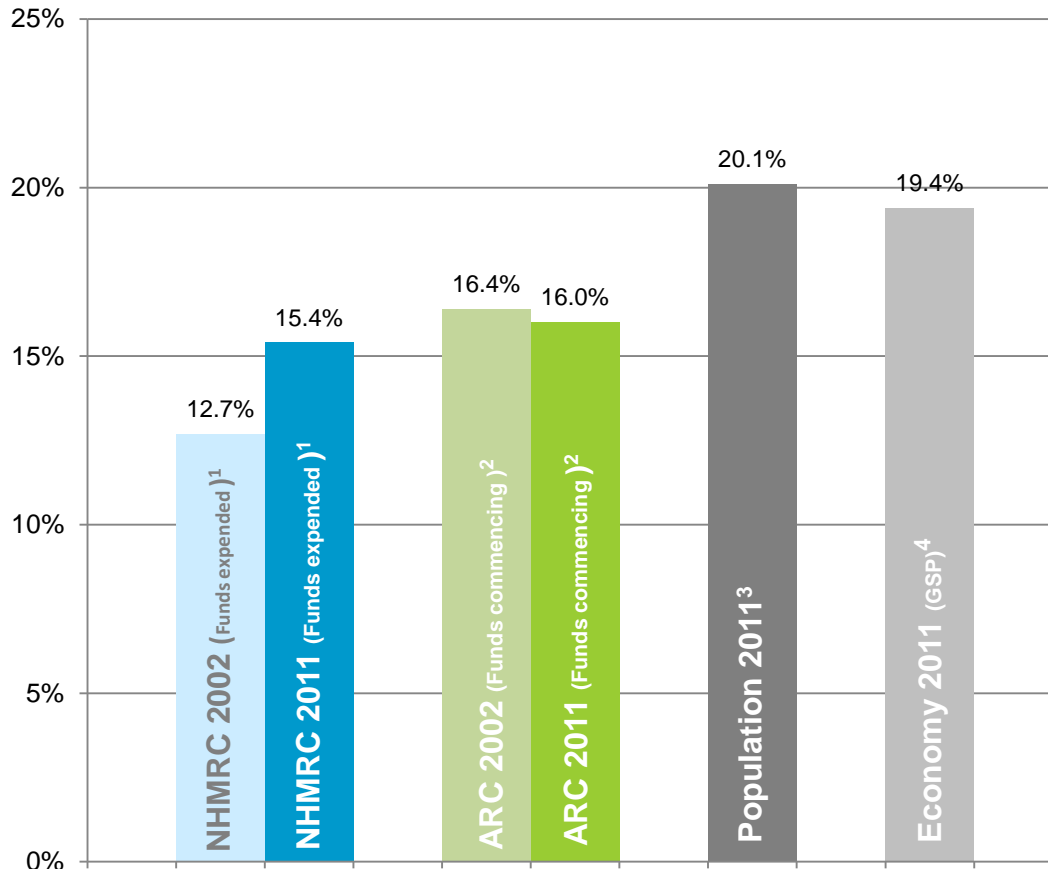
Investment and infrastructure: Observations and recommendations

- Gross Expenditure on R&D as a proportion of GDP or GSP ('R&D intensity') is a proxy measure of investment in science, and commitment to innovation. Queensland's investments have grown, but our overall R&D intensity is low by national and international standards.
- We should aim to match or exceed the national average of R&D intensity by 2025. Business, industry and government all have a strong role to play to see this come to fruition.
- Strong growth in our scientific output and STEM workforce and the establishment of world-class research infrastructure - particularly in the biological and medical research fields – has resulted from significant investment made over the past decade.
- We should now work to ensure we attract and retain talented people to fully leverage the infrastructure investment. Talent is generally attracted where there is funding predictability and continuity.
- We must also build and develop our strength in other targeted and niche areas – in line with Queensland Government priorities – to ensure an evolving and diversified research portfolio.
- Queensland Government investment in R&D has an impressive capacity to act as a catalyst and leverage additional substantial funding from other sources. However this has decreased 2011-12 (\$1.12 per \$1.00 spent in 2012-13 compared to \$1.74 per \$1.00 in 2011-12). Targeted state investment should continue to be fully leveraged from commonwealth, business and philanthropic sources.
- Concerning, the total estimated Queensland Government investment (including leveraged funds) for 2012-13 appears to be more than 30 per cent down on the previous year.
- When compared to other states and territories, R&D in higher education in Queensland has a relatively lower emphasis on pure basic research and a greater emphasis on applied research, consistent with the government's emphasis on 'practical and applied scientific and technology capability'.
- While business expenditure on R&D in the state has increased substantially over the past two decades, as a percentage of GSP/GDP, it remains well below the Australian average and most OECD nations. Policy interventions to support business growing its R&D investment require due consideration.

Performance

Commonwealth competitive grants

Queensland's share of the national total



- The Australian Research Council (ARC) and National Health & Medical Research Council (NHMRC) are major research funding agencies of the commonwealth.
- The ARC supports research in all fields of science, social sciences and the humanities, with the exception of clinical medicine and dentistry. The NHMRC funds research in the health and medical sphere.
- Queensland researchers received 15.4 per cent of NHMRC funding in 2011 (\$116.2 million), which is a modest increase on our position 10 years ago¹.
- Queensland researchers have a 16 per cent share (or approximately \$153 million) of ARC funding commencing in 2011. This is below our share of the population and economy as well as the proportion won a decade ago². However, Queensland did secure 20 per cent of ARC Linkage grants in 2012.

Sources: 1. NHMRC <http://www.nhmrc.gov.au/grants/research-funding-statistics-and-data/funding-datasets>; 2. ARC http://www.arc.gov.au/general/searchable_data.htm; 3. ABS Australian Demographic Statistics, Sep 2012 , Cat # 3101.0; 4. ABS Australian National Accounts: State Accounts, 2011-12 Cat # 5220.0

Queensland university research performance

		RESEARCH DISCIPLINE										
ERA 2012 ¹		Mathematic Sciences	Physical Sciences	Chemical Sciences	Earth Sciences	Environment Sciences	Biological Sciences	Agricultural & Veterinary Sciences	Information & Computer Sciences	Engineering	Technology	Medical & Health Sciences
QUEENSLAND UNIVERSITY	Bond University								2			4
	Central Queensland University	5				2	1	5	2	2		3
	Griffith University		3	3	3	3	3	4	3	2		3
	James Cook University	3	3	3	4	5	4	4	2	3		2
	Queensland University of Technology	4	3	3	3	4	3		3	3	3	3
	University of Queensland	4	5	5	3	4	5	4	4	5	5	5
	University of Southern Qld	3	3					3	2	2		2
	University of Sunshine Coast			2			3	4	1			1

Explanation of Ratings
5 = Outstanding performance well above world standard
4 = Performance above world standard
3 = Average performance at world standard
2 = Performance below world standard
1 = Performance well below world standard
Not assessed due to low volume. The number of research outputs doesn't meet volume threshold standard for ERA evaluation.

- The *Excellence in Research for Australia (ERA)* national report compares Australian research quality across disciplines and institutions, relative to the international playing field¹.
- Many of our universities continue to rate at, or above, world standard across a range of STEM-related fields.
- In these areas, The University of Queensland, Queensland University of Technology and James Cook University remain the most consistent Queensland performers.
- Other institutions have strengths in specific areas, e.g. Central Queensland University in mathematical sciences and the University of the Sunshine Coast in agricultural and veterinary sciences.
- ERA does credit other accomplishments, including patents and registered designs, plant-breeders' rights and research commercialisation income, but there is little evidence that assessments have given much weight to such achievements².

Source: 1. Excellence in Research for Australia (ERA) 2012 National Report, available at http://www.arc.gov.au/era/era_2012/outcomes_2012.htm 2. Powering up citations (2014) A. Finkel. *Nature*.

What Queensland science does well

Queensland institutions make significant contributions to the world's store of knowledge – one dimension of this being through peer reviewed publications. The table below shows the ranking of Queensland institutions in three of Nature's Publishing Indices: the Australian Institution Rankings; a dynamic rolling index based on the previous twelve months; and the Asia-Pacific and Global Indices for 2013 which reflect that calendar year. The indices reflect the number of articles contributed to the Nature journals' stable of 18 titles from Australian institutions, Asia-Pacific institutions or globally.

Highlighted below is the top 10 institutions in Australia, and those Queensland institutions outside of the top 10.

The University of Queensland has top ranking, ranked 1st in the Nature Index for Australian Institutions. James Cook University and the QIMR Berghofer Medical Research Institute ranked 9th and 11th respectively in Australia. The difference between the static and dynamic rankings for The University of Queensland suggests that the 2014 Index for the Asia-Pacific will see them improve.

There were eight Queensland-based institutions ranked in the Nature index for Australia institutions, five of which were universities. By contrast, only five Queensland institutions were included in the Asia-Pacific and only one in the Global Top 200.

Institution	Nature Publishing Index Institution rankings – Australia ¹	2013 Nature Publishing Index Asia-Pacific ²	2013 Nature Publishing Index Global Top 200 ³
The University of Queensland	1	16	91
The University of Melbourne	2	8	54
Monash University	3	26	160
Australian National University	4	11	72
The University of Sydney	5	25	154
The University of New South Wales	7	23	138
CSIRO	6	28	162
Macquarie University	8	62	--
James Cook University	9	68	--
University of Adelaide	10	--	--
QIMR-Berghofer Medical Research Institute	11	134	--
Australian Institute of Marine Science	17	199	--
Griffith University	31	--	--
Queensland University of Technology	33	180	--
University of the Sunshine Coast	54	--	--
Great Barrier Reef Marine Park Authority	63	--	--

Sources: 1. Nature (2014) Nature publishing index. Asia-Pacific. Institution rankings for Australia, [, accessed 10 October 2014, 2. Nature \(2014\) Nature Publishing Index Asia-Pacific, \[, 3.\]\(http://www.natureasia.com/en/publishing-index/pdf/NPI2013_Asia-Pacific.pdf#page=50\)](http://www.natureasia.com/en/publishing-index/asia-pacific/institution-by-country/Australia)

Our core areas of research

SUBJECT AREA	World		Australia			Queensland			China			USA			EU13			Asia10		
	total	% of world peer reviewed papers	total	% of world peer reviewed	% of Australia peer reviewed	total	% of world peer reviewed	% of Queensland peer reviewed	total	% of world peer reviewed	% of China peer reviewed	total	% of world peer reviewed	% of USA peer reviewed	total	% of world peer reviewed	% of EU13 peer reviewed	total	% of world peer reviewed	% of Asia10 peer reviewed
Agricultural and Biological Sciences	1,414,025	7.2%	61,618	4.4%	11.9%	15,640	1.1%	16.7%	129,287	9.1%	5.1%	348,202	24.6%	7.1%	385,305	27.2%	7.5%	317,380	22.4%	6.4%
Biochemistry, Genetics and Molecular Biology	2,348,540	11.9%	64,473	2.7%	12.4%	13,328	0.6%	14.2%	229,200	9.8%	9.0%	748,437	31.9%	15.4%	719,651	30.6%	14.0%	581,878	24.8%	11.7%
Chemical Engineering	840,663	4.3%	14,740	1.8%	2.8%	2,725	0.3%	2.9%	151,116	18.0%	5.9%	162,403	19.3%	3.3%	176,353	21.0%	3.4%	285,874	34.0%	5.8%
Chemistry	1,570,192	7.9%	26,845	1.7%	5.2%	5,328	0.3%	5.7%	276,319	17.6%	10.8%	296,350	18.9%	6.1%	393,885	25.1%	7.7%	564,240	35.9%	11.4%
Computer Science	2,048,374	10.4%	51,473	2.5%	9.9%	7,803	0.4%	8.3%	426,454	20.8%	16.7%	421,424	20.6%	8.7%	510,749	24.9%	9.9%	711,794	34.7%	14.3%
Earth and Planetary Sciences	886,527	4.5%	36,894	4.2%	7.1%	5,582	0.6%	6.0%	140,129	15.8%	5.5%	255,202	28.8%	5.2%	280,155	31.6%	5.4%	223,004	25.2%	4.5%
Engineering	3,983,435	20.2%	69,252	1.7%	13.3%	10,631	0.3%	11.4%	894,596	22.5%	35.0%	850,735	21.4%	17.5%	795,306	20.0%	15.5%	1,463,352	36.7%	29.4%
Environmental Science	877,295	4.4%	34,849	4.0%	6.7%	8,491	1.0%	9.1%	100,760	11.5%	3.9%	231,942	26.4%	4.8%	239,276	27.3%	4.7%	196,309	22.4%	3.9%
Materials Science	1,771,213	9.0%	29,717	1.7%	5.7%	4,897	0.3%	5.2%	375,741	21.2%	14.7%	303,604	17.1%	6.2%	401,518	22.7%	7.8%	715,266	40.4%	14.4%
Mathematics	1,151,878	5.8%	27,485	2.4%	5.3%	3,791	0.3%	4.0%	187,278	16.3%	7.3%	252,559	21.9%	5.2%	349,679	30.4%	6.8%	324,253	28.1%	6.5%
Medicine	4,873,260	24.7%	144,413	3.0%	27.8%	26,252	0.5%	28.0%	332,416	6.8%	13.0%	1,323,487	27.2%	27.2%	1,413,604	29.0%	27.5%	777,970	16.0%	15.7%
Physics and Astronomy	2,419,147	12.2%	44,687	1.8%	8.6%	5,549	0.2%	5.9%	388,705	16.1%	15.2%	568,630	23.5%	11.7%	725,996	30.0%	14.1%	816,242	33.7%	16.4%
Social Sciences	1,268,010	6.4%	51,280	4.0%	9.9%	9,079	0.7%	9.7%	57,865	4.6%	2.3%	399,517	31.5%	8.2%	321,635	25.4%	6.3%	122,453	9.7%	2.5%

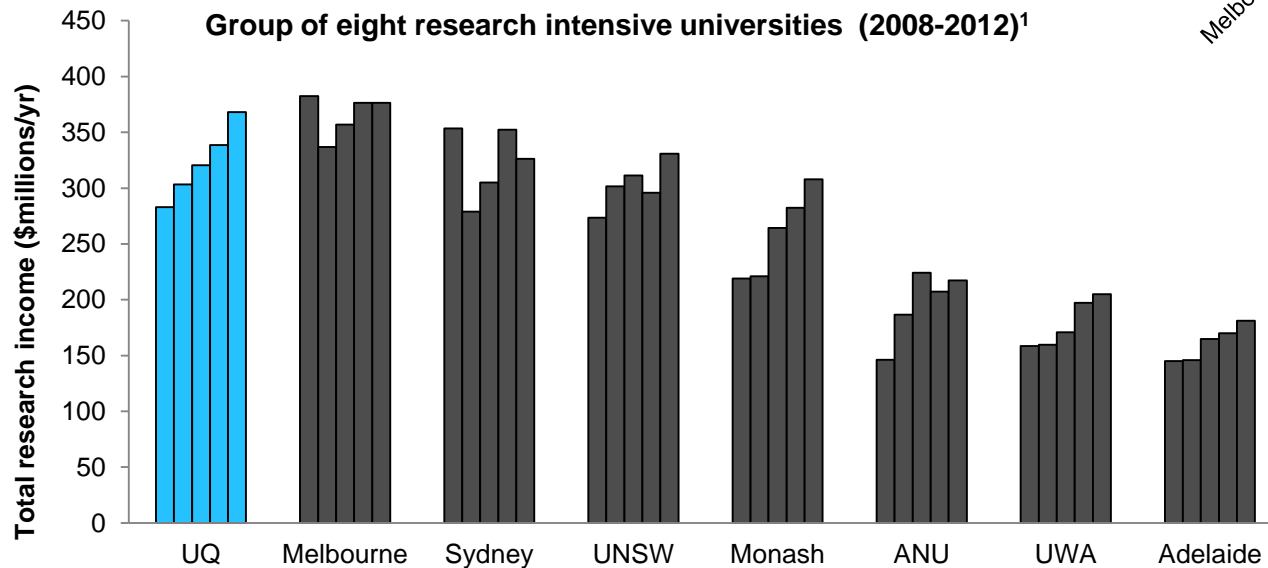
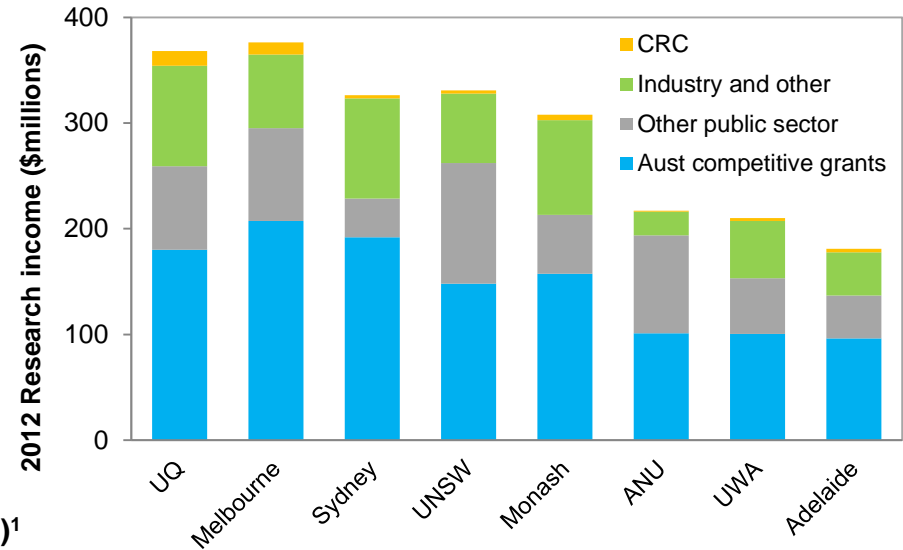
- Medicine is the area with the highest rate of publications for Queensland. This is also mirrored across the world and in the USA and the EU13.
- Queensland's rate of publication in Medicine is 18 per cent of Australia's total contribution in this area and only 2 per cent of the USA. Queensland's next core research publication areas are Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology and Engineering.
- Australia's core research areas after Medicine are Engineering followed by Biochemistry, Genetics and Molecular Biology followed by Agricultural and Biological Sciences.
- In comparison China's highest contribution to publications is in the Engineering area followed by Computer Science and Physics and Astronomy.
- While Asia 10 has its highest publication rate in Engineering, over 61 per cent of publications in this area are from China.

EU13 is represented by: United Kingdom, Germany, France, Netherlands, Switzerland, Sweden, Belgium, Austria, Denmark, Finland, Norway, Ireland and Italy.
Asia10 is represented by: China, Japan, India, South Korea, Singapore, Malaysia, Thailand, Indonesia, Vietnam, Philippines

Source: SCOPUS <http://www.scopus.com> articles, reviews and conference papers published between 2002 and 2012

Group of Eight research income

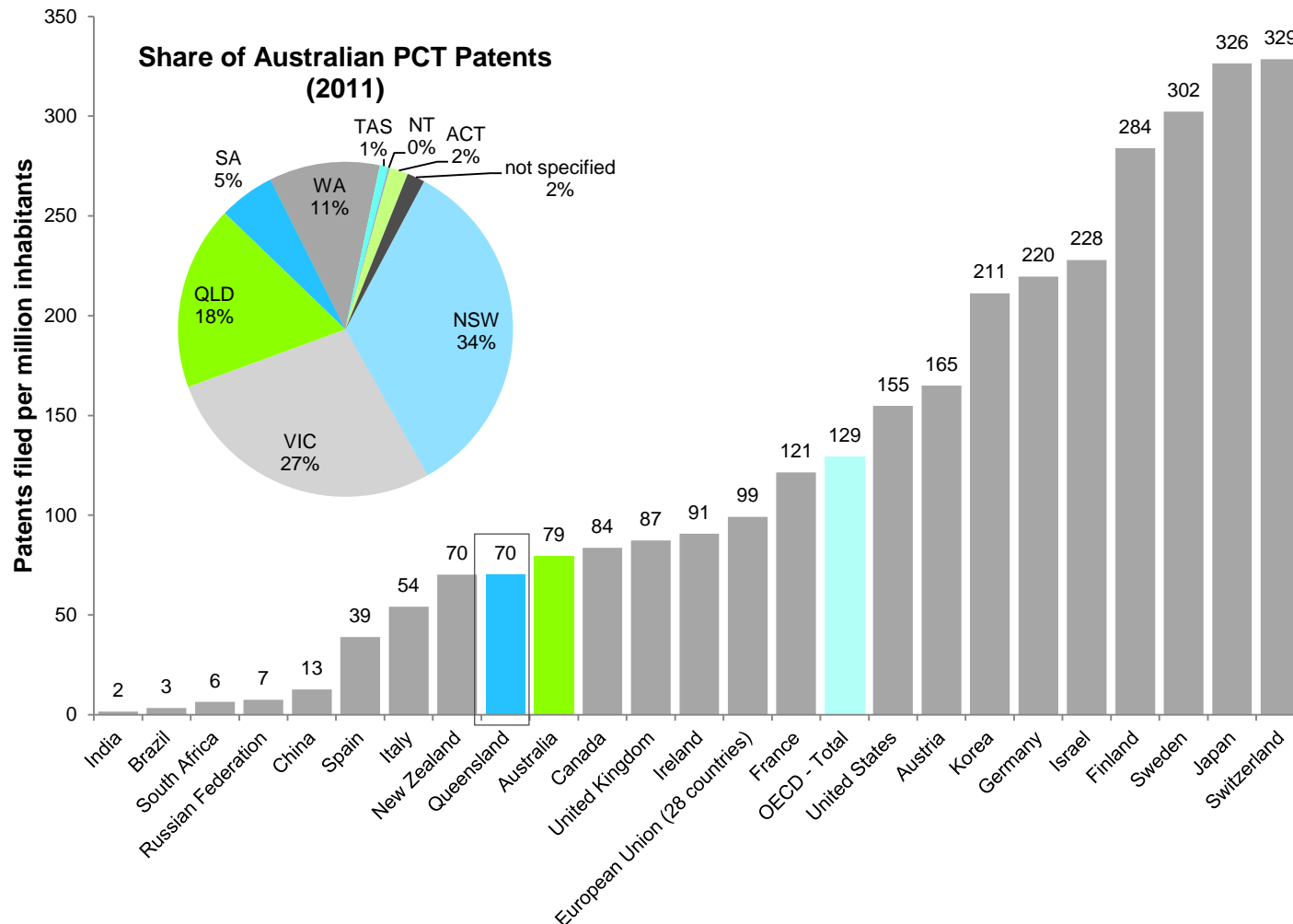
- Total research income from The University of Queensland (a 'Group of Eight Research Intensive University') has been growing steadily in recent years.
- In 2012, the total research income from The University of Queensland was comparable to that of the University of Melbourne and greater than all other Group of Eight universities.
- In 2012, the majority of research income was sourced from Australian competitive grants.²



Sources: 1, Group of Eight (2013)
<http://www.mis.admin.uq.edu.au/Content/Dashboards/GroupofEightExecutiveDashboard/Research.aspx> ; 2
 Australian Government (2013), 2012 Research income and publications data by sub category. Department of Education
<http://docs.education.gov.au/documents/2012-research-income-and-publications-data-sub-category>

Patenting performance

Patents filed under the Patent Cooperation Treaty 2011 ^{1,2}



- Patenting performance provides a partial measure of the potential for research to be translated into commercial and practical benefit.
- There is a very broad range of patenting performance per head of population, ranging from India at 2 applications per million people to Switzerland with almost 330.
- Queensland is a relatively poor performer with 70 applications (under the Patent Co-Operation Treaty) per million population – slightly below the Australian average (79 per million) but just over half that of the OECD (129 per million) average^{1,2}.
- The most active nations in this measure file more than 300 patents per million of population^{1,2}.

Sources: 1. OECD Patents Statistics (Patents by regions); 2. OECD, Demography and Population Statistics (Population)

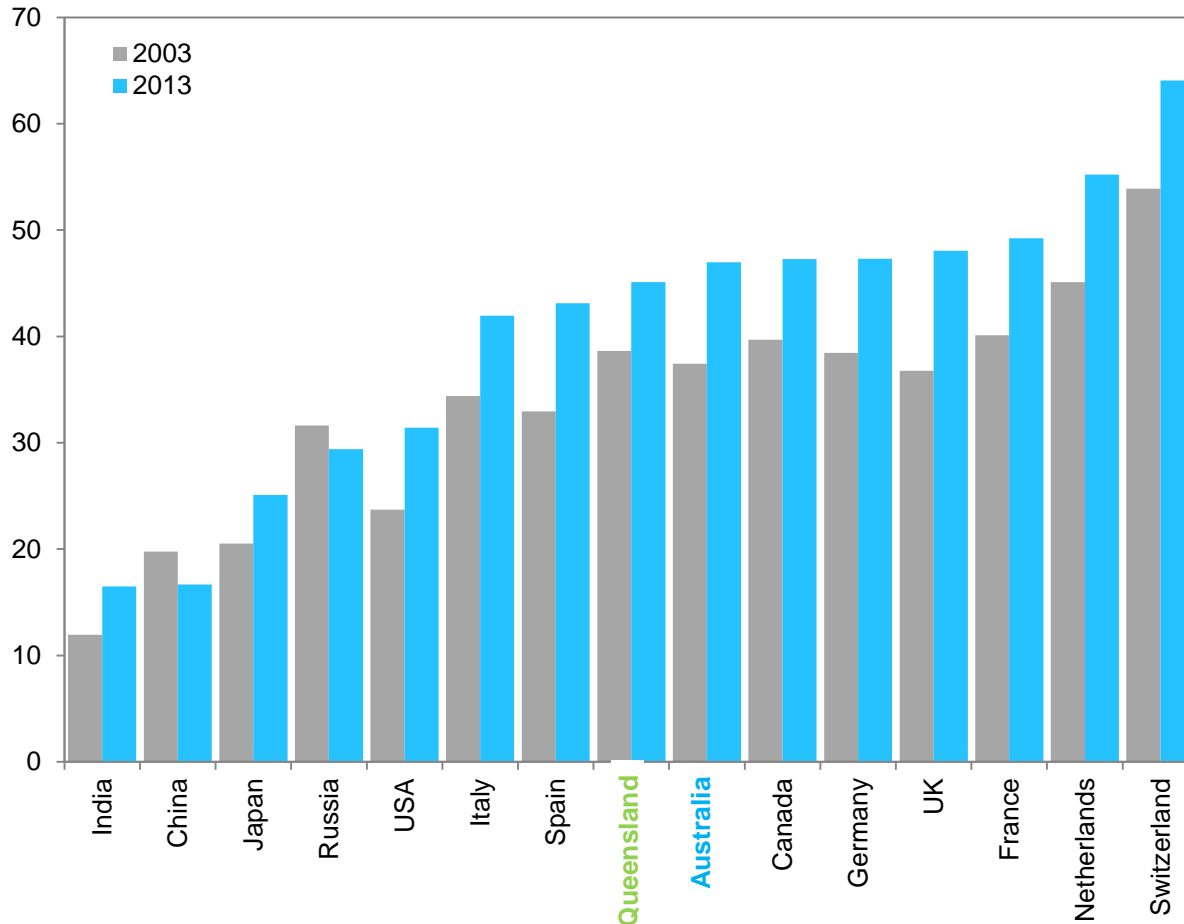
Performance: Observations and recommendations

- The share of funding won by Queensland-based researchers from commonwealth sources such as the major funding councils (NHMRC and ARC) is below Queensland's share of the economy and population. We should aim to increase our share of funding from the NHMRC, ARC and other commonwealth schemes to at least our population share (20 per cent) by 2025.
- Effective translation of research knowledge – for both economic and social benefit – is vital. One measure of translation, the level of patent filings, suggests room for improvement with our patent filing rate per head of population just over half the OECD average and well behind front runners Finland, Japan and Switzerland. We must increase our focus on realising and applying academic research findings. One approach is to engage end users as active partners from the very beginning of the process – not just at the end. The Queensland Government Accelerate Partnerships program is a good example of how government can encourage this type of research philosophy.
- Queensland has significant strength in the life sciences, chemistry and environmental sciences and our university and research institutions are highly valued on the world stage.
- We have built significant strength in the area of medicine and this aligns well with the USA and Europe. In future planning, areas such as computing science and engineering should be kept front of mind as they align strongly with some of our strongest collaborators such as China.
- When assessing our universities, it is not just publications that should be considered. In the world of collaboration and translation, research income will be valued as highly, if not more. Queensland has one of the top performers in the Group of Eight in terms of total research income for 2013.
- The importance of measuring our research impact and engagement will be valuable in getting greater value from our research and translating the research into great outcomes. Queensland has some great success stories but we need more.

Collaboration and translation

International research collaboration

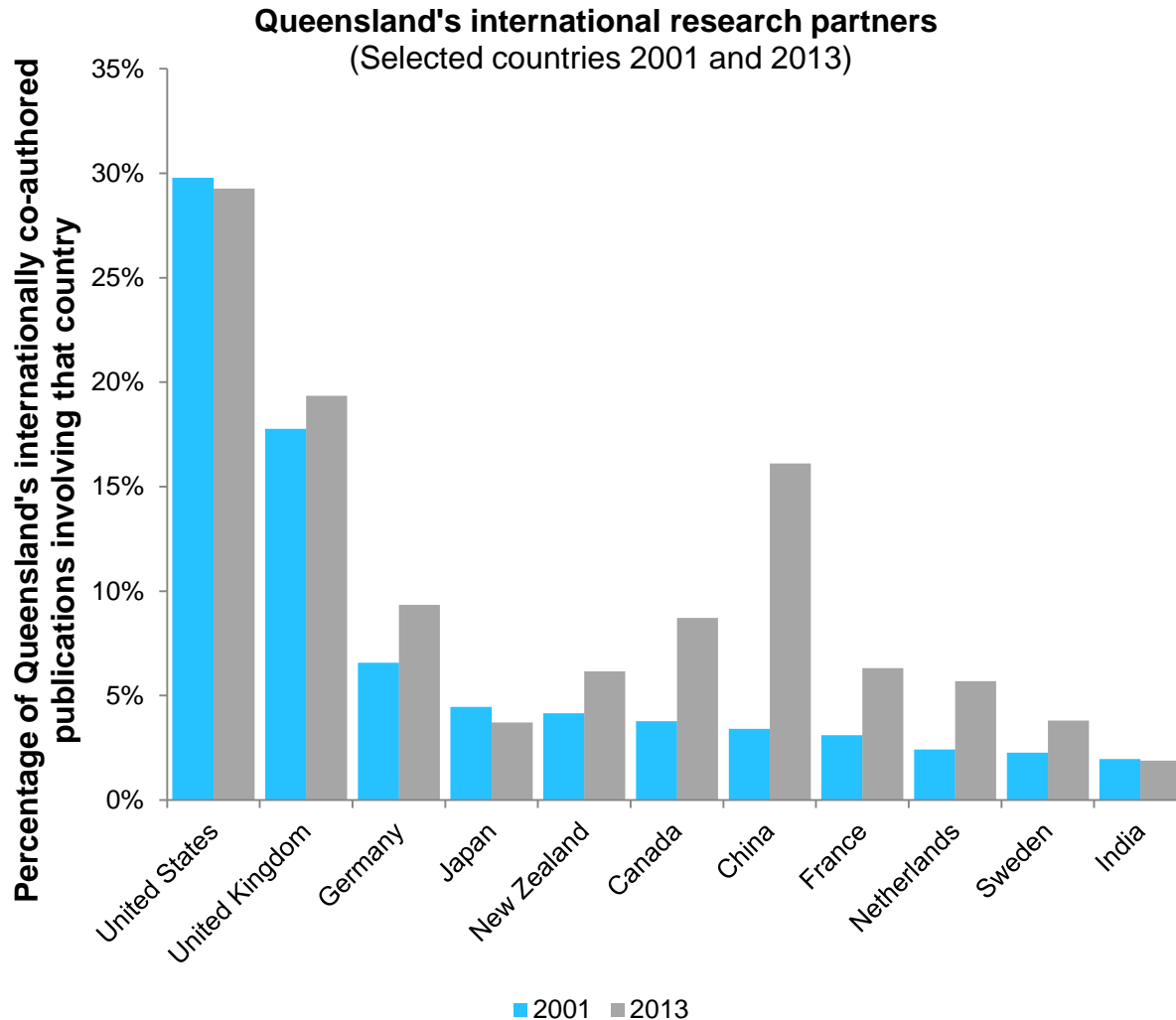
**International Research Collaboration
(selected countries, 2003 and 2013)**



- A highly collaborative research sector is a sign of a healthy research sector that is working and learning from the best. Collaborations also allow us to tap into other's expertise and leverage from their resources.
- In 2013, 46 per cent of publications with a Queensland affiliation also had an author or collaborative institution from overseas¹.
- That figure is similar to the Australian average, but a significant increase on Queensland's position in 2001, when it was just under 27 per cent. This reflects not only a recognition of the critical importance of connection and collaboration in research, but also greater capability by Queensland researchers to engage internationally as a result of long-term investment and the cultivation of strategic relationships.
- Countries engage in international collaborations where the effort is outweighed by the additional benefits generated. The greater domestic research 'market' of countries like the USA, India and China, means there is less need to go abroad for key capabilities, which is reflected in their lower rates of international collaboration.

Source: Analysis of the Scopus (Elsevier) database of publications and SCImago Journal and Country Rank

Trends in international research partners



- The pattern of Queensland's collaborations is shifting as researchers identify and link with established and emerging research partners with complementary expertise, capability and resources.
- Our links with the USA continue to be strong, reflecting that country's pre-eminent R&D position. However, collaborations with China have been increasing almost exponentially since 2001.
- China currently invests around 60 per cent of the US total in research but by 2022, thanks to its continued strong economic growth, is expected to be the world's largest funder of R&D². China is actively seeking international partners to collaborate on issues such as water supply, energy and agricultural productivity.
- In 2008, Queensland signed formal agreements with the Chinese Academy of Sciences and China's Ministry of Science and Technology, underpinned by a targeted joint funding program which has helped profile Queensland as a research partner for China.

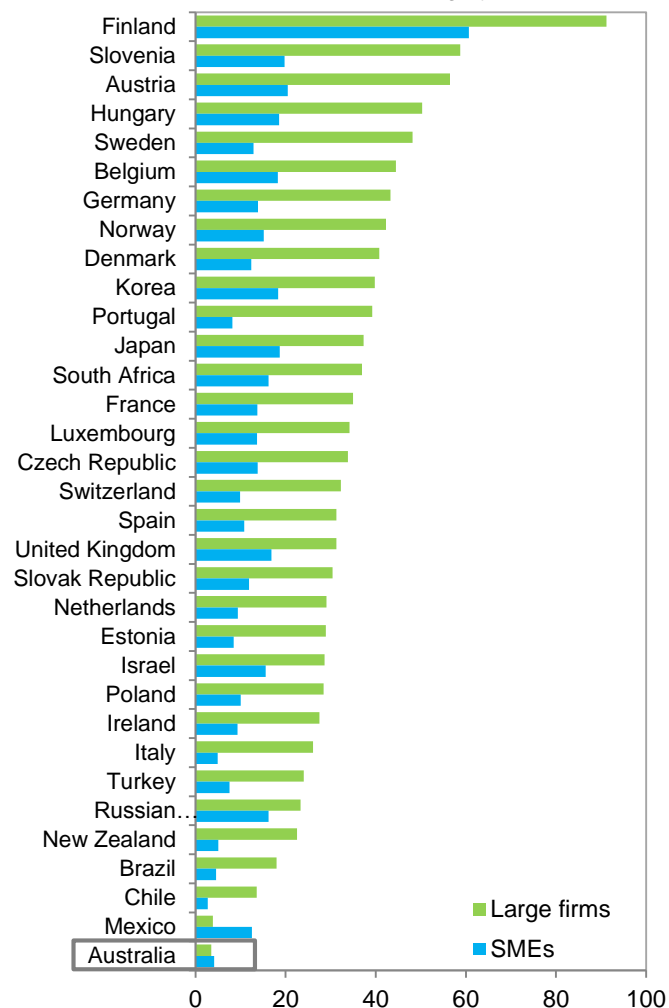
Note: The graph shows the percentage of Queensland international publications with the selected countries, e.g. in 2001 3.4% of Queensland internationally co-authored publications involved a Chinese co-author compared to 16% in 2013. As publications can involve more than one international partner, the total percentage exceeds 100%.

Source: 1. Analysis of the Scopus (Elsevier) database of publications. 2. 2014 Global R&D Funding Forecast, www.battelle.org

Firms collaborating on innovation

Firms collaborating on innovation with higher education or public research institutions, by firm size²

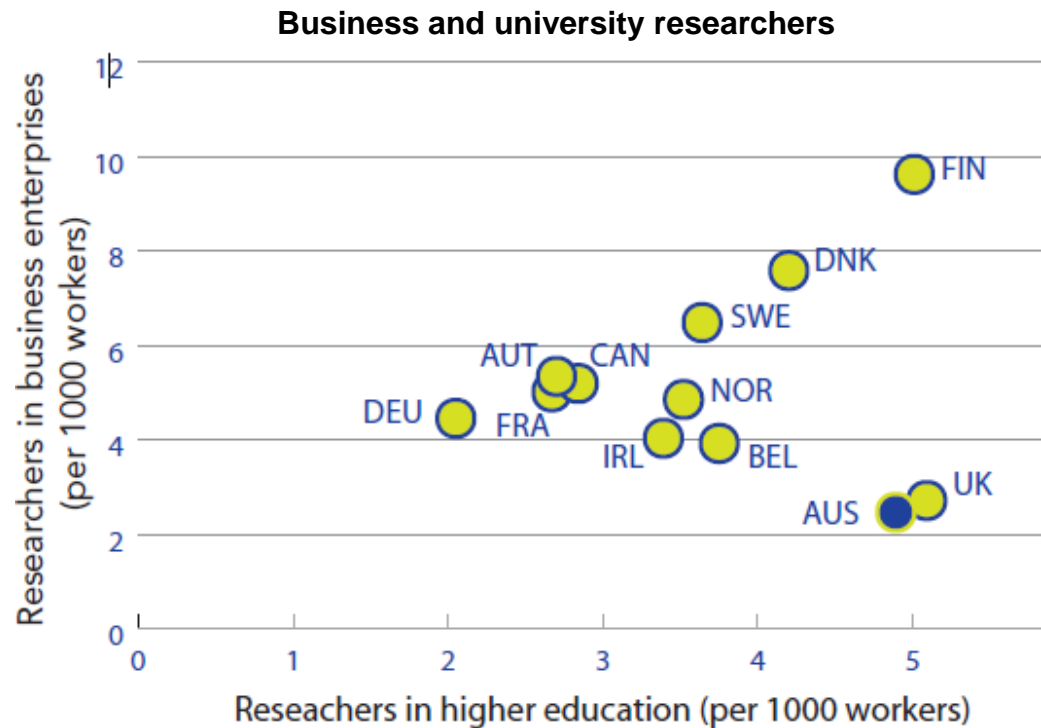
As a percentage of product and/or process innovative firms in each size category



- While it is clear Queensland has a very solid, and reasonably collaborative, science research base, Australia and Queensland have performed considerably less well in translating that research into commercial and social benefits.
- In 2012-13, 9.7 per cent of innovation-active businesses had a collaborative arrangement with universities or other higher education institutions; up from 4.6 per cent recorded in 2010-11.¹
- In an OECD ranking, Australia ranked 33rd - last - for innovation-active firms collaborating on innovation with universities and public funded research agencies.²

Sources: 1. ABS, Innovation in Australian Business, 2010-11, Cat # 8158.0; 2. OECD Science, Technology and Industry Scorecard 2013 http://dx.doi.org/10.1787/sti_scoreboard-2013-en

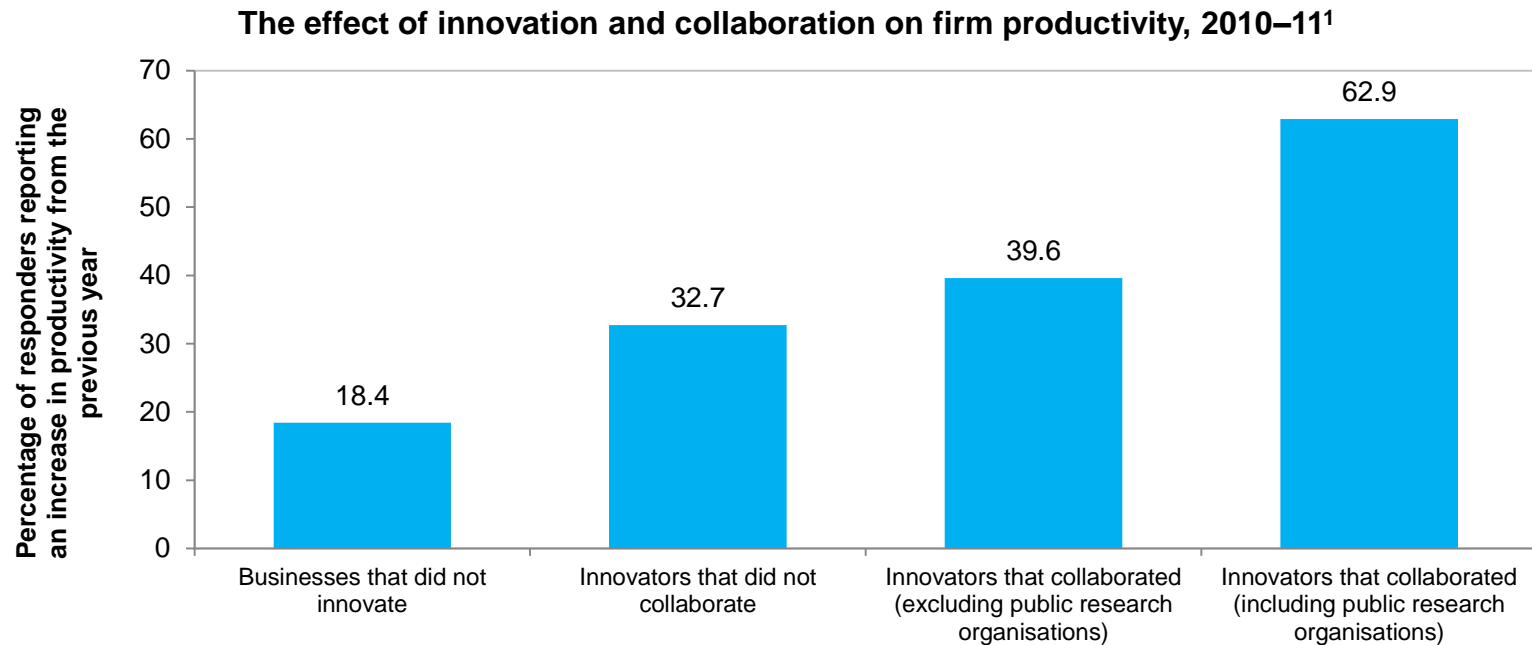
Business-research collaboration



- Compared to other OECD countries, Australia's researchers are much more concentrated in the university sector.
- There are almost 2.5 times as many researchers in the university sector than the business sector (about five and two researchers per 1000 workers, respectively).
- In some countries (such as Finland and Denmark), the ratio is nearly reversed with twice as many researchers in business.
- This has significant implications for cross sector communication and collaboration.

Source: Pettigrew A.G. (2012) 'Australia's Position in the World of Science, Technology and Innovation', Occasional paper series, Issue 2, Office of the Australian Chief Scientist, Canberra

Collaboration and innovation



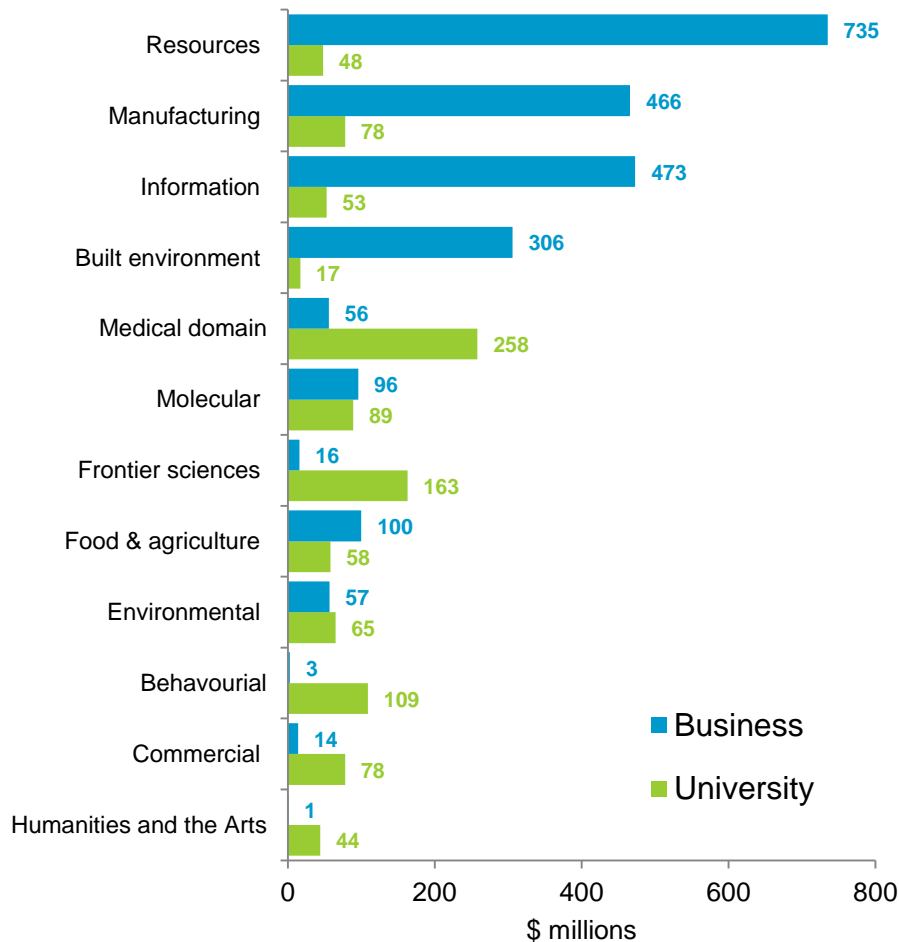
Source: DIISRTE Custom data request from the ABS (2012) *Innovation in Australian Business 2010–11*, cat. no. 8158.0

There are compounding productivity benefits accruing to businesses that pursue a culture of both innovation and collaboration. This is the case for most of the business performance measures.

Individually, innovation and collaboration can increase productivity for organisations. But together their impact is synergistic.

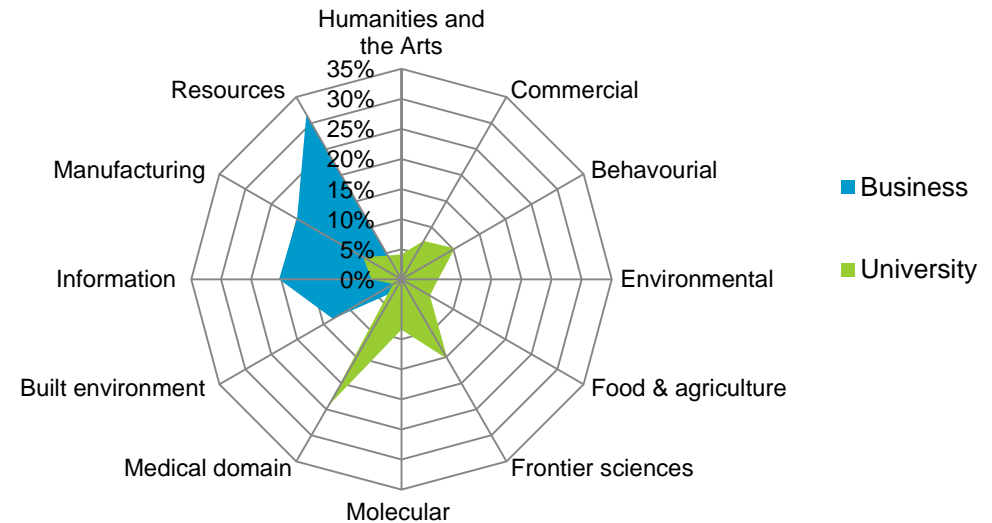
Alignment of business and university R&D

Business and university R&D spend (\$)²



Business and university R&D spend (%)²

(% of total spending by domain)



- Together, the business and university sectors account for nearly 90 per cent of Queensland R&D activity¹.
- The areas into which business and university contribute R&D investment are very different².
- HERD is focussed on medical, frontier and behavioural R&D domains², while most BERD is expended in the resources, manufacturing and information R&D domains.

Sources: 1. ABS, Research and Experimental Development, All Sector Summary, Australia, 2008-09 Cat # 81120; 2. Australian Research: Strategies for Turbulent Times (2011), Dr Thomas Barlow

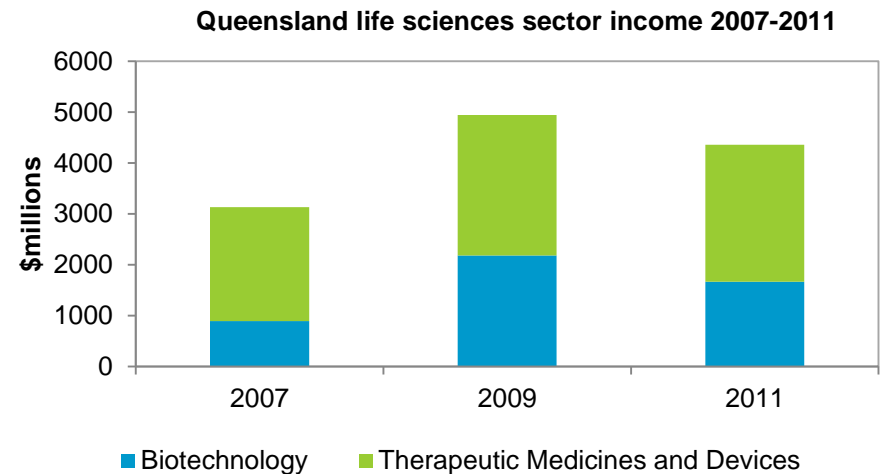
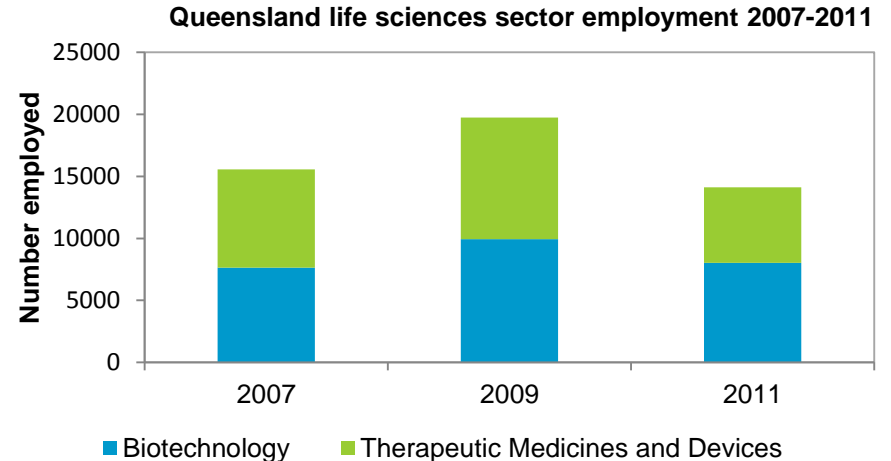
Queensland Life Sciences Industry

The Life Sciences sector and associated industry have grown significantly in Queensland over the past decade, mirroring the major 'Smart State' investment made in this area. In 2011, Queensland was home to 7.8 per cent of ASX-listed Life Sciences companies.

In 2011, it was estimated that the sector:

- employed at least 14,000 in 301 private companies and research organisations
- generated \$4.36 billion in income
- pumped over \$2.1 billion in wages and salaries to the Queensland economy
- invested \$657 million in R&D and made another \$692 million in capital expenditure.

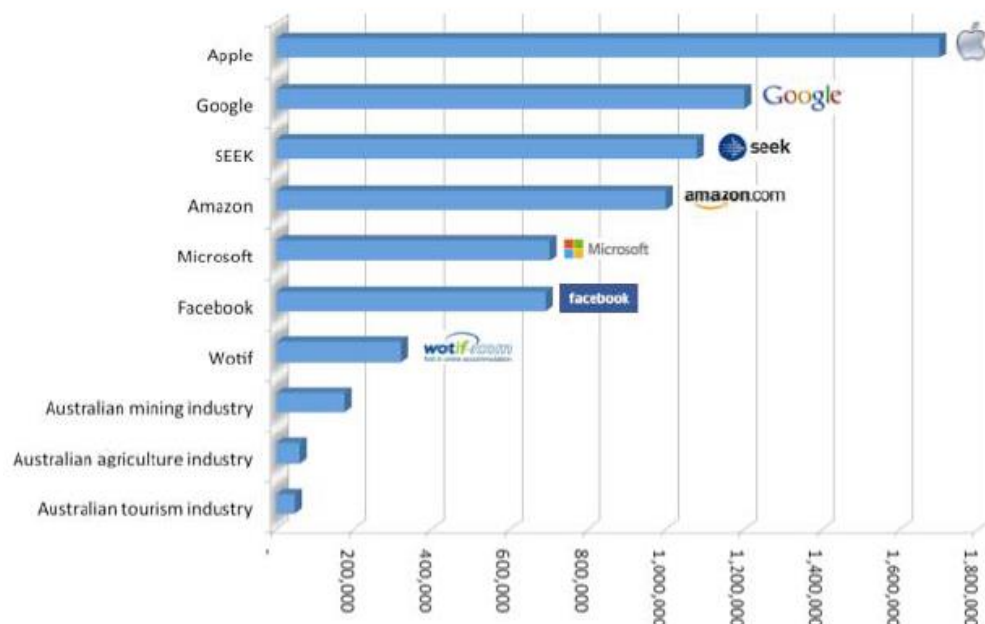
However, challenges remain and further effort will be needed to cement these gains and ensure the Queensland Life Sciences sector remains a vibrant and significant component of the state economy in the future. For example, the Queensland Life Sciences Industry Report 2012 indicated that between 2009 to 2011 there was a 28.5 per cent reduction in employment and 11.8 per cent reduction in income. The 2014 report is currently in preparation.



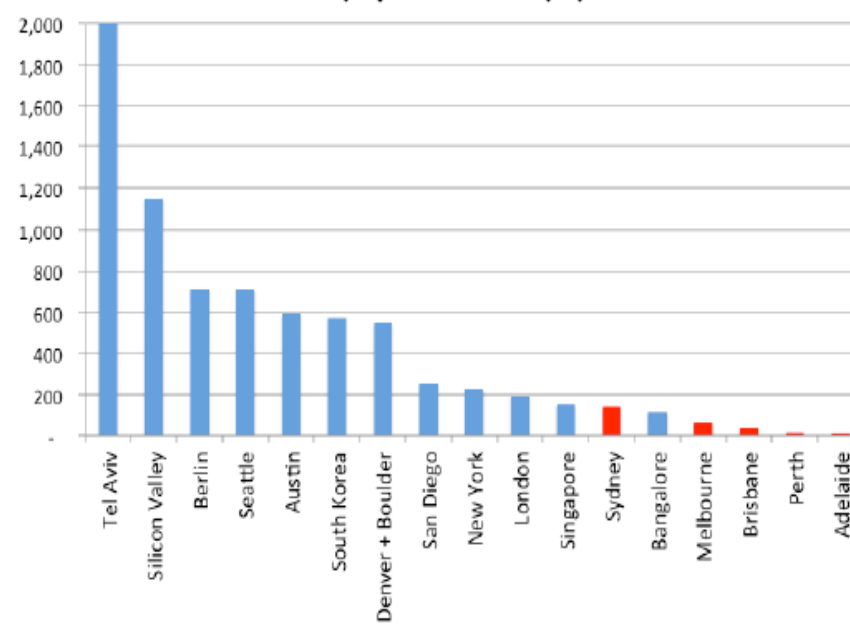
Source: Queensland Life Sciences Industry Report 2012 (available at <http://www.qld.gov.au/dsitia/assets/documents/qld-life-sciences-industry-report-2012.pdf>)

Technology companies and jobs

Revenue per employee



Tech startups per million of population



Technology-based companies are consistently able to generate jobs with much higher labour productivity (revenue per employee) than any other sector¹.

There are 1,000 tech startups in Australia, or 0.047 per cent of all Australian businesses. As can be seen in the figure above, Australia has a relatively low rate of tech startup formation in a global context².

Australia has four startup ecosystems - Sydney being the biggest, 55 per cent larger than Melbourne, six times bigger than Brisbane and nearly eight times the size of the Perth ecosystem. Adelaide, Hobart and Canberra cannot yet be considered as startup ecosystems as they don't show the requisite startup activity².

Source: 1. Kinner, C. (2014) Crossroads - An action plan to develop a vibrant tech startup ecosystem in Australia. Startup AUS April 2014 <http://startupaus.org/crossroads/>; 2. Morle, P., Kitschke, Z., Jone, A., and Tanchel, J. (2012) Silicon Beach - building momentum. A study of the Australian startup ecosystem. Deloitte Touche Tohmatsu <http://www.deloitte.com/au/siliconbeach>

Collaboration and translation: Observations and recommendations

- Innovative ideas need a vibrant and collaborative research sector with the right people, infrastructure and funding to flourish. We need to collaborate - across countries, subjects and sectors – to address future challenges and maximise our investments.
- Queensland has a relatively strong and growing international collaborative base in academic research - and our links with China, the world's second research power, are increasing rapidly. Queensland's formal agreement with China's Ministry of Science and Technology and targeted joint funding program has helped foster research links - ongoing resources will be needed to maintain and grow this relationship.
- Queensland's scientific output - as measured by publications - more than trebled between 2001 and 2013, to almost 13,600 articles and items. Our share of Australia's scientific output has risen to 19 per cent - within striking distance of the 20 per cent suggested in the 2012 version of *Health of Queensland Science*.
- To benefit all Queenslanders we need to nurture our research and innovation capacity in all sectors right across the state and not solely focused on South East Queensland.
- With the substantial investment made in health and biomedical research in the state over the past decade, developing a vibrant parallel commercial life sciences sector is a priority and a test of our ability to translate the government investment in science.
- The R&D spending priorities of business and university differ greatly. While it is not expected nor desirable for these sectors to be fully aligned, we need a greater understanding between the two groups to improve communication, collaboration and research translation.
- Mechanisms for promoting entrepreneurship amongst researchers and increasing their mobility across sectors should be a priority.
- One of the four key action areas under the Government's Science and Innovation Action Plan (SIAP) is to collaborate and share knowledge. SIAP provides a cohesive and clear framework to focus government effort and deliver economic benefits for Queensland.

