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Economic Impact of Medical Research in Australia

A report prepared for the Association of Australian Medical Research Institutes

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Glossary

AAMRI	Association of Australian Medical Research Institutes
ABS	Australian Bureau of Statistics
AIATSIS	Australian Institute of Aboriginal and Torres Strait Islander Studies
AIDS	Acquired Immunodeficiency Syndrome
AIWH	Australian Institute of Health and Welfare
ARC	Australian Research Council
ASRC	Australian Standard Research Classification
ATO	Australian Taxation Office
BCR	Benefit-Cost Ratio
BTF	Biomedical Translation Fund
CBA	Cost-Benefit Analysis
CGE	Computable General Equilibrium
CRC	Cooperative Research Centres
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DALY	Disability Adjusted Life Years
FTE	Full-time Equivalent
FDA	US Food and Drug Administration
EPPIC	Early Psychosis Prevention & Intervention Centre
GBD	Global Burden of Disease
GDP	Gross Domestic Product
HHF	Health and Hospital Fund
HIV	Human Immunodeficiency Virus
HPV	Human Papillomavirus
LFS	Labour Force Survey
MHRIF	Medical and Health Research Infrastructure Fund

MRFF	Medical Research Future Fund
MRSP	Medical Research Support Program
MRI	Medical Research Institute
NHMRC	National Health and Medical Research Council
NISA	National Innovation and Science Agenda
NSRC	National Survey of Research Commercialisation
OIC	Operational Infrastructure Support
PSTS	Professional, Scientific and Technical Services
ROI	Return on Investment
RTP	Research Translation Projects
SRS	Scientific Research Services
SSRI	Selective Serotonin Reuptake Inhibitors
START	Strategic Timing of Antiretroviral Therapy
UNSW	University of New South Wales
QALY	Quality Adjusted Life Years
WHO	World Health Organisation

Definitions

Commonwealth Government	The Australian Federal Government
State Government	A State or Territory Government in Australia
Sector	Any large segment of the economy comprising a few industries and that can be grouped together and be distinct from others.
Medical Research Sector	Comprised of medical researchers from relevant University Departments, Medical Research Institutes (MRIs), hospitals, and other medical research organisations undertaking and supporting medical research in Australia. For the purposes of this report, the medical research sector also includes the Medical Technology and Pharmaceutical (MTP) sector.
Medical Technology and Pharmaceutical (MTP) Sector	Represents and supports the development of innovative medical technology, biotechnology and pharmaceutical products. The MTP sector is comprised of companies and industry organisations that support the research and development, production and wholesale of medical technologies, devices and pharmaceutical goods as well as related services. The MTP sector is defined as employing Australian businesses classified within the following ANZSIC Classes[1]: • Pharmaceutical and Medicinal Product manufacturing • Professional and Scientific Equipment Manufacturing • Other Machinery and Equipment Wholesaling • Pharmaceutical and Toiletry Goods Wholesaling
Government sector	Comprises all government department and authorities of the Commonwealth government, each State/Territory government, and all local government authorities.
Higher Education sector	Comprises universities and other higher education institutions including TAFE.
Not-for-profit sector	Any type of organisation that does not earn profits for its owners. All of the money earned by or donated to a not-for-profit organisation is used in pursuing the organisation's objectives and keeping it running.
Industry	Any general business activity or commercial enterprise that can be isolated from others. Under the Professional, Scientific and Technical Services industry, the Scientific Research Services industry includes Medical Research Institutes (MRIs) that support medical research in Australia.
Industry-by-Occupation Matrix	Combines two sources of occupation data: the Census and Labour Force Survey (LFS) both of which are produced by the ABS. The census data provides the distribution of occupations across industries, whereas the LFS provides the latest employment totals by industry and occupation.

Research	Refers to "creative and systematic work undertaken in order to increase the stock of knowledge - including knowledge of humankind, culture and society - and to devise new applications of available knowledge" (ABS, 1998).[2]
Medical Research	Refers to theoretical and experimental work undertaken by universities, medical research institutes, hospitals, government agencies and businesses to support a healthy and productive nation.
Private funding on health and medical research	Comprises health and medical research and development spending by Australian businesses. Much of the spending by Australian businesses is on experimental development rather than applied research. Therefore, private expenditure on health and medical research is captured in the broad Socio-economic Objective of Manufacturing rather than Health.
Public funding on health and medical research	Consists of investments on medical research through the National Health and Medical Research Council (NHMRC), Australian Research Council (ARC), the Medical Research Future Fund (MRFF), Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS), Australian Institute of Health and Welfare (AIHW), Commonwealth Scientific and Industrial Research Organisation (CSIRO), and other investments made directly by Government Departments such as the Department of Foreign Affairs and Trade, Commonwealth Department of Health as well as the respective State Governments.

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Executive Summary

Key findings

- Australia's medical research sector makes a significant and long-lasting contribution to the economy through job creation, downstream and upstream linkages with other sectors, and through the creation of knowledge.
- Medical research plays a significant and critical role in improving the health and wellbeing of the population.
- As a direct result of medical research, Australians are remaining healthier for longer due to improved treatments and improved healthcare that results from this research.

Medical research and job creation

- The medical research sector employs around **32,000 people**, with a further **78,000 jobs** within the downstream Medical Technologies and Pharmaceuticals (MTP) sector.
- Medical research jobs are typically high-value, knowledge-based jobs. Medical researchers in the Professional, Scientific and Technical Services (PSTS) sector contribute **$134,000 per FTE**, while those in the Medical Technology and Pharmaceutical (MTP) sectors contribute **$107,000 per FTE**.
- The health gains from medical research also result in a larger and more productive workforce. KPMG estimate that medical research from 1990 to 2004 has resulted in a current workforce **23,000 FTEs** larger than it would have been in the absence of medical research.

The impact of medical research

- Medical research from 1990 to 2004 has delivered net present gains of **$78 billion** from a net present cost of $20 billion, returning a **benefit cost ratio (BCR) of 3.9**.
- A BCR greater than one indicates that the benefits exceed costs over the evaluation period. In cost-benefit analysis in other sectors, a BCR above 2 is considered a high rate of return.
- Of the $78 billion net present gains generated by medical research from 1990 to 2004, **$52 billion** has been delivered in the form of health gains, and **$26 billion** in wider economic gains from a larger and more productive population, and from commercialisation of medical research.
- The health savings from medical research significantly outweigh the cost of delivering them.
- Commercialisation gains estimated by the NSRC has increased from $72 million in 2000 to $627 in 2015, and from 5 per cent to 10 per cent as a proportion of overall medical research expenditure.
- Today's economy, as measured by GDP, is **$2.6 billion larger** as a result of historical medical research.
- Welfare, a measure of how well-off we are as a population, is **$1.5 billion higher** than it would have been in the absence of medical research.

The impact of future medical research

- With an increased focus on translation and commercialisation through the Medical Research Future Fund (MRFF), medical research in the future is expected to continue to deliver excellent returns on investment.

Project Overview

KPMG was commissioned by the Association of Australian Medical Research Institutes (AAMRI) to conduct an analysis of the economic contribution that medical research makes to Australia. In doing so, this report estimates both the direct and indirect returns from medical research, including health gains and health system savings as well as the ability to generate jobs, contribute to Gross Domestic Product (GDP) and enhance productivity of the workforce in Australia.

Background

Medical research plays a significant and critical role in improving the health and wellbeing of all. As a direct result of medical research, people are remaining healthier for longer due to improved treatments and improved healthcare that results from this research.

Given that the Commonwealth Government, on behalf of the Australian taxpayer, is the single largest investor in medical research in Australia, it is critical that the full benefits of this research are understood. Currently, the National Health and Medical Research Council (NHMRC) invests over $800 million per annum in medical research, after strong growth in NHMRC grants from the early 2000s. In 2015 the Commonwealth Government established the Medical Research Future Fund (MRFF), a sovereign wealth fund that, when reaching its target of $20 billion in 2020-21, will invest a further $1 billion per annum into medical research. The intent of the MRFF is to significantly increase funding for translational research that can directly improve health service delivery and clinical practice.

Methodology

KPMG developed a unique hybrid methodology that combined:

- Bottom-up case studies of Human Immunodeficiency Virus (HIV), mental health and Human Papillomavirus (HPV) to better understand the pathway between medical research and population health improvements.
- Top-down analyses of reductions in the burden of disease to help quantify the health gains.
- A bibliographic analysis of Australian guidelines and through consultations with research experts to estimate the share of benefits attributable to Australian medical research, and the associated time lag between expenditure and benefit.
- Economy-wide modelling of the productivity benefits from medical research using KPMG's computable general equilibrium model (KPMG-CGE) of the Australian economy.
- An evaluation of previous literature to ensure the findings from these case studies were also representative of earlier research into diseases such as cardiovascular disease and cancer.

The analysis of existing returns from medical research considered investment from 1990 to 2004, to allow for the lag between historical research and current outcomes, and the findings from the case studies were extrapolated out to wider medical research.

Results

Medical research and job creation

Medical research currently supports 32,000 jobs across a number of industries including the Professional, Scientific and Technical Services (PSTS) sector, which includes Medical Research Institutes (MRIs) and hospitals, and Tertiary Education. The downstream MTP sector which is reliant on medical research, supports another 78,000 jobs.

Table 1: Estimated number of jobs created through medical research

Sector	Estimated number of jobs
Tertiary Education	21,233
Professional, Scientific and Technical Services sector including Medical Research Institutes (MRIs) and hospitals	10,863
Sub-total	***32,096***
Medical Technologies and Pharmaceuticals (MTP)	78,409
Total including MTP	**110,505**

Source: KPMG Estimates, 2018

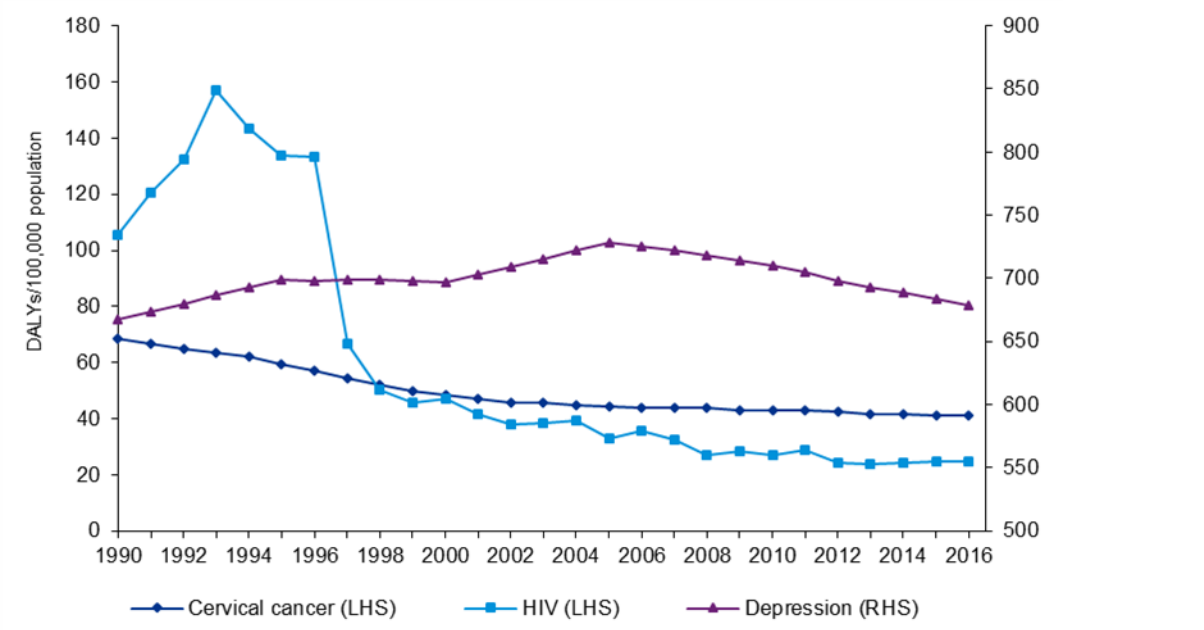
Jobs in medical research are high value, knowledge-based jobs that contribute substantially to the economy. In the PSTS industry, jobs generate $134,000 in value-add per employee; and $107,000 per employee in MTP industries. Value-add per employee provides an indication of the value that workers in each industry contribute to overall GDP.

The health gains from medical research result in a larger and more productive workforce. KPMG estimate that medical research from 1990 to 2004 has resulted in a workforce today that is some 23,000 FTEs larger than it would have been in the absence of medical research.

Medical research and health outcomes

Medical research has delivered substantial population health gains and improved quality of life to people across Australia. In each of the three case studies, there was clear evidence that medical research has reduced the burden of disease. In HIV, the development of antiretroviral drugs and other combinations of pharmaceutical treatments has dramatically reduced the mortality associated with HIV. In HPV, the mortality due to cervical cancer has been significantly reduced by medical research that led to population screening and vaccinations. The morbidity associated with poor mental health has similarly improved from where it would have been in the absence of medical research, through treatments such as selective serotonin reuptake inhibitors and cognitive behavioural therapy. More broadly, medical research has reduced the burden of morbidity and mortality across all diseases.

Figure 1: Historical burden of disease by case study



Source: Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017. Available from http://ghdx.healthdata.org/gbd-results-tool. Accessed 21 July 2018.

Overall, when considering only health gains, medical research from 1990-2004 delivered a BCR of 2.6 and net present value benefits of $52 billion from an investment of $20 billion. Importantly, the above figures consider the costs of delivering treatments to the Australian population (e.g. the cost of antiretroviral drugs for the treatment of HIV), however KPMG find that the health savings from medical research significantly outweigh the cost of delivering them.

Medical research and wider economic outcomes

The health gains from medical research translate into a larger and more productive workforce, which in turn has wider economic flow-on impacts across the economy. KPMG modelled these improvements to the workforce using a detailed Computable General Equilibrium (CGE) model of the Australian economy (KPMG-CGE). The results show that medical research from 1990-2004 has led to GDP today that is $2.6 billion greater than it would have been in the absence of medical research. Welfare, an economic measure that highlights how much better off we are as a population, is $1.5 billion higher than it would have been in the absence of medical research. These benefits are not confined to the medical research or pharmaceuticals sector, but accrue across the economy as all sectors have benefited from a healthier and larger workforce.

Commercialisation gains also accrue as medical research is turned into tangible, market products. KPMG's analysis of the National Survey of Research Commercialisation suggests that medical research commercialisation has increased from $72 million in 2000 to $627 million in 2015, and from 5 to 10 per cent of overall medical research expenditure.

When the wider economic benefits of medical research are combined with the health gains, medical research from 1990-2004 delivered a BCR of 3.9 (with a range of 1.8 to 4.2) and net present value of $78 billion from an investment of $20 billion.

Context of findings and comparison with previous literature

This research found overall BCRs for medical research of between 1.8 and 4.2. A BCR of greater than one indicates that the benefits exceed costs over the evaluation period, while a BCR above 2 is considered high. The findings confirm that investing in medical research to improve the health of the population has high economic returns.

The results are also broadly consistent with previous estimates. Australian research found exceptional returns across the board of returns with BCRs between 2.2 and up to 5.0 across medical research, and up to 6 and 8 for respiratory and cardiovascular disease respectively[3,4].

In the United Kingdom, the internal rate of return from investment for cardiovascular disease and cancer was estimated at 9 and 10 per cent respectively[5]. The results presented here suggest IRRs of around 12 per cent for HPV, rising to 23 and 26 per cent for HIV and mental health respectively. Despite some methodological differences, the findings across various studies and diseases consistently highlight a strong return on investment from medical research.

Strengths and limitations

This report adopted a unique methodology that utilised the strengths of bottom-up and top-down approaches to estimate the economic returns to medical research. In addition, the evaluation of the returns to medical research in HIV and HPV are, to the best of our knowledge, the first attempts across Australia and internationally.

However quantifying the economic benefits of Australian medical research is an inherently difficult task as each step in the methodology required assumptions and judgements. As a result, the findings presented here should be considered as indicative only, and a range of sensitivity analyses are presented to highlight the robustness of the results to changes in assumptions. Specific limitations included:

- The complexity of the causal pathway between expenditure on medical research and accrual of health and economic outcomes, and what would have happened to these outcomes in the absence of Australian medical research.
- The attribution of health gains to medical research and Australian medical research.
- Quantification of the lag time between medical research and outcomes.

The analysis here also assumes that the return on investments delivered by the three case studies are representative of the wider investment in medical research. The return on investment will vary by disease and the methods used to estimate it, however when compared to previous literature, the range of results presented here are broadly representative of diseases as diverse as cardiovascular disease, cancer and mental health.

Medical research in the future

With an increased focus on translation and commercialisation through the Medical Research Future Fund (MRFF), medical research in the future is expected to continue to deliver excellent returns on investment. In the case studies, there are clear examples of how further translation could help to deliver positive returns to medical research. In mental health, research has identified treatments for anti-psychosis that deliver excellent outcomes. Ensuring these are translated into practice would deliver improved population health outcomes and associated health and economic returns. In cervical cancer, new research into HPV vaccines is expected to reduce invasive cervical cancer rates by over 40 per cent from today's already much improved rates.

Projecting into the future with any certainty is difficult, however the historical findings suggest that future expenditure on medical research will continue to deliver a strong return on investment. An increased focus on translation will help to maximise this return.

Conclusion

Medical research is an integral factor in Australia's healthcare system and economy. It continues to progress treatment and prevention initiatives for the population, leaving a positive impact across the economy. As shown in the above three case studies, there are substantial existing economic and health benefits realised from medical research, with an average return on historical investment of $3.90 for every dollar invested.

Medical research is expected to continue to deliver excellent returns on investment into the future, but delivering further health gains to the population will require ongoing investment. An increased focus on translational research through the MRFF will help to realise the gains of Australia's stock of research that has been built up over previous generations.

1 Overview

1.1 Purpose

KPMG was commissioned by Association of Australian Medical Research Institutes (AAMRI) to conduct an analysis of the economic contribution that medical research makes to Australia. This includes both the direct and indirect impact of medical research on the economy. A healthier population results from investment in medical research, as it leads to improvements through new and innovative disease diagnostics, more effective treatments and a greater understanding of disease that allows for new preventative measures. It also has a significant multiplier effect on the broader economy and welfare through higher employment, household consumption and additional import/export activity.

This report attempts to quantify the current economic impact of historical medical research conducted in Australia by calculating the Return on Investment (ROI) in terms of broad population health gains and health system savings as well as the number of jobs created in the Australian economy, productivity levels of the workforce and contribution to GDP.

The report also acknowledges the potential economic impact of the Medical Research Future Fund (MRFF) which was recently established by the Commonwealth Government to "supercharge" the growth in cutting-edge health and medical research.[6] The major focus of this fund is on the translation and commercialisation of medical research that will lead to new cures and treatments and improve health outcomes as well as create jobs and economic growth.

1.2 Scope

The scope of this report is to understand the following economic impacts:

Health system savings
Including burden of disease improvements and direct and indirect savings in the health system

Job creation
Including the number of people directly employed in research and the number of people in reliant industries

Broad economic benefits
Including the overall impact on GDP, productivity gains and wider flow-on impacts to other industries

A number of external and internal data sources have been used to conduct the analysis, including from the Australian Bureau of Statistics (ABS), Australian Institute of Health and Welfare (AIHW) and the National Health and Medical Research Council (NHMRC), amongst others. KPMG undertook a short consultation exercise with medical research experts, and a desktop review of current literature around key parameters and methodologies for estimating them.

KPMG then conducted epidemiological modelling of health impacts, including burden of disease and quality of life. KPMG also completed economy-wide modelling of the impact on job creation and productivity using our detailed model of the Australian economy, KPMG-CGE. Relevant insights were then drawn from the analysis to develop benefit-cost metrics and to determine the return on investment for medical research in Australia.

1.3 Report structure

The report is organised into four key sections and structured as follows:

- **Section 2: Medical Research in Australia.** This section outlines the structure of medical research in Australia, highlights current and historical expenditure, and provides the background to the remainder of the report.
- **Section 3: The role of medical research in job creation.** This section estimates the jobs employed in medical research, and identifies the inter-linkages of medical research with the wider economy.
- **Section 4: Economic impact of investment in medical research in Australia.** This section explains the methodology for estimating the historical ROI in medical research, and estimates the ROI for three specific case studies. The analysis includes both the health gains and wider economic gains from medical research.
- **Section 5: Conclusion.** This section discusses the strengths and limitations of the study, and considers the wider implications of the findings, including the potential impact of future investment in medical research via the MRFF.

2 Medical research in Australia

2.1 Background

The World Health Organisation defines a healthcare system as one that "delivers quality services to all people, when and where they need them" and it requires "reliable information on which to base decisions and policies".[7] Medical research is the foundation of such information and plays a critical role in improving healthcare for all.

The Australian public recognises this.[8] Furthermore, the public also recognises the impact that medical research has on the economy more broadly. In a recent opinion poll, 82 per cent of respondents said they believe that medical research is important for job creation and 73 per cent believe it drives economic growth.[9]

Medical research has a number of facets and includes laboratory, clinical and community based studies. Broadly, medical research can be categorised as either discovery, translational or clinical research. Discovery research is where studies are done to develop an understanding of nature and its laws without necessarily having a practical end in mind.[10]

Translational or clinical research on the other hand involves bringing research findings from the discovery stage to the development of trials and studies in humans and enhancing the adoption of best practices in the community.[11]

The benefits from the outcomes of medical research accrue broadly across countries, and this is evident in Australia and internationally.[12,13] It has positively impacted how care is provided and conditions are avoided. This is seen in the detailed understanding of medical conditions, from prevention through to treatment.[14]Around the world, a range of institutions, in both the public and private sector, such as medical research institutes, governments, universities, start-ups and not-for-profit organisations conduct medical research.

2.2 Medical research in Australia

Medical research in Australia is largely funded by the Commonwealth and State governments, philanthropy, private sector and universities. A number of independent bodies have been set up by the Commonwealth and State governments to administer medical research funding.

These include the NHMRC, Medical Research Future Fund (MRFF) and Biomedical Translation Fund (BTF), Cooperative Research Centres (CRC) Program, Australian Institute of Health and Welfare (AIHW), Australian Research Council (ARC), Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS), Commonwealth Scientific and Industrial Research Organisation (CSIRO), amongst others.

2.3 Role of government

In Australia, both the Commonwealth and State governments play a significant role in funding medical research. Sustained investment in medical research provides the government a return through improved well-being of its citizens. Medical research enables governments to provide better quality healthcare to its citizens through the development of new and innovative ways to diagnose, treat or prevent diseases. Investments in medical research also sustain new industries that would add

innovative medical products and healthcare services to the economy, create high value jobs and promote broader economic growth, key priorities for any government.

Nationally, the Commonwealth Government is the largest investor in medical research, with around $850 million of funding provided each year through the NHMRC alone.[15] The Commonwealth Government has also established six industry Growth Centres, one of which is the Medical Technologies and Pharmaceuticals Growth Centre, MTPConnect.[16] It is a not-for-profit organisation, led by a board of industry experts, tasked with leading cultural change in the sector. They focus on:

- increasing collaboration and commercialisation
- improving international opportunities and market access
- enhancing management and workforce skills
- identifying opportunities for regulatory reform

State Governments also directly fund medical research. The major Commonwealth and State medical research funds are described below.

2.3.1 National Health and Medical Research Council

The NHMRC's role is to promote the development of health advice and manage Commonwealth funding for health and medical research, in particular investigator-initiated research projects that are not commercially sponsored. It aims to invest and support high quality medical research and provide a robust integrity framework for future research and guideline development.[17]

As outlined in its Corporate Plan 2017-2018, the NHMRC also focuses on translation research, supporting *"the translation of health and medical research into clinical practice, policy and health systems and the effective commercialisation of research discoveries".*

2.3.2 Biomedical Translation Fund

In addition to the NHMRC, the Commonwealth Government has recently established a $501 million BTF with $250 million of Commonwealth capital and $251 million private sector capital. This was established as part of the National Innovation and Science Agenda (NISA) which sets a focus on science, research and innovation as long-term drivers of economic prosperity, jobs and growth. The BTF is an equity co-investment venture capital program announced in 2015 and was set up to support the "commercialisation of biomedical discoveries in Australia".[18] It will help to translate biomedical discoveries into high growth potential companies to deliver long-term health benefits and national economic outcomes.[19]

2.3.3 Medical Research Future Fund

The Commonwealth Government also recently created the Medical Research Future Fund (MRFF), a sovereign wealth fund, to continue growth in Australian medical research.[20] The MRFF complements the NHMRC and BTF by funding research with a priority-driven focus including reducing burden of disease and improving the health system. It was set up to "support Australia's greatest minds to discover the next penicillin, pacemaker, cervical cancer vaccine or bionic ear".[21]

The MRFF drives improvements in real-life practice in four key streams.[22] Each stream has an overarching objective and focuses on different areas as shown in Figure 2

.

Figure 2: Medical Research Future Fund key streams and programs

Source: Commonwealth Government, Department of Health, 2018

The Commonwealth Government announced the first initial funding of the MRFF in the 2014 budget with the first contribution to the Fund made in 2015. Future Fund, Australia's Sovereign Wealth Fund, is responsible for the investment of the MRFF.[23]

With an account balance of around $9.5 billion as of July 2018, the MRFF is scheduled to reach its target of $20 billion in 2020-21 through further capital injections by the Commonwealth Government. Once the value of the MRFF reaches $20 billion, the net earnings from the MRFF are expected to provide around $1 billion of investment per annum in medical research and innovation (Department of Finance, 2017).[24]

Both the BTF and MRFF are new schemes introduced by the Commonwealth Government to boost translation of medical research breakthroughs to tangible outcomes for the population. The BTF has a commercial focus, investing in early-stage biotech companies who have reached the proof-of-concept stage in the commercialisation pathway to the market. The MRFF is primarily focused on reducing burden of disease and improving the healthcare system through priority-driven research programs. The successful commercialisation or application of such research would directly improve health outcomes for all, as well as create new businesses and industries that will make a significant contribution to the economic growth of the country.

2.3.4 State-based funds and investments

There are a number of funds supporting medical research that have been set up by State Governments across Australia often targeted at specific gaps in the local research space or complementing competitive research grants provided by the Commonwealth Government. In 2015-16, state and local governments across Australia collectively spent approximately $850 million on health research according to the AIHW.[25]

For instance, in Victoria, the State Government has developed the Victorian Medical Research Acceleration Fund under Victoria's Health and Medical Research Strategy 2016-20. The initiative intends to provide assistance in translating research into practice and influencing health and economic outcomes. It provides a platform for researchers to address current market gaps within the Victorian healthcare system. Additionally, it also supports the initial stages of innovations such as discovery and clinical research.[26]The Victorian Government also provides operational funding through the Operational Infrastructure Support (OIS) Program to independent medical research institutes that conduct fundamental or clinical biomedical research as their main focus. The OIS provides essential funding to eligible organisations for indirect research costs that are not met by competitive grants.[27]

Similarly, the New South Wales Government has the Medical Research Support Program (MRSP) which has been providing infrastructure support to independent Medical Research Institutes (MRI) since 2003.[28] NSW also has a Medical Devices Fund which is an $8.2 million per annum, competitive technology development and commercialisation program funded by the NSW Ministry of Health.[29]The State Government has also made other strategic investments in specific diseases such as the $150 million committed to cardiac research over the next 10 years[30] and $11.6 million provided to researchers in 2017 to find new treatments for cancer.[31]

In 2013, the South Australia Health and Medical Research Institute (SAHMRI) was officially opened with both the Commonwealth and State Governments contributing to the building and running of the facility. Since then, the State Government has committed more than $40 million to build a new, research hub known as SAHMRI 2 which will offer cutting edge therapy for cancer patients.[32]

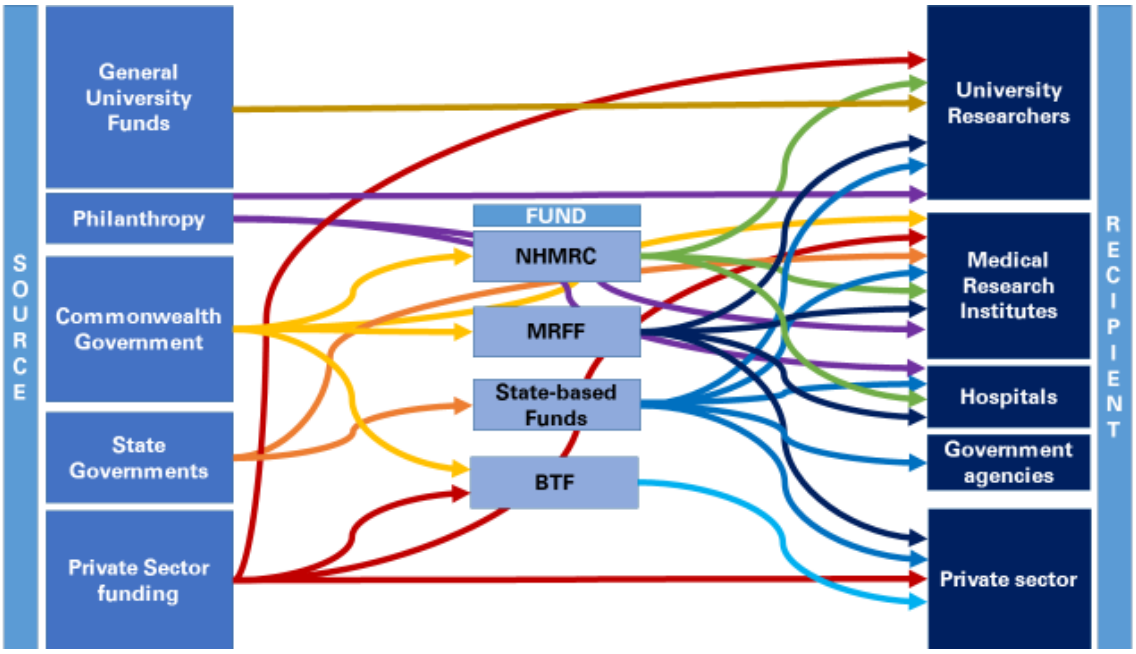
In Western Australia, the Government has been supporting medical research through the Medical and Health Research Infrastructure Fund (MHRIF). The MHRIF provides medical and health researchers with funding to support their research programs by covering infrastructure costs which are not usually a component of competitive research grants, such as research equipment, general support staff, computers and common office services.[33] They have also established the Research Translation Projects (RTP) program to support high-quality research projects that have the potential to demonstrate improved cost effectiveness and/or efficiencies that can be delivered to WA Health.[34]

In Queensland, the State Government has an 'Advancing Health 2026' strategy to help ensure its medical research is prioritised to deliver better health outcomes.[35] The State Government is also the second largest contributor, after the NHMRC, to the QIMR Berghofer Medical Research Institute that was established more than 70 years ago by the Queensland Government.[36]

2.4 Current and historical expenditure on medical research

This section presents estimates of expenditure on medical research in Australia. Medical research in Australia is conducted in higher education institutions, medical research institutes, government facilities, non-profit organisations, and in the private sector. *Figure 3* below summarises the major players in medical research in Australia and gives an overview of the flow of key medical research funding from the various sources through the major funds set up and to the grant recipients.

Figure 3: Overview of key medical research funding flows in Australia

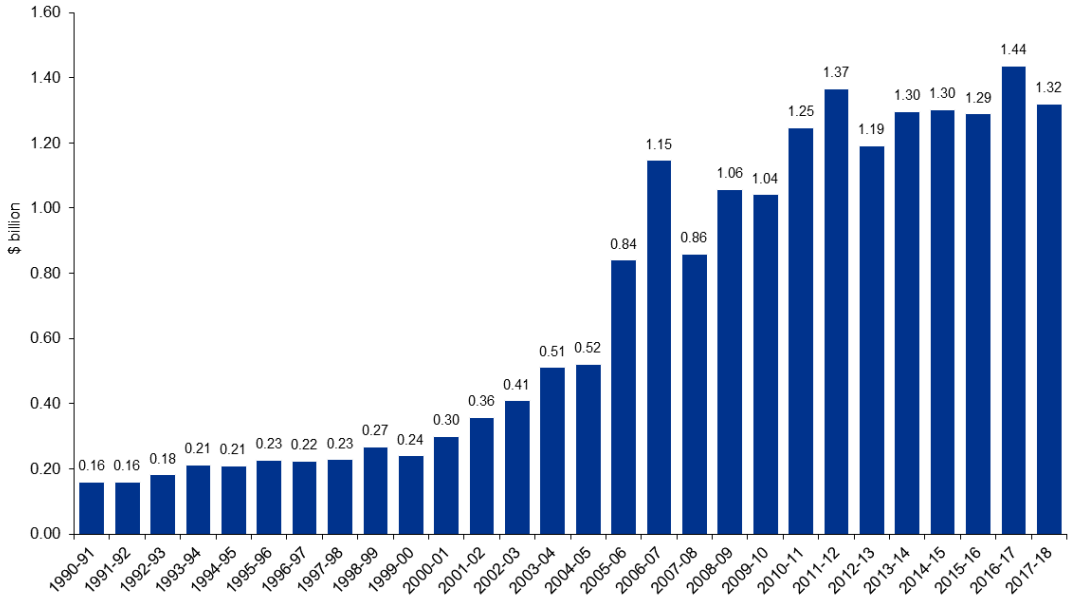


Source: KPMG Analysis

2.4.1 Overall Commonwealth Government expenditure

There has been a substantial increase in the overall Commonwealth Government spending on medical research over time, from less than $0.2 billion in 1990-91 to over $1.3 billion in 2011-12. The growth has since tapered off and annual expenditure has fluctuated between $1.2 and $1.4 billion (*Figure 4*). Government spending is projected to increase to over $1.5 billion by 2020-21.[37]

Figure 4: Total Commonwealth Government medical research investment, 1990-91 to 2017-18



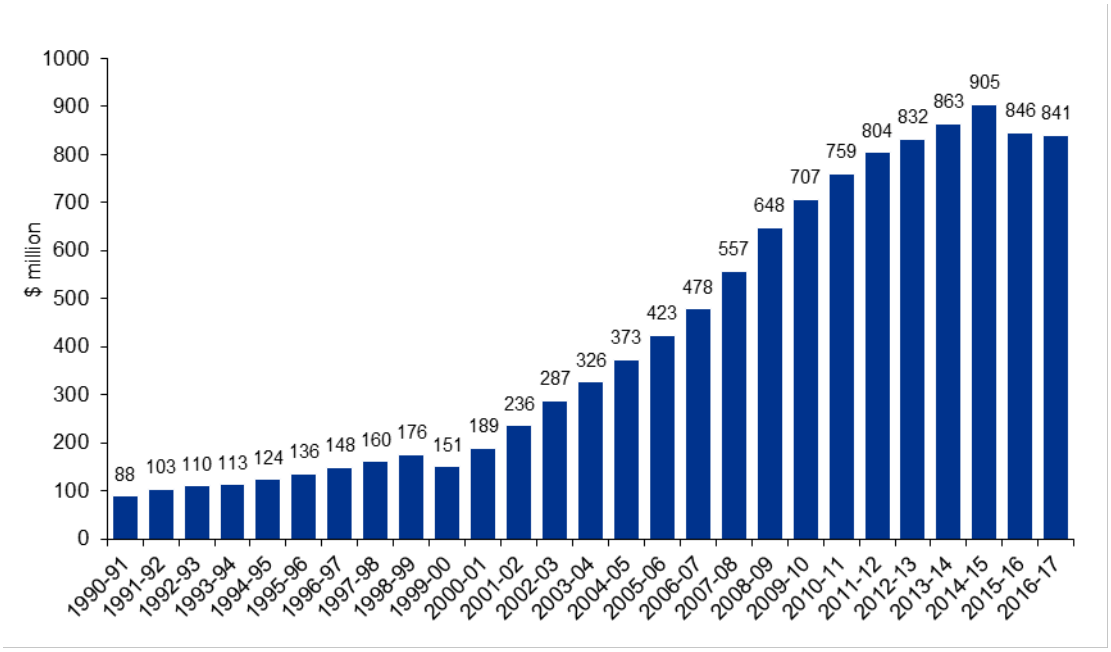
Source: 2017-18 Science, Research and Innovation Budget Tables

The Government has also committed to making significant investments through its Health and Medical Industry Growth Plan and the National Innovation and Science Agenda, with the objectives of supporting jobs and growth in new industries through research, while ensuring better health for all.[38]

2.4.2 Investments made through the NHMRC

The government has made significant investments in medical research through the NHMRC. *Figure 5* illustrates the overall NHMRC's medical research funding from 1990-91 to 2016-17.

Figure 5: Total investments made through the NHMRC, 1990-91 to 2016-17



Source: NHMRC (2018), and 2017-18 Science, Research and Innovation Budget Tables

NHMRC expenditure has grown rapidly from 2000-2015 settling at around $840 million per annum over the last two years. This growth was associated with the broadening of Australian research to include basic, biomedical science, clinical medicine and science, public health and health services.[39] The growth from the early 2000s was also driven by government policy supporting more innovation, and research and development in general.

3 The role of medical research in job creation

3.1 The medical research workforce

Medical research provides high value, knowledge-based jobs to many Australians. Medical research is critical to the ongoing success of multiple sectors throughout the Australian economy. Tertiary Education and the Professional, Scientific and Technical Services sector (including MRIs and hospitals) support over 32,000 jobs. The down-stream MTP sector which is reliant on medical research, supports another 78,000 jobs. The estimated number of jobs created through medical research is presented below in *Table 2.*

Table 2: Estimated number of jobs created through medical research (2016/17) [40]

Sector	Estimated number of jobs
Tertiary Education	21,233
Professional, Scientific and Technical Services sector including Medical Research Institutes (MRIs) and hospitals	10,863
Sub-total	***32,096***
Medical Technologies and Pharmaceuticals (MTP)	78,409
Total including MTP	**110,505**

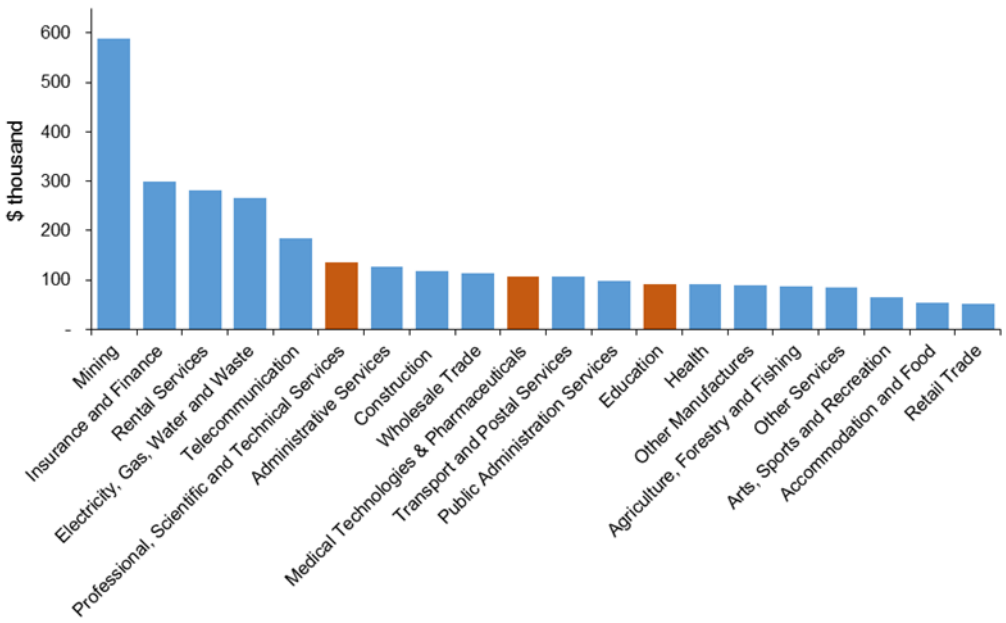
Note: The assumptions and the supporting evidence for these are documented in the Appendix B.

3.2 Economic returns of the medical research workforce

Medical research jobs create significant value for the Australian economy. The value add of an industry is a measure of the industry's return to labour and capital, and is calculated as the outputs of the industry less the inputs used from other industries. Value add is therefore an estimation of the contribution that each industry makes to overall GDP. When divided by the number of full-time equivalent (FTE) employees in the industry, the value add per FTE provides an indication of workforce productivity and the relative value of jobs in each respective industry.

KPMG utilised the 2015-16 Input-Output database to compute the value added by industry divided by the number of FTE employees. The average value add per FTE for Professional, Scientific and Technical Services (PSTS) sector and Medical Technology and Pharmaceutical (MTP) sectors is estimated to be around $134,000 and $107,000 respectively. These figures suggest that medical research jobs are high value jobs that make a strong contribution to the economy. Further, the figures are averages across all occupations within the sector, so it is expected that there is a higher value-add associated with pure medical research occupations. Meanwhile, the value add per FTE for the Education sector, which includes Higher Education, is around $91,000 (see *Figure 6* below). While medical research is a core component of the PSTS and MTP sectors, it is a smaller contributor to the Education sector, and thus the value-add per FTE for Education is less likely to be representative of the returns to medical research jobs.

Figure 6: Workforce Productivity – Average Value Add per FTE ($)

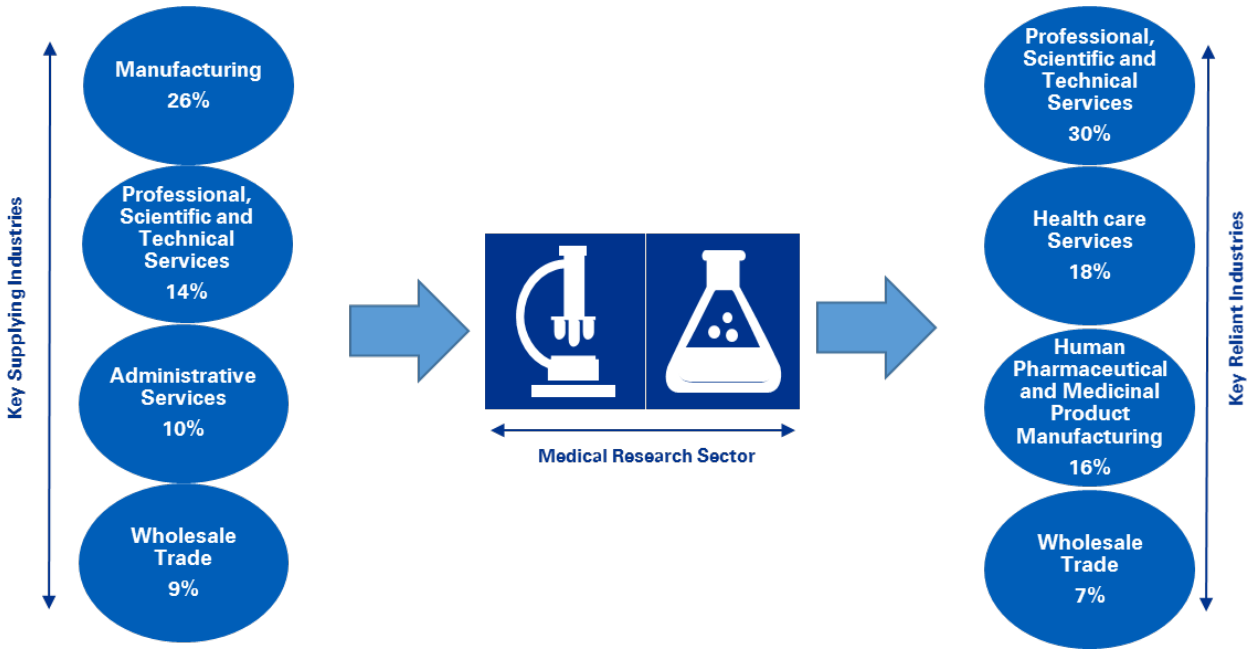


Source: KPMG Estimates, 2018

3.3 Medical research sector linkages

Australia's medical research sector is highly intertwined with other sectors. The medical research sector is dependent on external industries for inputs, and the resulting products and services become key contributors to other industries. *Figure 7* provides an overview of the key inputs into Australia's medical research and the key reliant industries using medical research in Australia.

Figure 7: Overview of key supplying and reliant industries



Source: KPMG Analysis, 2018

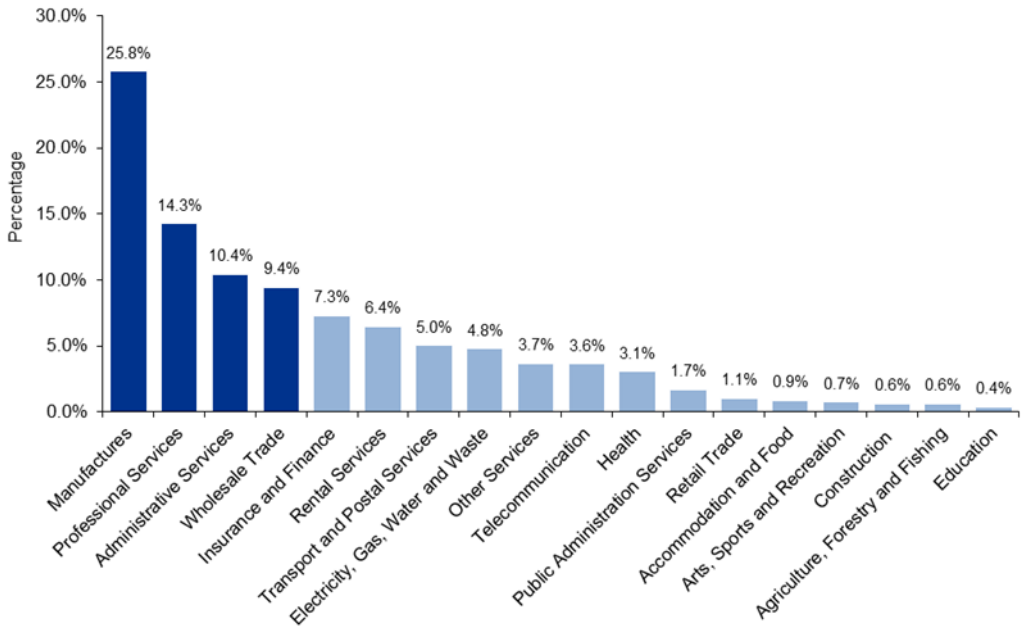
To critically evaluate the economic flow of the medical research sector, KPMG has analysed the 2015-16 Input-Output tables.[41] The tables comprise 114 sectors and are a relatively disaggregated data base. Analysis of the tables enabled the structure and inter-relationships between Australian industries to be determined. This includes the supply and use of products within the Australian economy. As the industries within the tables do not perfectly align with medical research sector, a range of assumptions were applied. These are documented in the appendix.

3.3.1 Key supplying industries

The economic flows of the medical research and MTP sector suggest that they are highly interdependent with other sectors and play a critical role in the Australian economy. The medical research sector linkages can be seen through monetary input into other sectors.

Figure 8 outlines the share of the medical research sector purchases from other industries. The analysis highlights that the sector has the greatest direct reliance upon Manufacturing (through the supply of materials required for research such as device prototypes and compounds for study), Professional, Scientific and Technical services (for example the supply of facilities), Administrative Services, and Wholesale Trade. Examples of these inputs range from the supply of materials required for research, such as device prototypes and compounds for study, access and provision of research facilities, through to financing arrangements for research.

Figure 8: The Medical research sector purchases from reliant industries (per cent) – 2015-16



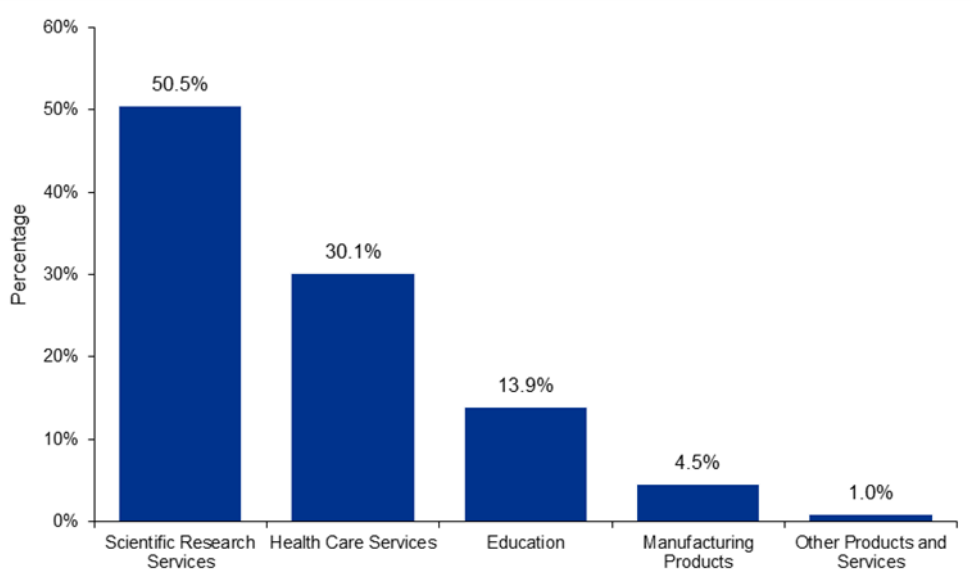
Source: KPMG Analysis, 2018

3.3.2 The medical research sector sales to reliant industries

Further analysis of the 2015-16 Input-Output tables identified the medical research reliant industries that purchase the output of the medical research sector.

Figure 9 presents the key outputs produced by the sector. Scientific Research Services, Health Care services, Tertiary Education and Manufactured Products including Human Pharmaceutical and Medicinal Products make up the bulk of the products and services generated through medical research that have economic benefit to other industries in the Australian economy.

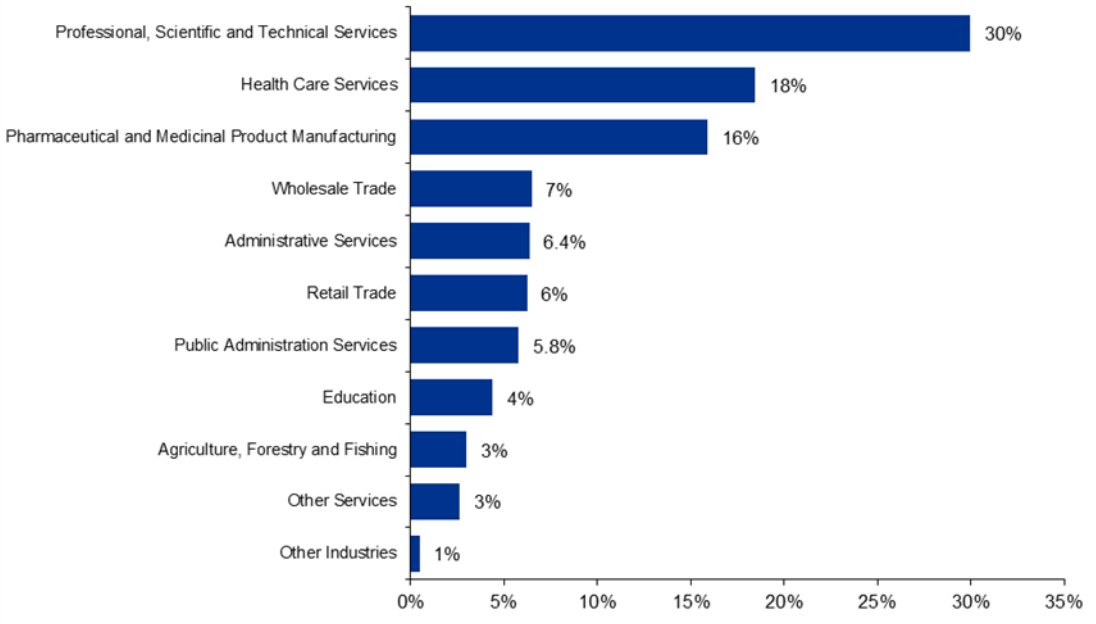
Figure 9: The Medical Research and MTP Sector Production by Product Group (per cent) – 2015-16



Source: KPMG Analysis

There are a broad range of industries reliant on these products and services as summarised in *Figure 10*. Professional, Scientific and Technical Services forms the major consumer of the medical research sector output, followed by Health Care Services, manufacturers including Pharmaceutical and Medicinal Product Manufacturing, and Wholesale Trade sectors. Given that over 50 per cent of the defined output is Scientific Research services, the results presented below are not surprising as this output covers discovery of new innovation that will lead to greater scientific outcomes.

Figure 10: The Medical Research Sector Sales to reliant industries (per cent) – 2015-16



Source: KPMG Analysis

3.3.3 Summary

The analysis presented in this section shows that spending on medical research has direct flow-on impacts to the wider economy, even before considering the longer-term impacts of the research itself. Medical research is a particularly integrated sector, with strong upstream and downstream linkages. These linkages spread the benefits of expenditure in medical research across the wider economy.

4 Economic Impact of Investment in Medical Research

4.1 Methodology

A review of the previous literature suggests there is no clear consensus on the overall methodology that should be employed to estimate the economic benefits from medical research.[42] KPMG therefore adopted a unique hybrid approach that combined parts of previous methods:

- Bottom-up case studies were used as the basis for the overall estimate of the economic impact of medical research. Using case studies helps with the attribution of health gains to medical research because a clearer causal pathway can be developed between research and impact.
- Top-down burden of disease improvements were used to help quantify the gains in the specific disease case studies. Burden of disease improvements capture wider health benefits across the population.

Three diseases were selected as case studies to be broadly representative of the return on investment from medical research: HIV, mental health and HPV. For each, the translation from research to benefit has followed a unique pathway:

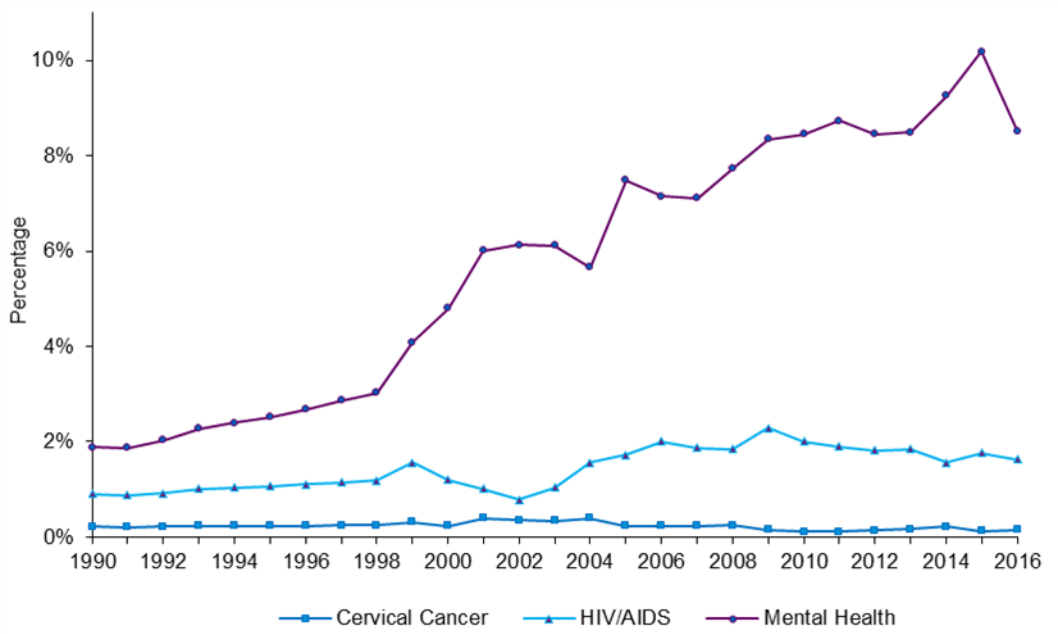
- For HIV, the development of a pharmaceutical treatment and associated treatment guidelines delivered substantial health gains to the population with HIV.
- For HPV, wider population health gains were delivered by both the vaccination and wider translation of the screening process across the population.
- In mental health, some health gains have been achieved in managing depression through a large scale use of pharmaceutical treatment.
- The expected gains from further translational medical research is also expected to differ across the three diseases.

For each disease, KPMG worked through the process of estimating the return on medical research as described below.

4.1.1 Expenditure on medical research

From 1999, the NHMRC disaggregates their historical expenditure on medical research by disease. For the period from 1990 to 1998, the 1999 share of total NHMRC expenditure was used to apportion spending on each disease. However, for all other medical research expenditure, there was limited data or evidence available to disaggregate by disease, particularly in private businesses. KPMG therefore applied the NHMRC proportion of spending on each of the three disease case studies to the total amount of medical research expenditure by government and universities. There are potential limitations with this approach. In recent years, mental health has been a priority area for the NHMRC, and thus has had a relatively high share of overall NHMRC funding. This may not be representative of wider medical research spending in other sectors such as government, universities, non-government organisations and the private sector. As a result, low and high expenditure paths were also considered in sensitivity analyses. In the low path, the share of NHMRC funding was applied to all government and half of university expenditure; in the high path, the share of NHMRC funding to all government, university, non-government and business expenditure.

Figure 11: The share of total NHMRC expenditure on each disease – 1990-2016



Source: KPMG Analysis

4.1.2 Estimating the health gains from medical research

To estimate the overall population health gains associated with medical research involves a number of steps:

- Estimate the net health benefits associated with medical research, including the direct health care costs to achieve those gains, and the direct and indirect savings from a healthier population.
- Estimate the share of net health benefits associated with Australian medical research.
- Estimate the lag between medical research expenditure and benefits.
- Estimate the health system return on investment in medical research.

Each step is described in more detail in the following sections.

The net health benefits associated with medical research

There have been two broad approaches adopted in the literature:

- Top down: this approach evaluates the broad population health gains from burden of disease studies, and apportions a share of those gains to the medical research, based on some high-level estimates in the literature.
- Bottom up: this approach looks at individual disease areas as case studies, and identifies the medical research that has led to guidelines and treatments, and in turn estimates the population health benefits from the use of those treatments; it is inherently more research intensive than the top-down approach, but also delivers a more robust analysis.

KPMG applied a hybrid approach, focusing on health gains delivered in specific case studies of HIV, mental health and HPV, where the impact of medical research is well-established. For each case study, the analysis identified the key guidelines and interventions that have been implemented within Australia, and the associated improvement in population health outcomes. These were derived from the literature and the global burden of disease study, and informed by expert advice. Specifically, the

Disability Adjusted Life Years (DALYs) averted by medical research in each of the disease areas was estimated using:

- The actual time series of DALY rates for Australia for each disease by age group and gender from the Global Burden of Disease (GBD) study.[43]
- An estimate of the above DALY rates in the absence of medical research. This was informed by bottom-up analysis of the population health impacts of key guidelines and treatments, and advice from disease experts.
- Population statistics by age group and gender, from the ABS.[44]

The value of each DALY averted was $50,000, in line with the opportunity cost of spending on health care rather than medical research, and in line with the approach used in the United Kingdom,[45] with a sensitivity analysis at $25,000 and $75,000. Previous research has considered higher values based on the 'Value of a Statistical Life',[46] however these estimates tend to conflate a number of benefits into this value, including productivity gains which we explicitly estimate in the 'Wider Economic Benefits' section that follows.

Two further costs and benefits were considered:

- Direct costs associated with delivering the health gain: these were estimated from the costs associated with the treatment, as derived from the literature and administrative data sources.
- Direct and indirect healthcare savings associated with a healthier population, such as reduced hospitalisation costs and reduced carer costs: these were derived from the economic evaluation literature for each disease.

The share of health gains associated with Australian medical research

Previous Australian researchers have adopted Australia's share of world health output (around 3 per cent) as a proxy for the share of health gains that can be attributed to Australian medical research,[47] while other studies have adopted an analysis of the citations that have been used to inform key treatment guidelines.[48] KPMG adopted the following similar approaches:

- A bibliographic analysis of key treatment guidelines. This approach gives a broad indication of the countries of origin of the authors that have contributed research that has been used to inform the guidelines, but it does not say anything about the sources of funding for the research; similarly, there is no weighting of impact or quality adjustment of the cited references.
- A weighted version of the above where the references were weighted according to their number of citations. This was an attempt to mitigate one of the limitations of the above approach by adjusting the cited references for impact.
- Expert opinion of Australia's contribution to key research efforts in the specific diseases in question.

Given the uncertainty around this parameter, a sensitivity analysis with relatively broad ranges for this value was also conducted.

The lag between expenditure and outcome

Previous Australian research adopted an average lag of 40 years from medical research expenditure to accrual of population health gain[49], however bottom-up analyses of specific diseases found a lag of 17 years for CVD and 12 years for mental health.[50] KPMG adopted a similar bottom-up approach that aimed to estimate the lag for the disease case studies in question:

- A bibliographic analysis of key treatment guidelines. This approach gives a broad indication of the timing of research that has been used to inform the guidelines, known as the 'knowledge cycle time'.
- A review of the population health burden of disease trends to identify key timings in uptake of guidelines and treatments.

- Expert opinion of the lag times between research and outcomes for the specific diseases in question.

A sensitivity analysis with relatively broad ranges was also conducted for this parameter.

The health gain return from investment in Australian medical research

For each disease, the time series of health gains were calculated from the preceding steps, and compared to the investment in medical research, with a lag between expenditure and outcomes, and a discount rate of 5 per cent and a sensitivity analysis of 3.5 per cent and 0 per cent, as per the Pharmaceutical Benefits Advisory Committee (PBAC) economic evaluations.[51]

The analysis considered investment in medical research for a period of 15 years from 1990, to allow for actual health gains to be quantified without requiring long-term projections into the future, after accounting for the lag between expenditure and outcome. However given the strong increase in expenditure on medical research through the 2000s, a sensitivity analysis was completed with a start date of 2000.

Extrapolating from the case studies

The bottom-up case study approach was selected to develop a fuller understanding of how medical research translates to population health gains. However the case study diseases are only part of the overall investment in medical research; there has been substantial medical research into cancer, cardiovascular disease, and osteoarthritis to name but three. The case studies were combined to estimate an overall BCR that was then extrapolated to wider expenditure in medical research, to estimate the health gains from overall medical research.

We note that the specific return on investment in medical research will vary by disease. However by providing three disparate case studies, the aim of this study was to provide a plausible range of the returns from investment in medical research. The three case studies were chosen to be broadly representative of the wider investment in medical research. They have contrasting levels of burden of disease, and medical research has impacted each disease quite differently: for example, medical research has reduced mortality in HIV and HPV, compared with reduced morbidity in mental health.

There are diseases that have a larger burden on the population, such as cardiovascular disease and cancer. Medical research has helped to make significant improvements in these areas, however there has also been large investments in these areas. The calculation of a BCR, a ratio of gains to investment, allows the case study results to be applied to other diseases even if the absolute level of investments differs. As a sense check, we also compare the results calculated here to those estimated in the literature.

While there are limitations in extrapolating from three diseases to overall medical research, the alternative of estimating overall health gains from medical research from the top-down is potentially more problematic. There is no simple way to estimate the benefits of overall medical research on overall health gains, as the pathways of attribution are less well-defined. We therefore believe the approach we have used in this study adds to the level of understanding around the returns to medical research, and quantifies a plausible range of those returns.

4.1.3 Estimating the wider economic benefits

Productivity impacts

The productivity impacts of medical research were directly estimated by disaggregating the health gains into morbidity and mortality. The major impact of both HIV and HPV is on mortality, and so the gains from medical research are realised through an increased workforce population. Specifically, the workforce losses averted by medical research in each of the disease areas were estimated using:

- The actual time series of death rates for Australia for each disease by age group and gender from the GBD study[52].

- An estimate of the above death rates in the absence of medical research. This was informed by bottom-up analysis of the population health impacts of key guidelines and treatments, and advice from disease experts.
- Population statistics by age group and gender, from the ABS.[53]
- The average labour force participation by age group and gender, from the ABS.[54]

For mental health, the major impact of treatments such as antidepressants is on improved function and quality of life. For this case study, KPMG used the estimates from literature to inform the likely productivity improvements derived from improved mental health, which are converted to an equivalent increase in the size of the workforce.

The results across the case studies were then combined and extrapolated to estimate the impact of medical research on the size of the workforce, which was then used to estimate the wider economic impact of medical research on GDP and jobs.

Wider impact on GDP and jobs

To model the wider economic benefits of medical research in Australia, it is necessary to employ a modelling technique that incorporates information about the linkages of the medical research and the MTP sectors within the broader economic context. KPMG used a computable general equilibrium (CGE) model to estimate the overall economic benefits of medical research in Australia. KPMG-CGE is a multi-sectoral model of the Australian economy that has been specifically designed for policy analysis. A more detailed summary of KPMG-CGE is presented in Appendix A.

The CGE analysis used the findings from the case studies, in terms of impact on workforce size and productivity, as inputs, and estimated the wider flow-on impact to all sectors of the economy. The key outputs considered were employment, GDP and welfare. A comparative-static approach is used for 2015-16, and adjusted for each year according to the size of the annual shock.

Commercialisation benefits

Commercialisation gains from medical research accrue when medical research is translated into marketable products and processes.

The National Survey of Research Commercialisation (NSRC) time series data from 2000 to 2015[55] was used to provide an indication of the commercialisation gains from medical research. It captures income from executed licenses, options and agreements, income derived material transfer agreements, equity holdings in research commercialisations, and the value of direct sales transactions and collaborations.

The survey disaggregates commercialisation by institution and commercialisation activity. KPMG included all commercialisation activity by medical research institutions and 23 per cent of commercialisation activity by universities, based on an estimate of the medical share of University activity.[56]

The overall return on investment in Australian medical research

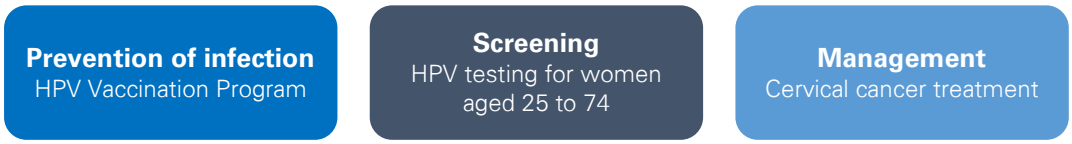
Finally, the overall return on investment in Australian medical research is calculated by combining the health gains and wider economic gains (welfare), and comparing it with the investment in medical research, with a lag between expenditure and outcomes, adjusting for inflation and discounting at a rate of 5 per cent (sensitivity analysis of 3.5 per cent and 0 per cent), as per PBAC economic evaluations.[57] As the commercialisation gains were not able to be split by disease, the gains were apportioned across the case studies according to the share of medical research expenditure on each disease.

4.2 Health gains

4.2.1 HPV case study

Research on the Human Papillomavirus (HPV) and its contribution to the health and wellbeing of Australians has been significant over the last three decades, with progress of treatment and prevention clearly attributable to Australian medical research. Australian advancements have enabled the continual improvement of guidelines and community vaccination against HPV.

Figure 12: Guidelines relating to the Human Papilloma Virus (HPV)



Source: KPMG consultation with disease experts

Broadly, there are three types of guidelines related to the prevention and treatment against HPV, as shown above. Based on expert consultation and available evidence, Australia's influence on HPV was predominantly related to the screening guidelines and HPV vaccine.

Screening

The screening guidelines were initially established in 1993[58] and were based on the traditional practice of Papanicolaou testing, more commonly known as the 'pap smear'.[59] They were subsequently replaced in 2005[60] and 2016 based on a Cochrane review of internationally published evidence.[61] Although the 2016 published guidelines were initiated by an international Cochrane review, the first testing of guidelines were established in an Australian environment. The formal pilot study of the new guidelines took place in Australia, with results supporting the implementation of primary HPV screening in vaccinated populations.[62] The initial confirmation of improvement in cervical cancer detection through HPV screening subsequently informed the development of the current guidelines.[63] These guidelines were also endorsed by the Medical Services Advisory Committee.

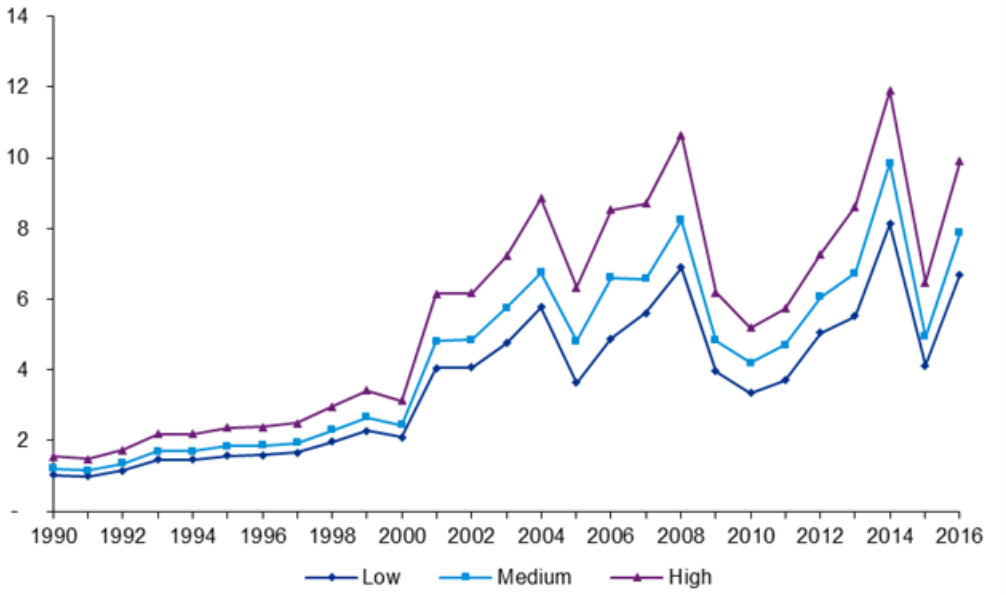
Vaccine

Australian research in the early 1990s[64] underpinned the development of the HPV vaccine and subsequent successful trials in 2005.[65] It was then quickly approved by the United States Food and Drug Administration (FDA) and Australian Therapeutic Goods Administration.[66] [67] Australia then led the implementation of the vaccine and introduced the vaccine as part of the National Immunisation Program. The vaccine was initially available for school-aged females and women under the age of 26 in 2007 at no cost.[68] [69] Not only has Australia played a critical role in the development of vaccine technology, but results from the initial universal immunisation initiatives have led to a substantial reduction in malignancy nationally and around the world.[70] Research has shown that its introduction in Australia more than 10 years ago has led to the reduced prevalence of smears in younger women and changed the management of abnormal test results.[71] This has created global action, with more than 270,000 HPV vaccines administered around the world.[72]

Medical research expenditure on cervical cancer

The overall medical research expenditure on cervical cancer was estimated from the proportion of NHMRC funding directed towards cervical cancer. It has risen from $1.2 million in 1990 to almost $8 million today (*Figure 13*).

Figure 13: Medical research expenditure on cervical cancer ($ million, nominal)

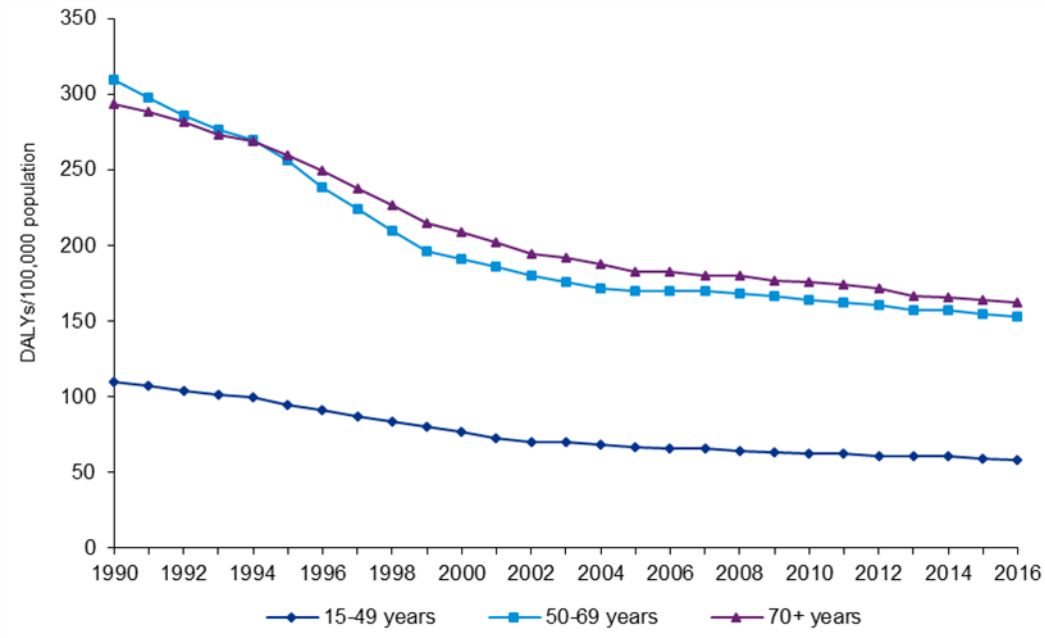


Source: KPMG analysis, NHMRC, 2018

The health gains from medical research

A literature review and consultation with a leading Australian HPV expert suggest that the screening guidelines developed in the early 1990s have directly resulted in the significant reduction in the incidence and burden of disease of cervical cancer (see *Figure 14*).[73]

Figure 14: Female cervical cancer DALY rates by age group



Source: Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017. Available from http://ghdx.healthdata.org/gbd-results-tool. Accessed 21 July 2018.

The costs to deliver these gains were derived from a cost evaluation in the literature that estimated the cost of screening of $23 per adult woman in the population, and between $100 and $150 per screened woman.[74]

The direct and indirect healthcare savings were calculated from the number of averted cervical cancer deaths. The direct savings were valued at $79,000 per averted cancer death, based on cancer treatment costs from an economic evaluation of the National Cervical Screening Program.[75] The indirect savings were valued at $52,000 per averted cancer death based on a detailed analysis of the wider costs of cancer.[76]

The Australian contribution

It is evident that Australian advancements in research have been a significant contributor to the progression of prevention and screening guidelines nationally and around the world. Initial Australian research of the vaccine technology is anecdotally thought to have influenced all other treatment guidelines and prevention strategies. The quantification of impact however, remains difficult.

Five key guidelines related to screening and vaccination were identified and analysed.[77] [78] [79] [80] [81] KPMG found that:

- 7 per cent of the references cited in the guidelines contained Australian authors. The high percentage is predominantly due to the inclusion of the 1993 Australian guidelines, where 26 per cent of authors were Australian.
- 3 per cent of the references cited in the guidelines contained Australian authors, when weighted by citations.
- Experts suggested a potentially higher level of Australian contribution.

We therefore adopted a base case rate of 5 per cent, with a sensitivity of 3 per cent and 10 per cent.

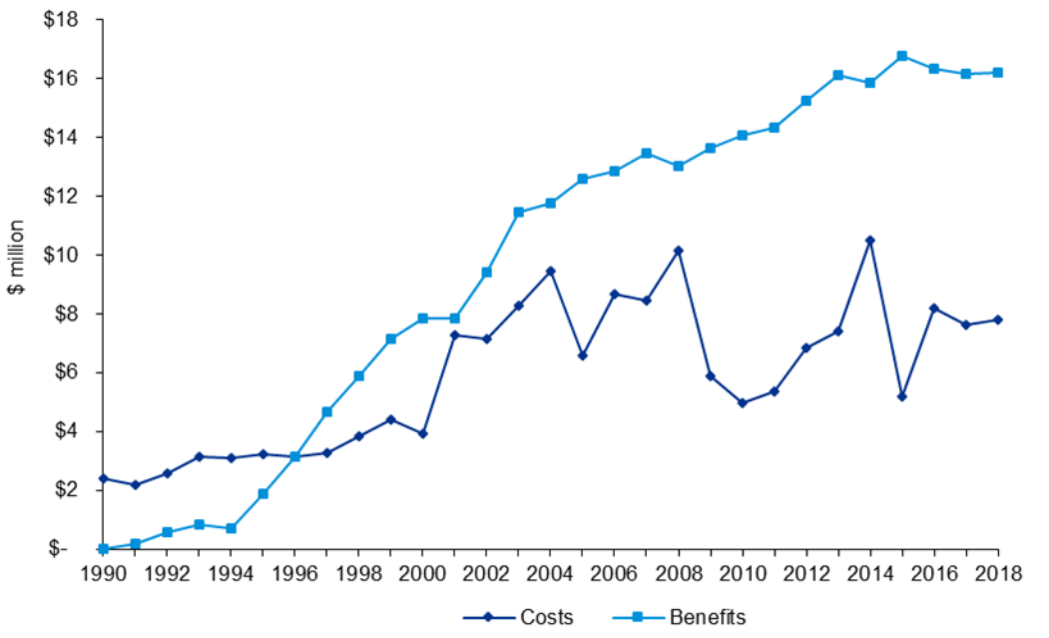
The lag time

The lag time between HPV research and benefit varies, with more than a decade between research and guideline change in comparison to almost an immediate translation from guidance development to practice. The analysis of references cited in the guidelines indicated an average knowledge cycle time of five years, however expert advice suggested a longer lag-time. Adding three years for time between funding and publication, and two years for adoption of guidelines, we adopt a lag time for HPV of 10 years, with 15 and 20 years considered in sensitivity analyses.

The overall net health gains and return on investment

For the period of investment from 1990 to 2004, medical research has delivered net present health gains from 2000 to 2014 of $56 million for a net present cost of $42 million, returning a BCR of 1.3.

Figure 15: Estimated health expenditure (costs) and net health gains (benefits) of medical research in cervical cancer ($million, 2018 dollars)



Source: KPMG analysis

The sensitivity analysis (*Table 3*) highlights the results are sensitive to changes in the key parameters, particularly around the value of a DALY and the Australian contribution to health gains.

Table 3: Sensitivity analysis of HPV results

Assumptions	BCR
Lower estimate of research expenditure	1.6
Lower Australian contribution: 3 per cent	0.8
Higher Australian contribution: 10 per cent	2.7
15-year time lag	1.3
20-year time lag	1.1
DALY value of $25,000	0.0
DALY value of $75,000	2.8
Later Cost-Benefit Analysis (CBA) starting date (2000)	1.0
Discount rate 0 per cent	2.0
Discount rate 3.5 per cent	1.5

Source: KPMG analysis

4.2.2 Mental health case study

Mental health is a broad umbrella term which encompasses a range of conditions such as depression and schizophrenia. It is non-discriminatory and can affect any person at any stage of their lives, including young children and adolescents. Unlike other major diseases, the wider burden of disease due to mental health has been increasing over time. This has been hindered by the negative stigma associated with mental health.[82] To analyse the impact, two major mental health conditions have been considered: schizophrenia and depression.

Schizophrenia

If untreated, schizophrenia can have a devastating impact on quality of life.[83] It is considered to be one of the most disabling conditions and is commonly diagnosed when a person reaches their late teens to early 30s.[84] The cause of schizophrenia remains unknown, however, extensive research has found that treatment is best administered in the early stages of the condition.[85] This research has been translated into guidelines, however translation into practice has been slower. Non-pharmacological treatments have been recommended within guidelines and utilised for a number of years, yet psychosocial supports and cognitive therapy access remain difficult for a number of Australians.[86] Greater efforts are required with translational and clinical research to improve patient access and care.

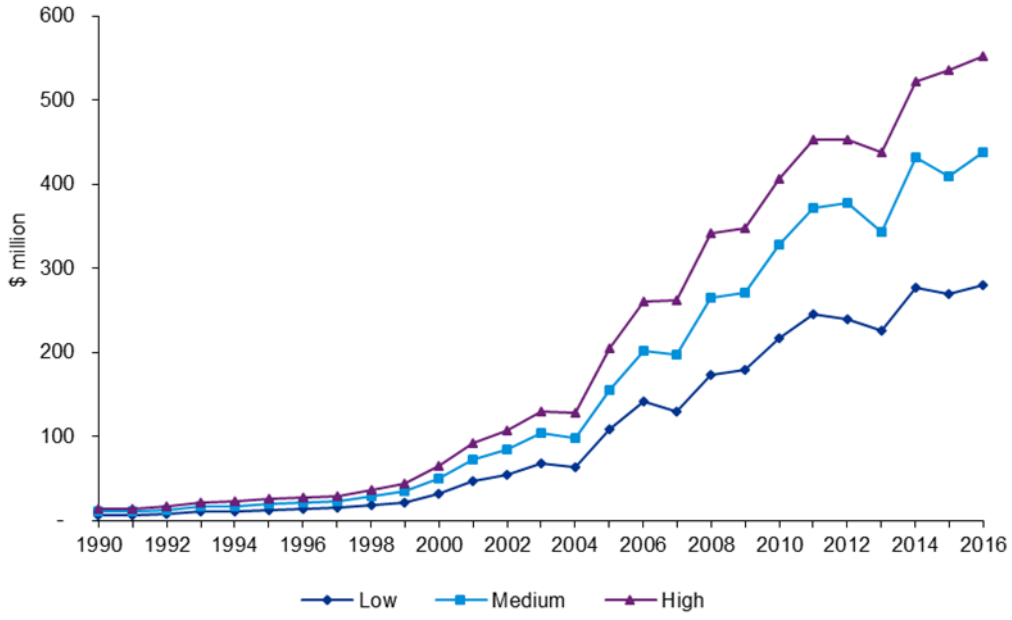
Depression

Like schizophrenia, depression can negatively affect a person's quality of life and impacts on average around one in six people.[87] It is associated with high levels of co-morbidity and can lead to a shorter life expectancy. Treatment for depression includes medication, such as selective serotonin reuptake inhibitors (SSRIs), medical interventions and psychological interventions.[88] Although depression is highly prevalent and there has been research on the effective treatments, only 35 per cent of at-risk Australians access treatment.[89]

Medical research expenditure on mental health

The overall medical research expenditure on mental health was estimated from the proportion of NHMRC funding directed towards mental health. It has risen from $10 million in 1990 to over $400 million today. Like expenditure in other countries, this is considered to be an under-investment that is not providing sufficient support to address key mental health issues.[90]

Figure 16: Medical research expenditure on mental health ($ million, nominal)



Source: KPMG Analysis, NHMRC, 2018

The health gains from medical research

The methodological challenge with mental health was to understand how the growing burden of disease might look in the absence of Australian medical research. A method used by UK researchers was to take a bottom-up approach, and track the linkages from research to guidelines to treatment to population health benefit, for a selection of key mental health treatments such as anti-depressants, cognitive therapy and psychiatric nurses.[91]

A similar methodology is adopted here, utilising the commonalities of the UK research where appropriate. In particular, the following treatments were considered:

- SSRIs
- Cognitive behavioural therapy
- Early diagnosis and management of psychosis.

However, consultations with Australian mental health experts suggested that for some key treatments, such as early and assertive outreach for patients with psychosis, implementation road blocks have limited the translation of medical research into population gains. The analysis therefore focused on the gains delivered by SSRIs.

The number of Australians using SSRIs over time was estimated from key literature and data from the AIHW.[92] The adherence rate was assumed to be 65 per cent, and the gains per adhering patient year was assumed to be 0.13 DALYs based on earlier analysis of the returns to mental health research.[93]

The costs to deliver these gains were estimated from average PBS data on expenditure on SSRIs at $36 per prescription.[94]

The direct and indirect health care savings from improved mental health are known to be large. For example, an analysis of the Australian National Survey of Health and Wellbeing found average health sector costs of $808 for those with depression, and indirect welfare costs were on par with productivity losses[95]. However, there is limited clear evidence that SSRIs significantly reduce health service utilisation[96]; therefore, no further cost savings are considered in the base case analysis.

The Australian contribution

Australia has been a lead contributor in the treatment of schizophrenia, in particular youths affected by early psychosis. Australian research has enabled the development of new service models and focus on the needs of youths. The Early Psychosis Prevention & Intervention Centre (EPPIC) is an Australian initiative that has led to a change in practice in Australia and internationally.[97] Various studies have suggested that the model is as cost-effective in comparison to standard care and produced effective patient outcomes.[98] [99] With respect to the quantitative contribution of medical research, this is hindered by the poor translation of effective guidelines into practice.

Four key guidelines related to schizophrenia and depression were identified and analysed.[100] [101] [102] [103] KPMG found that:

- 11 per cent of the references cited in the guidelines contained Australian authors.
- 8 per cent of the references cited in the guidelines contained Australian authors, when weighted by citations.
- When considering depression only, the unweighed and weighted shares were 6 per cent and 3 per cent respectively.

KPMG therefore adopted a base case rate of 5 per cent, with a sensitivity of 3 per cent and 10 per cent. There is potential for a higher attribution with the future translation of Australian psychosis prevention research.

The lag time

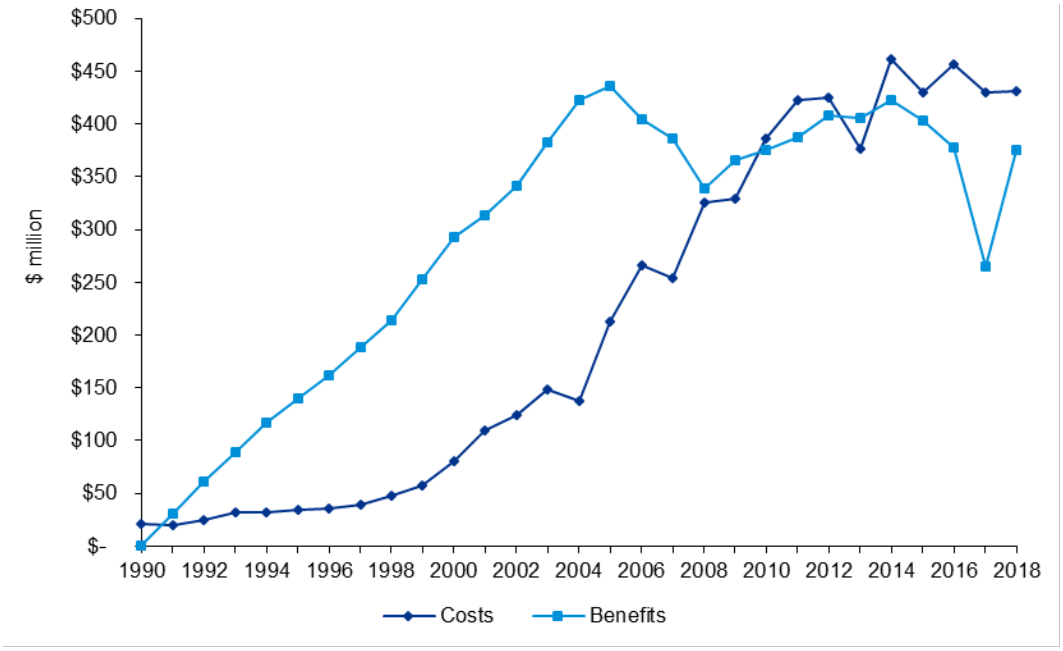
Based on the guidelines analysed, the lag time between mental health research and benefit varies. It ranges from three to nine years. For depression, the knowledge cycle time was seven years. Adding three years for time between funding and publication, and two years for adoption of guidelines, KPMG adopts a lag of 12 years, with 15 and 20 years considered in sensitivity analysis.

For schizophrenia, a pertinent issue was the difficulty in guideline implementation. Although research has supported the development of guidelines, uptake has been poor according to industry experts, suggesting that lag time may be more than 10 years.

The overall net health gains and return on investment

For the period of investment from 1990 to 2004, medical research has delivered net present health gains from 2000 to 2014 of $1,507 million for a net present cost of $568 million, returning a BCR of 2.7.

Figure 17: Estimated health expenditure (costs) and net health gains (benefits) of medical research in mental health ($million, 2018 dollars)



Source: KPMG analysis

The sensitivity analysis (*Table 4*) highlights that the results are relatively robust to changes in the key parameters, with the exception of the start date for the CBA. Expenditure in mental health medical research increased dramatically during the 2000s, while the health gains delivered continue to rise at a relatively linear rate.

Table 4: Sensitivity analysis of mental health results

Assumptions	BCR
Lower estimate of research expenditure	4.1
Lower Australian contribution: 3 per cent	1.6
Higher Australian contribution: 10 per cent	5.3
15-year time lag	2.1
20-year time lag	1.6
DALY value of $25,000	1.2
DALY value of $75,000	4.1
Later CBA starting date (2000)	0.7
Discount rate 0 per cent	3.8
Discount rate 3.5 per cent	2.9

Source: KPMG analysis

4.2.3 HIV case study

Background

The Human Immunodeficiency Virus (HIV) has affected countries across the world, with an estimated 36.7 million people living with HIV.[104] Extensive research towards effective and sustainable treatments has taken place which has dramatically increased the health and life expectancy of those living with HIV.

Figure 18: HIV Milestones

Source: KPMG consultation with disease experts

Four key milestones have enabled people living with HIV to continue with their day to day lives, as shown in *Figure 18*. Based on consultation with industry experts, Australia actively contributed to all milestones and a signification number of publications. Unlike other conditions, Australian guidelines for HIV are based on the US Department of Health and Human Services Guidelines and are updated contemporaneously with guidelines from the World Health Organisation (WHO) and various other European and British guidelines.[105] Commentary and recommendations are provided about the Australian context around the US guidelines. This adds another consideration when determining the precise quantitative contribution.

Diagnosis and Treatment

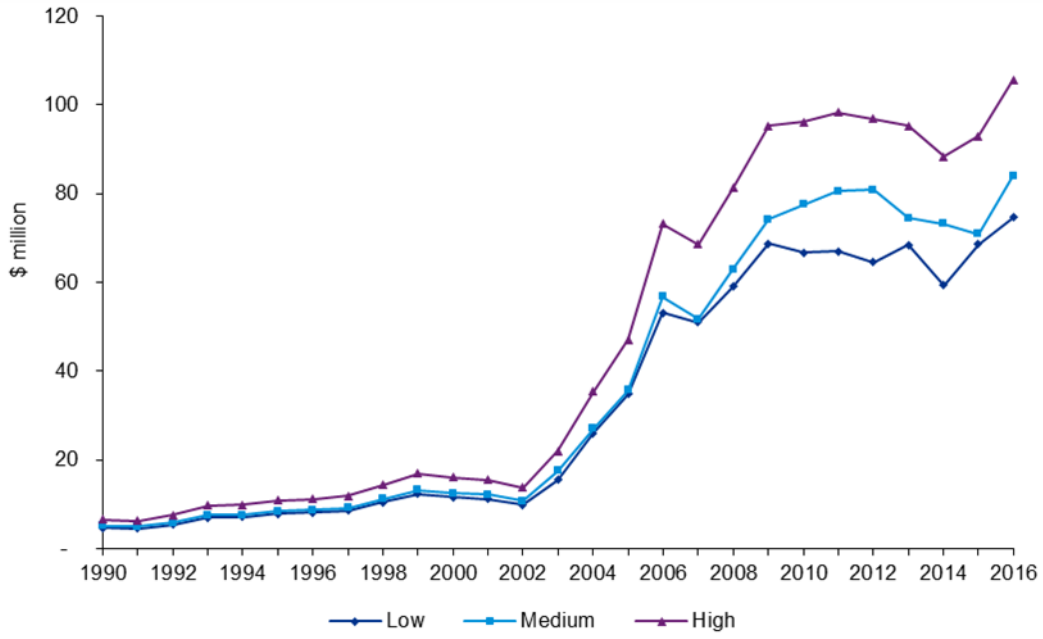
A critical event that supported the advancements in HIV treatment was the Strategic Timing of Antiretroviral Therapy (START) trial. In partnership with three other international research centres, the Kirby Institute at the University of New South Wales (UNSW)[106] set up four national centres in 1986. Australia quickly progressed from a country with no HIV capabilities, to identifying the type of virus causing acquired immunodeficiency syndrome (AIDS). The established capacity of testing of antibodies, isolation and virus meant that Australia was able to detect and test HIV strains. Although this started in a research setting, testing was rapidly commercialised.[107] Outcomes of the START trial influenced the duration of treatment for people with HIV, regardless of their clinical status of CD4 count.[108]

In addition to progressing HIV treatment, a multi-disciplinary approach to patient care was established for HIV patients. Social workers and other health professionals were introduced to support and facilitate patient care and this approach was later introduced into other settings.[109]

Medical research expenditure on HIV

The overall medical research expenditure on HIV was estimated from the proportion of NHMRC funding directed towards HIV. It has risen from $5 million in 1990 to over $80 million today.

Figure 19: Medical research expenditure on HIV ($ million, nominal)

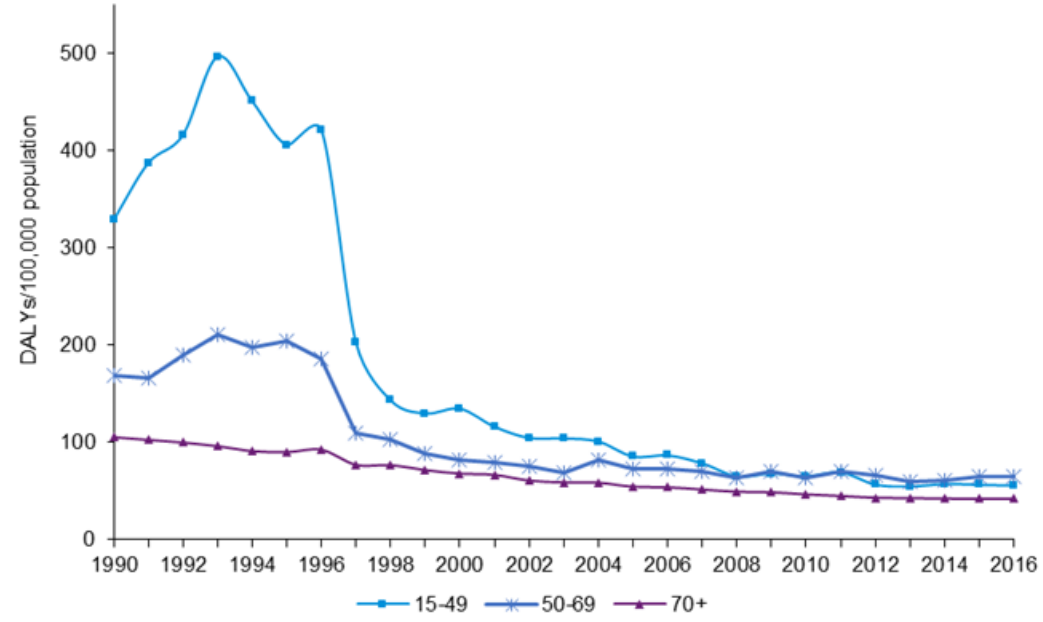


Source: KPMG Analysis, NHMRC, 2018

The health gains from medical research

A literature review and consultation with leading Australian HIV experts suggest that the development and adoption of antiretroviral treatments in the early 1990s has directly resulted in the significant reduction in the burden of disease of HIV, particularly for male adults (*Figure 20*).[110]

Figure 20: Male HIV DALY rates by age group



Source: Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017. Available from http://ghdx.healthdata.org/gbd-results-tool. Accessed 21 July 2018.

The costs to deliver these gains were estimated from a Department of Health CBA that found first and second line ART treatment costs of around $15,000 per year[111]. Inspection of the current PBS listings do not show clear evidence of significantly higher or lower costs across the range of ARTs considered.

The direct and indirect health care savings from improved HIV health outcomes were estimated based on patient and carer data from the CBA completed by the Department of Health, which decomposed healthcare costs by level of CD4 count. On average, it found a healthcare cost differential of approximately $7,200 per year in current dollars for HIV infections with a CD4 count of <200 versus >500.[112] The crude share of patients at each CD4 group was estimated from Australian HIV observational database annual reports.[113]

The Australian contribution

It is evident that Australian advancements in research have been a significant contributor to HIV research around the world. In particular, the Kirby Institute has conducted a number of HIV trials over the past two decades which have engaged key leaders to create change treatment. This includes facilitating the Sydney centre of the International Network for Strategic Initiatives in Global HIV Trials (INSIGHT) study, which aimed to create collaboration of HIV research on an international scale.[114]

More recently, results from the Australian research trial *"Efficacy of 400 mg efavirenz versus standard 600 mg dose in HIV-infected, antiretroviral-naive adults"* (ENCORE1), has enabled more people in low and middle-income countries to be treated for HIV. Not only has Australian medical research impacted the Australian economy, it has also shifted treatment internationally.[115]

To ascertain Australia's contribution, two key guidelines related to HIV treatment were identified and analysed.[116] [117] KPMG found that:

- 3 per cent of the references cited in the guidelines contained Australian authors
- 4 per cent of the references cited in the guidelines contained Australian authors, when weighted by citations
- Experts suggested a substantially higher level of Australian contribution.

We therefore adopted a base case rate of 5 per cent, with a sensitivity of 3 per cent and 10 per cent.

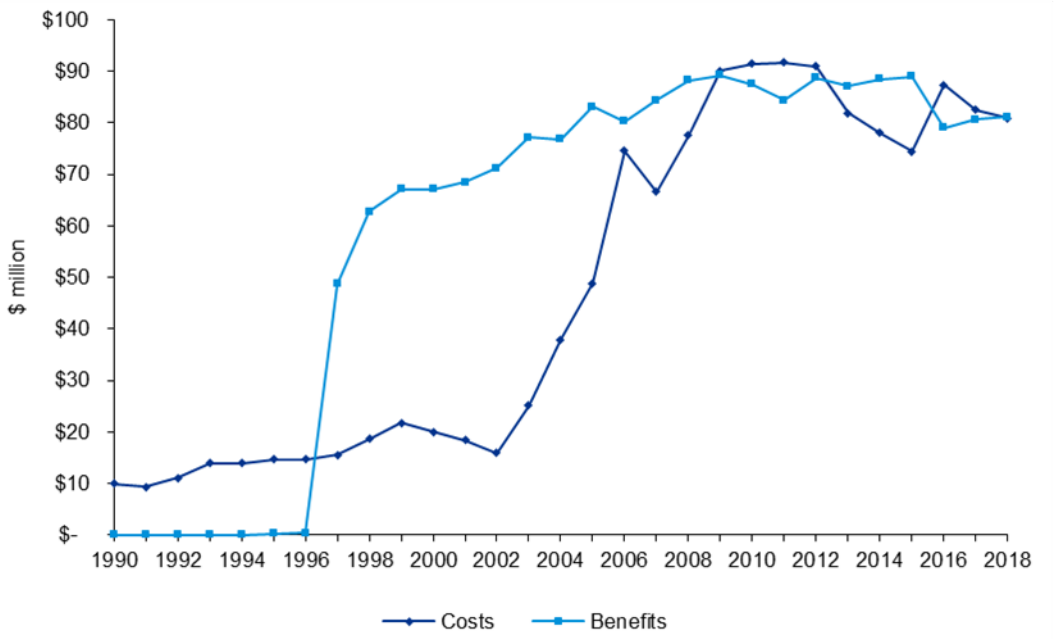
The lag time

The lag time between HIV research and benefit is particularly short. The analysis of references cited in the guidelines above indicated an average knowledge cycle time of just three years. Adding three years for time between funding and publication, and two years for adoption of guidelines, we adopt a lag time for HIV of eight years. The short lag time is thought to be associated with the active involvement of HIV patients and clinicians in research. Consequently, when a treatment of method of testing demonstrated promising results, uptake by clinicians into practice was relatively rapid.[118]

The overall net health gains and return on investment

For the period of investment from 1990 to 2005, medical research has delivered net present health gains from 1998 to 2012 of $424 million for a net present cost of $168 million, returning a BCR of 2.5.

Figure 21: Estimated health expenditure (costs) and net health gains (benefits) of medical research in HIV ($million, 2018 dollars)



Source: KPMG analysis

The sensitivity analysis (*Table 5*) highlights the results are relatively robust to changes in the key parameters, with the exception of the start date for the CBA. Expenditure in HIV medical research increased dramatically during the 2000s, while the health gains delivered continue to rise at a relatively linear rate, such that current medical research into HIV is estimated to be larger than current health gains attributable to Australian medical research.

Table 5: Sensitivity analysis of HIV results

Assumptions	BCR
Lower estimate of research expenditure	2.7
Lower Australian contribution: 3 per cent	1.5
Higher Australian contribution: 10 per cent	5.0
15-year time lag	1.8
20-year time lag	1.3
DALY value of $25,000	1.0
DALY value of $75,000	4.0
Later CBA starting date (2000)	0.7
Discount rate 0 per cent	3.5
Discount rate 3.5 per cent	2.8

Source: KPMG analysis

4.2.4 Extrapolating from the case studies

Combining the case studies together delivers an overall health gains BCR of 2.6. Extrapolating this BCR across wider Australian medical research results in a net present value of health benefits of $52 billion from investment of $20 billion in medical research from 1990-2004. These results highlight the health gains from medical research; they do not include the wider economic gains which are calculated in the next section.

Table 6: Weighed average health gains BCR ($NPV million)

Case study	Benefits	Costs	BCR
HPV	$56	$42	1.3
Mental health	$1,507	$568	2.5
HIV	$424	$168	2.7
Sum of case studies	$1,987	$778	2.6
Medical research extrapolation using BCR from case studies	$51,727	$19,895	2.6

Source: KPMG analysis

4.3 Wider economic benefits

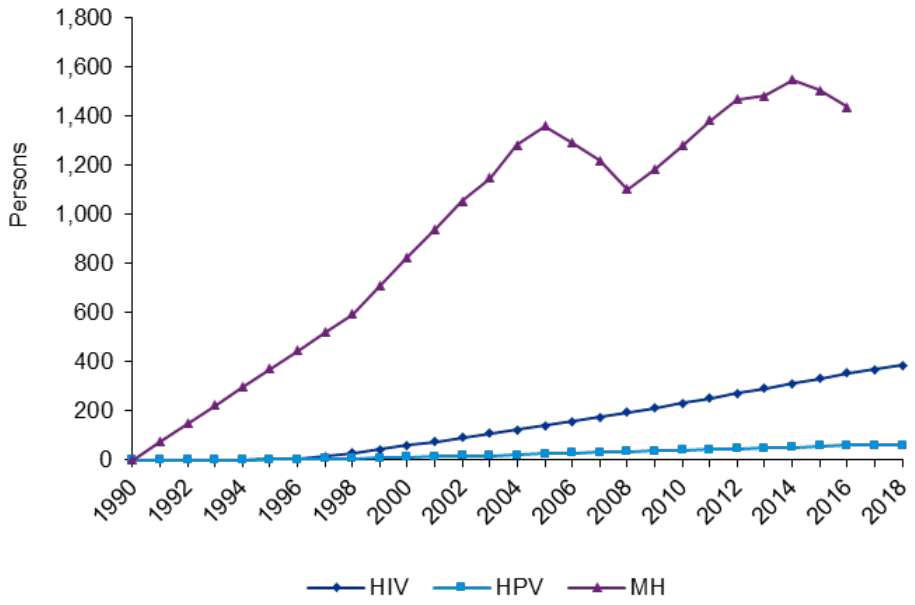
This section presents the overall economic benefits of the gains in the workforce size and productivity due to Australian medical research. These estimates are presented as deviations from the scenario in which the historical Australian expenditure on the medical research did not occur.

4.3.1 Productivity impacts of medical research

The health gains from Australian medical research have resulted in a larger and more productive workforce. In HPV and HIV, the gains resulted directly in a larger workforce; in mental health, the gains manifest in higher productivity of the current workforce which have been converted to an equivalent increase in the size of the workforce based on a 4 per cent productivity improvement due to improved mental health[119].

In total, KPMG estimate that today's workforce is around 1,900 FTEs larger because of historical Australian medical research into HIV, mental health and HPV. When extrapolated to medical research across all diseases, this suggests that the workforce is over 23,000 FTEs larger than it would been in the absence of historical Australian medical research.

Figure 22: Workforce gains due to Australian medical research

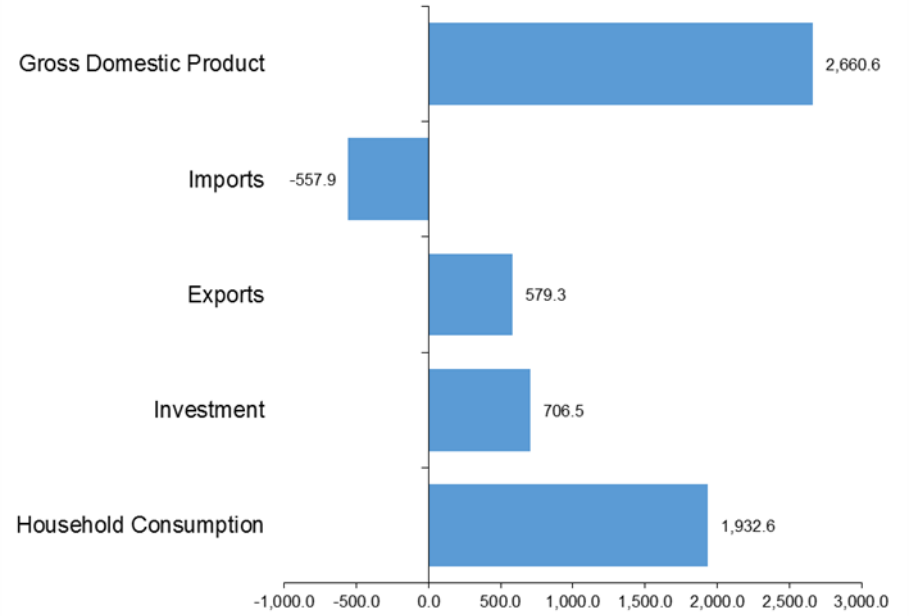


Source: KPMG analysis

4.3.2 Economy-wide impacts of medical research

The economy-wide impacts of the gains in the workforce size and productivity due to Australian medical research activity were estimated using KPMG's model of the Australian economy (KPMG-CGE) and are outlined in the following figure.

Figure 23: Average annual economy-wide impacts ($ million change, deviation from baseline)



Source: KPMG Estimates

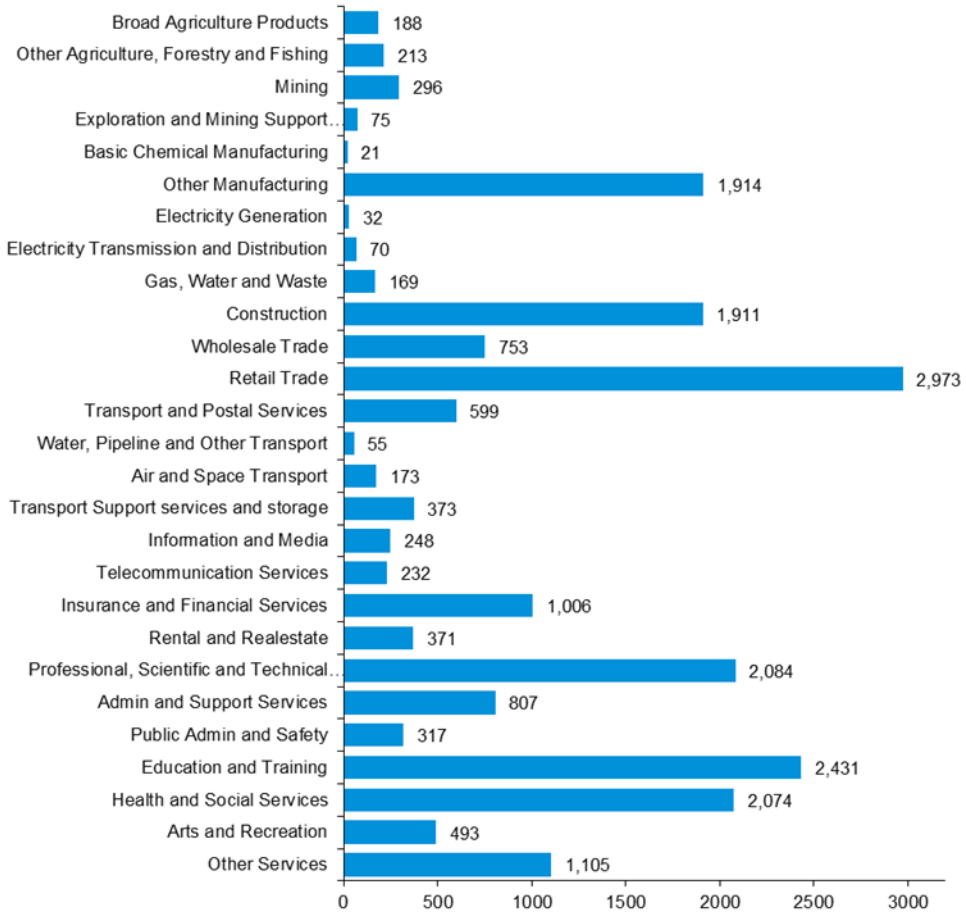
Overall, the results show that historical Australian medical research has resulted in a much larger Australian economy today:

- With more employment, household consumption is $1.9 billion higher than it would have otherwise been in the absence of medical research.
- Investment is $707 million higher, as firms invest in more capital as a result of the larger workforce.
- The gains in the workforce size and productivity due to historical Australian medical research flows through to provide a $2.6 billion boost to Australia's GDP, and an increase in welfare of nearly $1.5 million.
- These gains continue to accrue over time.

4.3.3 Industry Impacts – Employment

Historical Australian medical research has resulted in a healthier and larger workforce. *Figure 24* illustrates how these employment gains have accrued across all industries in the economy, but in particular labour-intensive industries like retail trade, education, health and social services.

Figure 24: Employment impacts by Industry, 2016-17 (Jobs, deviation from baseline)

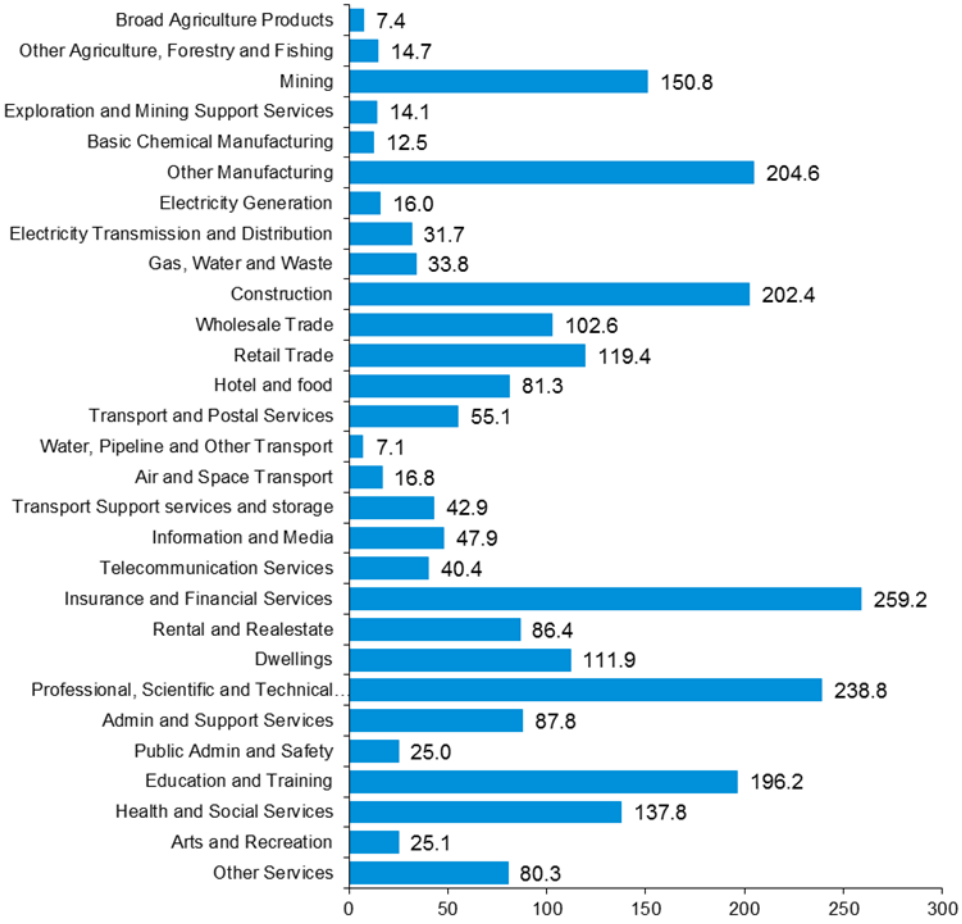


Source: KPMG Estimates

4.3.4 Industry Impacts – Value Added

The gains from historical Australian medical research vary across sectors. The industry distribution of the value added impact is illustrated in the following chart. As per the employment impacts, labour-intensive industries have been the largest beneficiaries, however construction and manufacturing have also benefitted from a larger economy and increased investment. Overall, it is estimated that historical Australian medical research has led to industry value added that is $2.4 billion higher than it would have been in the absence of medical research.

Figure 25: Annual value-added impacts by Industry ($ million change from baseline)

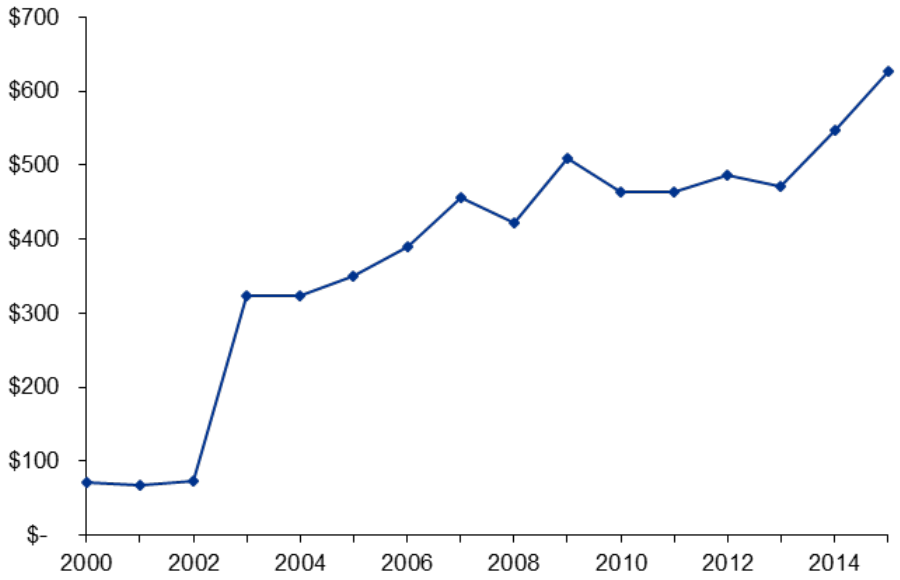


Source: KPMG Estimates

4.3.5 Commercialisation benefits

Commercialisation benefits were estimated from the National Survey of Research Commercialisation (NSRC). Over the period from 2000 to 2015, the medical research component of the overall commercialisation gains estimated by the NSRC has increased from $72 million to $627, and from 5 per cent to 10 per cent as a proportion of overall medical research expenditure.

Figure 26: Value of medical research commercialisation ($ million, nominal)



Source: KPMG analysis of the NRSC

4.4 Overall return on investment on historical medical research

4.4.1 Case studies

When considering the overall return on investment, including health benefits, and the welfare from the wider economic gains, and productivity changes as a result of improved health gains, the BCR for each case study increases to between 1.8 and 4.2. As per the individual case studies, these results are broadly robust to individual changes in the key assumptions, however while the gains from medical research have continued to grow over time, so too has Australia's expenditure on medical research. This resulted in lower BCRs for CBAs that start in 2000, however there are potentially further benefits from medical research that are yet to be discovered that would increase this return.

Table 7: Return on investment from existing health and overall gains

Result	HPV	Mental health	HIV
Health benefit-cost ratio	1.3	2.7	2.5
Overall benefit-cost ratio	**1.8**	**4.2**	**3.2**
Sensitivity analysis (overall benefit-cost ratio)			
Lower estimate of research expenditure	2.1	6.5	3.4
Lower Australian contribution: 3 per cent	1.3	3.1	2.2
Higher Australian contribution: 15 per cent	3.1	6.8	5.7
20-year time lag	1.5	2.6	2.0
DALY value of $25,000	0.4	2.8	1.7
DALY value of $75,000	3.3	5.6	4.7
Later CBA starting date (2000)	1.3	1.0	1.0
Discount rate 0 per cent	2.8	6.0	4.5
Discount rate 3.5 per cent	2.1	4.7	3.5

Source: KPMG analysis

4.4.2 Extrapolating from the case studies

Combining the case studies together yields an overall BCR of 3.9. Extrapolating this BCR across Australian medical research results in an overall net present value of benefits of $78 billion from investment of $20 billion in medical research from 1990-2004.

Table 8: Weighed average overall BCR ($NPV million)

Case study	Benefits	Costs	BCR
HPV	$76	$42	1.8
Mental health	$2,386	$568	4.2
HIV	$538	$168	3.2
Sum of case studies	$2,999	$778	3.9
Medical research extrapolation using BCR from case studies	$77,590	$19,895	3.9

Source: KPMG analysis

5 Conclusion

5.1 Context and comparison with previous research

This research found that overall economic BCRs for medical research into HPV, HIV and mental health of between 1.8 and 4.2. This represents a strong economic return from investment in medical research. A BCR greater than one indicates that the project benefits exceed project costs over the evaluation period, while a BCR less than one indicates that the project costs exceed the project benefits over the evaluation period. In a cost benefit analysis in other sectors, a BCR above 2 is considered high, a BCR between 1 and 2 medium, while a BCR below 1 low[120]. The BCRs estimated for medical research confirm that investing to improve the health of the population has high economic returns.

The findings presented here add to a growing body of research that highlights the strong economic return from investment in medical research. Previous Australian research found exceptional returns across the board of returns with BCRs between 2.2 and up to 5.0 across medical research, and up to 6 and 8 for respiratory and cardiovascular disease respectively[121,122].

In the United Kingdom, the internal rate of return from investment for cardiovascular disease and cancer was estimated at 9 and 10 per cent respectively[123]. The results presented here suggest IRRs of around 12 per cent for HPV, rising to 23 and 26 per cent for HIV and mental health respectively. Despite some methodological differences, the findings across various studies and diseases consistently highlight a strong return on investment from medical research. The comparison also highlights that the return on investment in the case studies presented here are broadly representative of other diseases as diverse as cardiovascular disease and cancer.

5.2 Strengths and limitations

Quantifying the economic benefits of Australian medical research is an inherently difficult task. Medical research is both focused on discovery and translation. The time periods between expenditure in medical research and the realisation of benefits can vary dramatically. Australia's medical research does not occur in isolation, but is directly and indirectly linked to global research efforts. The results presented here should be considered as indicative only, due to a range of limitations, including:

- The complexity of the causal pathway between expenditure on medical research and accrual of health and economic outcomes, and what would happen to these outcomes in the absence of Australian medical research.
- The attribution of health gains to medical research and Australian medical research.
- Quantification of the lag time between medical research and outcomes.
- The assumption that the return on investments delivered by the three case studies are representative of the wider investment in medical research.

Each of the steps in the methodology required assumptions and judgements based on imperfect data, however in line with the approach by the Health Economics Research group of Rand Europe[124], the methodology employed here made a number of improvements over previous Australian research:

- The explicit consideration of the health service costs and benefits associated with delivering the health gains within this analysis.

- The valuation of a Disability Adjusted Life Years (DALY) at $50,000, in line with the opportunity cost of spending on health care rather than medical research.
- A use of case studies from the bottom-up approach linked to the burden of disease to help inform the overall health gains associated with medical research.

In addition, the research provides, to the best of our knowledge, the first Australian evaluation of the return on investment from medical research into HIV and HPV. It is a useful addition to the knowledge base around the economic outcomes from medical research.

5.3 Implications for the future

Medical research is an integral component in Australia's healthcare system and economy. It continues to progress treatment and prevention initiatives for the population, leaving a positive impact across the economy. As shown in the three case studies above, there are substantial existing economic and health benefits realised from medical research.

Since the 1990s, there has been a substantial increase in medical research in Australia. To ensure that medical research continues to deliver 'bang for the buck', there needs to be a focus on translational research that realises the gains of Australia's stock of research that has been built up over the last three decades. The MRFF, with its focus on translational research, will help to ensure that medical research continues to deliver an excellent return on investment by improving health outcomes and growing the economy.

Appendix A: Supporting tables and figures

A.1 Sector Aggregation

A listing of 20 aggregated sectors along with their relationship to the 114 sectors available in the Input-Output data base is shown in *Table 14.*

Table 9: The 2015-16 Input-Output Aggregated Sectors

20 Aggregated Sectors	Input-Output Sectors
1. Agriculture, Forestry and Fishing	Sheep, Grains, Beef and Dairy Cattle, Poultry and Other Livestock, Other Agriculture, Aquaculture, Forestry and Logging, Fishing, hunting and trapping, Agriculture, Forestry and Fishing Support Services.
2. Mining	Coal mining, Oil and gas extraction, Iron Ore Mining, Non Ferrous Metal Ore Mining, Non Metallic Mineral Mining, Exploration and Mining Support Services.
3. Manufacturing	Meat and Meat product Manufacturing, Processed Seafood Manufacturing, Dairy Product Manufacturing, Fruit and Vegetable Product Manufacturing, Oils and Fats Manufacturing, Grain Mill and Cereal Product Manufacturing, Bakery Product Manufacturing, Sugar and Confectionery Manufacturing, Other Food Product Manufacturing, Soft Drinks, Cordials and Syrup Manufacturing, Beer Manufacturing, Wine, Spirits and Tobacco, Textile Manufacturing, Tanned Leather, Dressed Fur and Leather Product, Manufacturing, Textile Product Manufacturing, Knitted Product Manufacturing, Clothing Manufacturing, Footwear Manufacturing, Sawmill Product Manufacturing, Other Wood Product Manufacturing, Pulp, Paper and Paperboard Manufacturing, Paper Stationery and Other Converted Paper Product Manufacturing, Printing (including the reproduction of recorded media), Domestic Appliance Manufacturing, Specialised and other Machinery and Equipment Manufacturing, Furniture Manufacturing, Other Manufactured Products, Petroleum and Coal Product Manufacturing, Human Pharmaceutical and Medicinal Product Manufacturing, Veterinary Pharmaceutical and Medicinal Product Manufacturing, Basic Chemical Manufacturing, Cleaning Compounds and Toiletry Preparation Manufacturing, Polymer Product Manufacturing, Natural Rubber Product Manufacturing, Glass and Glass Product Manufacturing, Ceramic Product Manufacturing, Cement, Lime and Ready-Mixed Concrete Manufacturing, Plaster and Concrete Product Manufacturing, Other Non-Metallic Mineral Product Manufacturing, Iron and Steel Manufacturing, Basic Non-Ferrous Metal Manufacturing, Forged Iron and Steel Product Manufacturing, Structural Metal Product Manufacturing, Metal Containers and Other Sheet Metal Product manufacturing, Other Fabricated Metal Product manufacturing, Motor Vehicles and Parts; Other Transport Equipment manufacturing, Ships and Boat Manufacturing, Railway Rolling Stock Manufacturing, Aircraft Manufacturing, Professional, Scientific, Computer and Electronic Equipment Manufacturing, Electrical Equipment Manufacturing.
4. Electricity, Gas, Water and Waste	Electricity Generation, Electricity Transmission, Distribution, On Selling and Electricity Market Operation, Gas Supply, Water Supply, Sewerage and Drainage Services, Waste Collection, Treatment and Disposal Services.
5. Construction	Residential Building Construction, Non-Residential Building Construction, Heavy and Civil Engineering Construction, Construction Services.
6. Wholesale Trade	Wholesale Trade
7. Retail Trade	Retail Trade
8. Accommodation and Food	Accommodation, Food and Beverage Services.

20 Aggregated Sectors	Input-Output Sectors
9. Transport and Postal Services	Road Transport, Rail Transport, Water, Pipeline and Other Transport, Air and Space Transport, Postal and Courier Pick-up and Delivery Service, Transport Support services and storage.
10. Telecommunication	Publishing (except Internet and Music Publishing), Motion Picture and Sound Recording, Broadcasting (except Internet), Internet Service Providers, Internet Publishing and Broadcasting, Web search Portals and Data Processing, Telecommunication Services, Library and Other Information Services.
11. Insurance and Finance	Finance, Insurance and Superannuation Funds, Auxiliary Finance and Insurance Services.
12. Rental Services	Rental and Hiring Services (except Real Estate), Non-Residential Property Operators and Real Estate Services.
13. Dwelling	Ownership of Dwellings
14. Professional Services	Professional, Scientific and Technical Services, Computer Systems Design and Related Services.
15. Administrative Services	Employment, Travel Agency and Other Administrative Services, Building Cleaning, Pest Control and Other Support Services.
16. Public Administration Services	Public Administration and Regulatory Services, Defence, Public Order and Safety.
17. Education	Primary and Secondary Education Services (including Pre-Schools and Special Schools), Technical, Vocational and Tertiary Education Services (including undergraduate and postgraduate), Arts, Sports, Adult and Other Education Services (including community education).
18. Health	Health Care Services, Residential Care and Social Assistance Services.
19. Arts, Sports and Recreation	Heritage, Creative and Performing Arts, Sports and Recreation, Gambling.
20. Other Services	Automotive Repair and Maintenance, Other Repair and Maintenance, Personal Services, Other Services.

Source: KPMG Analysis

The level of sector disaggregation in the 2015-16 Input-Output tables is a major limitation in capturing the medical research sector linkages with other industries. Input-Output industries that directly relate to medical research in Australia include Human Pharmaceutical and Medicinal Product Manufacturing, Professional, Scientific and Technical Services, Technical, and Tertiary Education Services. However, these industries produce other goods and services in the economy. Thus, it can be difficult to compute the share of medical research in the activities undertaken by these relevant Input-Output industries.

Given the data limitation, KPMG took the following assumptions as a basis for this analysis:

- All activities undertaken by **Human Pharmaceutical and Medicinal Product Manufacturing** industry are directly related to the medical research sector.
- Analysing the 2017-18 Labour Force Survey suggests that only 6 per cent of **Professional, Scientific and Technical Services** activity is related to the medical research sector.
- KPMG utilised the proportion of academic staff in medical sciences and the proportion of research only staff from the studies undertaken by Universities Australia (2018)[1] and Department of Education and Training data (2014)[2] to estimate the share of medical research in the **Tertiary Education** sector. The analysis suggests that just over 6 per cent of activities undertaken by the Tertiary Education sector are directly related to the medical research sector.

Thus analysing inter-linkages for medical research that is conducted within the Professional, Scientific and Technical Services, and the Tertiary Education sector in particular, can be clouded by the inter-linkages of the non-medical research components.

A.2 Medical Research Workforce

Industries reliant on medical research in Australia are significant contributors to the Australian economy. It is estimated that in 2016-17 medical research directly employed over 32,000 researchers and support staff across Australia's universities, medical research institutes and hospitals.

- Australia's **Higher Education sector** brings together health and medical researchers to collaborate on medical research activities. Academic and research staffs in Medical Sciences and Health accounts for 23 per cent of total number of FTEs academic and research staffs in Australia in 2014 (Department of Education and Training data, 2014)[1]. Analysis undertaken by Universities Australia (2018)[2] found that 27 per cent of academic staff are research only, and 46 per cent are both teaching and research staff. KPMG utilised the proportion of academic staff in medical sciences and the proportion of research only staff from the above studies to identify the total number of medical researchers in Australia's Universities from the 2016-17 industry-by-occupation matrix. It is estimated that in 2016-17 there were 21,223 medical research jobs in the higher education sector in 2016-17.
- **Research and Services** sector including **Hospital, Medical Services, Pathology and Diagnostic Imaging, and Scientific Research Services industries** are a major avenue for medical research job creation in Australia. Overall, the industry supported over 10,000 jobs related to health and medical research in 2016-17.
- **Scientific Research Services** - According to the 2016-17 industry-by-occupation matrix there were around 23,666 employees in scientific research services industry. It is estimated that in 2016-17, there were over 8,500 medical researchers in this industry.
- **Hospital** - According to the 2016-17 industry-by-occupation matrix there were over 367,000 employees working in **Hospitals**. Analysing the matrix suggests in 2016-17 there were around 1,289 medical researchers in hospitals, accounting for 0.35 per cent of total employment in this industry.
- **Medical Services** - In 2016-17 there were over 102,000 employees working in **Medical Services** industry. Analysing the 2016-17 industry-by-occupation matrix suggests that there were around 772 medical researchers in medical services, accounting for around 0.75 per cent of total employment in this industry.
- **Pathology and Diagnostic Imaging** - Pathology and diagnostic imaging industry supports over 34,850 jobs in Australia, of which around 0.65 per cent of total number of jobs (227 jobs) in this industry are directly related to medical research.

Table 15 summaries the total number of employment in the medical research related industries and the number of medical research workforce as well as support staff by industry. This does not include the medical research workforce in the medical technologies and pharmaceuticals (MTP) sector.

[1] Science in Australia Gender Equity. (2016 August). *Gender Equity in STEMM*. Retrieved from: http://www.sciencegenderequity.org.au/gender-equity-in-stem/
[2] Universities Australia. (2018). *Data snapshot*.

Table 10: Health and medical research workforce by industry (person, 2016-17)

		Full sector employment	Medical research employment
	Industry	Counts	Counts
Higher Education	Tertiary Ed	184,631	21,233
Research and Services	Hospitals	367,084	1,289
	Medical services	102,841	772
	Pathology and diagnostic imaging	34,851	227
	Scientific research services	23,666	8,575
Total		713,073	32,096

Source: KPMG Estimate

Medical research in Australia is also expected to create jobs in medical research reliant industries. The **medical technologies and pharmaceuticals (MTP)** sector is most impacted and influenced by medical research.

The MTP sector is defined as employing Australian businesses classified within the following ANZSIC Classes[3]:

- Pharmaceutical and medicinal product manufacturing (including human and veterinary pharmaceutical),
- Professional and scientific equipment manufacturing (including 1. photographic, optical and ophthalmic equipment manufacturing, and 2. Medical and surgical equipment manufacturing),
- Professional and scientific goods wholesaling, and
- Pharmaceutical and toiletry goods wholesaling.

Occupations directly related to health and medical research are assumed to fall under MTP. Other occupations outside of this sector are assumed to be indirectly related. Table 41 summarises the total number employees and the number of medical research workforce in the MTP sector.

Analysing the 2016-17 industry-by-occupation matrix suggests that there were over **78,400** employees with different skills in the MTP sector. In the MTP sector, staff are typically employed as medical scientists, health and medical professionals, pharmacists, medical technicians, scientific advisors, project managers, regulatory, safety and quality officers, training and development professionals, engineers and staff focused on data analysis. This includes software and applications programmers, d data managers and statisticians.

[3] For more details see ABS - Characteristics of Businesses in Selected Growth Sectors, Australia, 2013-14, http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/8170.0Main%20Features52013-14?opendocument&tabname=Summary&prodno=8170.0&issue=2013-14&num=&view=

Appendix B: KPMG CGE Model

KPMG-CGE is a multi-sectoral model of the Australian economy that has been specifically designed for policy analysis. KPMG-CGE belongs to the computable general equilibrium (CGE) class of models exemplified by the world-leading ORANI and MONASH models created at the Centre of Policy Studies. KPMG-CGE builds on the ORANI and MONASH traditions by incorporating a number of theoretical and empirical advancements. We briefly describe these features below.

- KPMG-CGE has a flexible simulation design: it can be run in comparative-static or dynamic mode. In dynamic mode, a KPMG-CGE simulation of the effects of a policy change involves running the model twice to create the baseline and policy runs. The baseline is designed to be a plausible forecast of how the economy will evolve over time in the absence of the policy shock of interest. The policy run quantifies deviations of variables from their baseline values caused by the policy shock modelled. In default applications of KPMG-CGE, the paths of most macroeconomic variables are exogenous in the baseline and are set in accordance with forecasts made by KPMG-MACRO, KPMG's macroeconomic model. For specific applications, alternative settings for the paths of macroeconomic variables can be sourced from other forecasting groups (e.g., Treasury). In the policy run, macroeconomic variables are endogenous. With the exception of the policy variables of interest (e.g., tax variables), all exogenous variables in the policy run are assigned the values they had in the baseline run. The differences in the values of variables in the policy and baseline runs quantifies the effects of moving the variables of interest away from their baseline values.
- KPMG-CGE distinguishes 114 sectors and commodities, based on the 2013-14 input-output tables published by the ABS (Australian Bureau of Statistics, 2016a). Primary factors are distinguished by 114 types of capital (one type per industry), nine occupations, two types of land, and natural resource endowments (one per industry).
- A representative firm in each sector produces a single commodity. Commodities are distinguished between those destined for export markets and those destined for domestic sales.
- Production technology is represented by nested CRESH functions (Hanoch, 1971) allowing a high degree of flexibility in the parameterisation of substitution and technology parameters. Energy goods are treated separately to other intermediate goods and services in production, and are complementary to primary factors.
- The supply of labour is determined by a labour-leisure trade-off that allows workers in each occupation to respond to changes in after-tax wage rates thus determining the hours of work they offer to the labour market. The overall supply of labour is normalised on working-age population.
- KPMG-CGE measures the change in welfare as the sum of the changes in real consumption and leisure hours.
- Household preferences are represented by an infinitely-lived representative agent, and household demands for composite goods are determined by maximisation of a Stone-Geary utility function subject to a budget constraint that is consistent with the LES (Stone, 1954). The LES functional form distinguishes between subsistence (necessity) and discretionary (luxury) consumption. Total household spending moves with household disposable income.
- KPMG-CGE includes detailed government fiscal accounts including the accumulation of public assets and liabilities; these are based on the ABS's Government Finance Statistics (ABS, 2016c). On the revenue side, detailed modelling of over 20 direct and indirect taxes and income from government enterprises is included. On the expenditure side, government consumption, investment and payments of various types of transfers (such as pensions and unemployment benefits) are modelled.
- Investment behaviour is industry specific and is positively related to the expected rate of return on capital. This rate takes into account company taxation and a variety of capital allowances, including the structure of the imputation system.

- Foreign asset and liability accumulation is explicitly modelled, as are the cross-border income flows they generate and that contribute to the evolution of the current account; these accounts are based on ABS (2016b). Along with other foreign income flows, such as labour payments and unrequited transfers, KPMG-CGE takes into account primary and secondary income flows in Australia's current account; these are particularly important for Australia as they typically comprise the significant share of the balance on the current account.

Appendix C References

[1] For more details see ABS - Characteristics of Businesses in Selected Growth Sectors, Australia, 2013-14. Retrieved from: http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/8170.0Main%20Features52013-14?opendocument&tabname=Summary&prodno=8170.0&issue=2013-14&num=&view=

[2] The definition is based on the Australian Standard Research Classification (ASRC). ABS (1998), Australian Standard Research Classification (ASRC), a set of classification for R&D projects. Retrieved from: http://www.ausstats.abs.gov.au/ausstats/free.nsf/0/32F7CB57443A341BCA256ADA0001F74B/$File/12970_98.pdf

[3] Economics, L., 2010. The Economic Value of Australia's Investment in Health and Medical Research: Reinforcing the Evidence for Exceptional Returns.

4 Economics, A., 2003. Exceptional Returns: the Value of Investing in Health R & D in Australia. Australian Society for Medical Research.

5 Glover, M., Buxton, M., Guthrie, S., Hanney, S., Pollitt, A. and Grant, J., 2014. Estimating the returns to UK publicly funded cancer-related research in terms of the net value of improved health outcomes. BMC medicine, 12(1), p.99.

[6] Department of Health (2018), Medical Research Future Fund. Retrieved from: https://beta.health.gov.au/initiatives-and-programs/medical-research-future-fund

[7] The World Health Organisation. Health topics: Health systems. Retrieved from: http://www.who.int/topics/health_systems/en/

[8] Research Australia. (2017). Australia Speaks! Research Australia Opinion Polling 2017. Retrieved from: https://researchaustralia.org/wp-content/uploads/2017/08/2017-Opinion-Poll-Digital.pdf

[9] Research Australia. (2017). Australia Speaks! Research Australia Opinion Polling 2017. Retrieved from: https://researchaustralia.org/wp-content/uploads/2017/08/2017-Opinion-Poll-Digital.pdf

"Australians understand health and medical research is important to job creation and economic growth. While the results are not quite as high, a combined 82% believe that health and medical research is very or moderately important for job creation, and 73% believe it drives economic growth."

[10] Bush V, editor. Science: The Endless Frontier A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development. Washington, DC: United States Government Printing Office; Jul1945. Section 3 (The Importance of Basic Research), Chapter 3 (Science and the Public Welfare)http://www.nsf.gov/about/history/nsf50/vbush1945_content.jsp.

[11] Rubio, D. M., Schoenbaum, E. E., Lee, L. S., Schteingart, D. E., Marantz, P. R., Anderson, K. E., … Esposito, K. (2010). Defining Translational Research: Implications for Training. *Academic Medicine : Journal of the Association of American Medical Colleges*, *85*(3), 470–475. http://doi.org/10.1097/ACM.0b013e3181ccd618

[12] Department of Health. (11 April 2016). Review of Health and Medical Research in Australia. Retrieved from: http://www.health.gov.au/internet/main/publishing.nsf/content/review+of+health+and+medical+research+terms+of+reference

[13] All-party Parliamentary Group on Medical Research. (2014 June). A Healthy Future for UK Medical Research. Retrieved from: https://mrc.ukri.org/publications/browse/a-healthy-future-for-uk-medical-research/

[14] Australian Research Council. (2018 June 17). ARC Medical Research Policy. Retrieved from: http://www.arc.gov.au/arc-medical-research-policy

[15] Department of Health. (2018). Budget 2018-19: Portfolio Budget Statements 2018-19, Budget Related Paper No. 1.9, Health Portfolio. Retrieved from: http://health.gov.au/internet/budget/publishing.nsf/Content/2018-2019_Health_PBS_sup1/$File/2018-19_Health_PBS_1.00_Complete.pdf

[16] Department of Industry, Innovation and Science, Growth Centres (2018). Retrieved from: https://www.industry.gov.au/strategies-for-the-future/growth-centres

[17] National Health Medical Research Council. (2017 October 16). NHMRC's mission and functions. Retrieved from: https://www.nhmrc.gov.au/about/nhmrcs-mission-and-functions

[18] https://www.business.gov.au/assistance/venture-capital/biomedical-translation-fund

[19] Department of Industry, Innovation and Science. Biomedical Translational Fund (BTF) (2018) https://www.business.gov.au/Assistance/Venture-Capital/Biomedical-Translation-Fund

[20] Department of Health. (2018 May 8). About the MRFF. Retrieved from: https://beta.health.gov.au/initiatives-and-programs/medical-research-future-fund/about-the-mrff

[21] https://beta.health.gov.au/initiatives-and-programs/medical-research-future-fund/about-the-mrff

[22] Department of Health. (2018 May 8). About the MRFF. Retrieved from: https://beta.health.gov.au/initiatives-and-programs/medical-research-future-fund/about-the-mrff

[23] Futurefund. Our funds. Retrieved from: https://www.futurefund.gov.au/about-us/our-funds

[24] Australian Government, Department of Finance (2017), Portfolio Budget Statements 2017-18, Budget Related Paper No. 1.8, https://www.finance.gov.au/publications/portfolio-budget-statements/17-18/

[25] Australian Institute of Health and Welfare, Health Expenditure Australia 2015-16, Retrieved from: https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure-australia-2015-16/contents/data-visualisations#vis

[26] Department of Health and Human Services. (2018). Victorian Medical Research Acceleration Fund. Retrieved from: https://www2.health.vic.gov.au/about/clinical-trials-and-research/health-and-medical-research/victorian-medical-research-acceleration-fund

[27] Victorian Government, Department of Health and Human Services (2018), Operational Infrastructure Support Program. Retrieved from: https://www2.health.vic.gov.au/about/clinical-trials-and-research/operational-infrastructure-support
[28] Ministry of Health (2018) NSW Medical Research Support Program. Retrieved from: http://www.health.nsw.gov.au/ohmr/Pages/nsw-medical-research-support-program.aspx
[29] Ministry of Health (2018) NSW Medical Research Support Program. Retrieved from: http://www.health.nsw.gov.au/ohmr/mdf/pages/default.aspx
[30] The Sydney Morning Herald, NSW government to give $150 million to cardiovascular disease research, 2 June 2018. Retrieved from: https://www.smh.com.au/politics/nsw/nsw-government-to-give-150-million-to-cardiovascular-disease-research-20180602-p4zj38.html
[31] New South Wales Government, Department of Premier and Cabinet, Researchers receive funding to help fight cancer (2017) Retrieved from: https://www.nsw.gov.au/news-and-events/news/researchers-receive-funding-to-help-fight-cancer/
[32] The Advertiser, State Government commits $40 million to build new research hub, known as SAHMRI 2, 23 November 2015. Retrieved from: https://www.adelaidenow.com.au/news/south-australia/state-government-commits-40-million-to-build-new-research-hub-known-as-sahmri-2/news-story/68409937182e03b3379d968e99514826
[33] Department of Health (2018) Medical and Health Research Infrastructure Fund. Retrieved from: https://ww2.health.wa.gov.au/Articles/J_M/Medical-and-Health-Research-Infrastructure-Fund
[34] Government of Western Australia, Department of Health, Research Translation Projects (2018). Retrieved from: https://ww2.health.wa.gov.au/Articles/S_T/SHRAC-Research-Translation-Projects
[35] Queensland Health (2018). Queensland Advancing Health Research 2026. Retrieved from: https://www.health.qld.gov.au/__data/assets/pdf_file/0036/676188/research-strategy-faq.pdf
[36] QIMR Berghofer Medical Research Institute, Annual Report (2015-16). Retrieved from: https://www.qimrberghofer.edu.au/wp-content/uploads/2015-2016-Annual-Report-QIMR-Berghofer-Final.pdf
[37] Commonwealth Government, Department of Industry, Innovation and Science (2018), 2017-18 Science, Research and Innovation Budget Tables, https://industry.gov.au/innovation/reportsandstudies/Pages/SRIBudget.aspx
[38] Department of Health (2018-19), Portfolio Budget Statements, Budget Related Paper No. 1.9, https://beta.health.gov.au/news-and-events/news/budget-announces-new-investments-in-health-and-medical-research
[39] T Dyke, W Anderson (2014), The Medical Journal of Australia, Volume 201 / Issue 1, https://www.mja.com.au/journal/2014/201/1/history-health-and-medical-research-australia
[40] To estimate the number of jobs in medical research, the 2016-17 industry-by-occupation matrix has been interrogated. The industry-by-occupation matrix is a table representing the occupational structure of employment by industry across the Australian economy. It combines two sources of occupation data: the Census and Labour Force Survey (LFS), both of which are produced by the Australian Bureau of Statistics (ABS). The Census data provides the distribution of occupations across industries and the LFS provides the latest employment totals by industry and occupation. Jobs where both the occupation and industry are related to medical research to a reasonable extent have been considered.
[41] ABS. (2018). Australian National Accounts: Input-Output Tables. Retrieved from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5209.0.55.0012015-16?OpenDocument
[42] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008 Retrieved from: https://acmedsci.ac.uk/file-download/34943-51b9c5e8a8c41.pdf
[43] Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017. Available from http://ghdx.healthdata.org/gbd-results-tool. Accessed 21 July 2018.
[44] Australian Bureau of Statistics (2018), Australian Demographic Statistics, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202017?OpenDocument
[45] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008 Retrieved from: https://acmedsci.ac.uk/file-download/34943-51b9c5e8a8c41.pdf
[46] Deloitte Access Economics (2003), Exceptional Returns; the Value of Investing in Health R&D in Australia, Prepared for The Australian Society for Medical Research.
[47] Deloitte Access Economics (2003), Exceptional Returns; the Value of Investing in Health R&D in Australia, Prepared for The Australian Society for Medical Research.
[48] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008 Retrieved from: https://acmedsci.ac.uk/file-download/34943-51b9c5e8a8c41.pdf
[49] Deloitte Access Economics (2003), Exceptional Returns; the Value of Investing in Health R&D in Australia, Prepared for The Australian Society for Medical Research.
[50] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008 Retrieved from: https://acmedsci.ac.uk/file-download/34943-51b9c5e8a8c41.pdf
[51] Pharmaceutical Benefits Advisory Committee, 2016. Guidelines for preparing a submission to the Pharmaceutical Benefits Advisory Committee (PBAC Guidelines), version 5.0. Retrieved from: https://pbac.pbs.gov.au/section-3a/3a-9-uncertainty-analysis-model-inputs-and-assumptions.html
[52] Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017. Available from http://ghdx.healthdata.org/gbd-results-tool. Accessed 21 July 2018.
[53] Australian Bureau of Statistics (2018), Australian Demographic Statistics, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202017?OpenDocument
[54] OECD (2018), Labour force participation rate (indicator). doi: 10.1787/8a801325-en (Accessed on 03 August 2018)

[55] National Survey of Research Commercialisation 2015 time series unit data. https://www.industry.gov.au/data-and-publications/national-survey-of-research-commercialisation-nsrc. Accessed July 23rd, 2018.
[56] Department of Education and Training, 2014
[57] https://pbac.pbs.gov.au/section-3a/3a-9-uncertainty-analysis-model-inputs-and-assumptions.html
[58] National Health and Medical Research Council. (2005). Screening to Prevent Cervical Cancer: Guidelines for the Management of Asymptomatic Women with Screen Detected Abnormalities. Retrieved from: https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/wh39_screening_to_prevent_cervical_cancer_150610.pdf
[59] National Cancer Institute. NCI Dictionary of Cancer Terms. Retrieved from: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/papanicolaou-test
[60] National Health and Medical Research Council. (2005). Screening to Prevent Cervical Cancer: Guidelines for the Management of Asymptomatic Women with Screen Detected Abnormalities. Retrieved from: https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/wh39_screening_to_prevent_cervical_cancer_150610.pdf
[61] Koliopoulos, G., Nyaga, V.N., Santesso, N., Bryant, A., Martin-Hirsch, P.P.L., Mustafa, R.A., Schünemann, H., Paraskevaidis, E., Arbyn, M. (2017). Cytology versus HPV testing for cervical cancer screening in the general population. Cochrane Database of Systematic Reviews, (8). Art. No.: CD008587. DOI: 10.1002/14651858.CD008587.pub2
[62] Canfell, K., Caruana, M., Gebski, V., Darlington-Brown, J., Heley, S., Brotherton, J., … Saville, M. (2017). Cervical screening with primary HPV testing or cytology in a population of women in which those aged 33 years or younger had previously been offered HPV vaccination: Results of the Compass pilot randomised trial. PLoS Medicine, 14(9), e1002388. http://doi.org/10.1371/journal.pmed.1002388
[63] Canfell,K, Saville,M, Cancer Council Australia Cervical Cancer Screening Guidelines Working Party. National Cervical Screening Program: Guidelines for the management of screen-detected abnormalities, screening in specific populations and investigation of abnormal vaginal bleeding. Retrieved from: https://wiki.cancer.org.au/australia/Guidelines:Cervical_cancer/Screening/Rationale_for_primary_HPV_screening#Primary_HPV_Screening
[64] McNeil, C. (2006). Who Invited the VLP Cervical Cancer Vaccines. *JNCI: Journal of the National Cancer Institute*, Volume 98, Issue 7, 5 April 2006, Pages 433,https://doi.org/10.1093/jnci/djj144
[65] The Editors of Encyclopaedia Britannica. (2017). Ian Frazer. Retrieved from: https://www.britannica.com/biography/Ian-Frazer
[66] The Editors of Encyclopaedia Britannica. (2017). Gardasil. Retrieved from: https://www.britannica.com/science/Gardasil
[67] Therapeutic Goods Administration. Gardasil 9. Retrieved from: https://www.tga.gov.au/sites/default/files/auspar-human-papillomavirus-9-valent-vaccine-170103-pi.pdf
[68] Department of Health and Human Services. (2018). Vaccine history timeline. Retrieved from: https://www2.health.vic.gov.au/public-health/immunisation/immunisation-schedule-vaccine-eligibility-criteria/vaccine-history-timeline
[69] Therapeutic Goods Administration. (2015). Gardasil (quadrivalent human papillomavirus vaccine). Retrieved from: https://www.tga.gov.au/alert/gardasil-quadrivalent-human-papillomavirus-vaccine-update-2
[70] Saraiya, M., Unger, E.R., Thompson, T.D., Lynch, C.F., Hernandez, B.Y., Lyu, C.W., … Goodman, M.T. (2015). HPV Typing of Cancers Workgroup; US Assessment of HPV Types in Cancers: Implications for Current and 9-Valent HPV Vaccines, *JNCI: Journal of the National Cancer Institute* 107 (6). djv086, https://doi.org/10.1093/jnci/djv086
[71] Garland, S. M., Kjaer, S. K., Muñoz, N., Block, S. L., Brown, D. R., DiNubile, M. J., … Velicer, C. (2016). Impact and Effectiveness of the Quadrivalent Human Papillomavirus Vaccine: A Systematic Review of 10 Years of Real-world Experience. Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America, 63(4), 519–527. http://doi.org/10.1093/cid/ciw354
[72] World Health Organization (WHO). Meeting of the Global Advisory Committee on Vaccine Safety, 7–8 June 2017. Weekly Epidemiological Record 2017;92:393-402.
[73] Canfell, K., Sitas, F., & Beral, V. (2006). Cervical cancer in Australia and the United Kingdom: comparison of screening policy and uptake, and cancer incidence and mortality. Medical Journal of Australia, 185(9), 482-486.
[74] Lew, J. B., Howard, K., Gertig, D., Smith, M., Clements, M., Nickson, C., & Kang, Y. J. (2012). Expenditure and resource utilisation for cervical screening in Australia. BMC health services research, 12(1), 446.
[75] Anderson, R., Haas, M., & Shanahan, M. (2008). The cost-effectiveness of cervical screening in Australia: what is the impact of screening at different intervals or over a different age range?. Australian and New Zealand journal of public health, 32(1), 43-52.
[76] Economics, A. (2007). Cost of Cancer in NSW. A report by Access Economics Pty Limited For The Cancer Council NSW.
[77] National Health and Medical Resesarch Council for the Organised Approach to Preventing Cancer of the Cervix. (1993). Screening to Prevent Cervical Cancer: Guidelines for the Management of Women with Screen Detected Abnormalities. Retrieved from: https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/wh16.pdf
[78] Wright Jr., T.C., Thomas Cox, J., Stewart Massad, L., Twiggs, L.B., Wilkinson, E.J., (2002). 2001 consensus guidelines for the management of women with cervical cytological abnormalities. JAMA 287(16):2120–2129. doi:10.1001/jama.287.16.2120
[79] Saslow, D., Runowicz, C.D., Solomon, D., Moscicki, A.-B., Smith, R.A., Eyre, H.J., Cohen, C. (2003). American Cancer Society guideline for the early detection of cervical neoplasia and cancer. CA Cancer J Clin. 52(6):342-62.
[80] Saslow, D., Castle, P.E., Cox, J.T., Davey, D.D., Einstein, M.H., Ferris, D.G., Goldie, S.J., (...), Garcia, F. (2007). American Cancer Society Guideline for Human Papillomavirus (HPV) Vaccine Use to Prevent Cervical Cancer and Its Precursors. CA Cancer J Clin. 57(1):7-28.
[81] Saslow, D., Solomon, D., Lawson, H.W., Killackey, M., Kulasingam, S.L., Cain, J.M., Garcia, F.A.R., (...), Myers, E.R. (2012). American Cancer Society, American Society for Colposcopy and Cervical Pathology, and American Society for clinical pathology screening guidelines for the prevention and early detection of cervical cancer. CA: A Cancer Journal for Clinicians, 62(3), 147-172. http://doi.org/10.3322/caac.21139
[82] Martin, G., (2018). Mental Health stigma is holding back progress. Retrieved from: https://thewest.com.au/opinion/mental-health-stigma-is-holding-back-progress-ng-b88856987z

[83] Briggs, A., Wild, D., Lees, M., Reaney, M., Dursun, S., Parry, D., & Mukherjee, J. (2008). Impact of schizophrenia and schizophrenia treatment-related adverse events on quality of life: direct utility elicitation. Health and Quality of Life Outcomes, 6, 105. http://doi.org/10.1186/1477-7525-6-105
[84] National Institute of Mental Health. (2018). Schizophrenia. Retrieved from: https://www.nimh.nih.gov/health/statistics/schizophrenia.shtml#part_156807
[85] Patrick D McGorry, On behalf of the Australian Early Psychosis Research Network Writing Group. (2015). Australian Early Psychosis Research Network: national collaboration, international competitive advantage. Med J Aust 202 (4): 170-171. || doi: 10.5694/mja14.00914
[86] Galletly, C., Castle, D., Dark, F., Humberstone, V., Jablensky, A., Killackey, E., Kulkarni, J., (...), Tran, N. (2015). Royal Australian and New Zealand College of Psychiatrists clinical practice guidelines for the management of schizophrenia and related disorders. Retrieved from: https://www.ranzcp.org/Files/Resources/Publications/CPG/Clinician/CPG_Clinician_Full_Schizophrenia-pdf.aspx
[87] Australian Bureau of Statistics. (2008). National Survey of Mental Health and Wellbeing: Summary of Results, 2007. Cat. no. (4326.0). Canberra: ABS.
[88] Manicavasagar, V. (2012). A review of depression diagnosis and management. Retrieved from: https://www.psychology.org.au/publications/inpsych/2012/february/manicavasagar/
[89] Australian Bureau of Statistics. (2008). National Survey of Mental Health and Wellbeing: Summary of Results, 2007. Cat. no. (4326.0). Canberra: ABS.
[90] Trautmann, S., Rehm, J., & Wittchen, H. (2016). The economic costs of mental disorders: Do our societies react appropriately to the burden of mental disorders? EMBO Reports, 17(9), 1245–1249. http://doi.org/10.15252/embr.201642951
[91] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008.
[92] McManus, P., Mant, A., Mitchell, P. B., Montgomery, W. S., Marley, J., & Auland, M. E. (2000). Recent trends in the use of antidepressant drugs in Australia, 1990-1998. The Medical Journal of Australia, 173(9), 458-461; AIHW Mental health-related prescriptions, Table PBS.3.
[93] Health Economics Research Group, Office of Health Economics, RAND Europe. Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. London: UK Evaluation Forum; 2008.
[94] KPMG analysis of PBS ATC2 expenditure
[95] Lee, Y. C., Chatterton, M. L., Magnus, A., Mohebbi, M., Le, L. K. D., & Mihalopoulos, C. (2017). Cost of high prevalence mental disorders: findings from the 2007 Australian National Survey of mental health and wellbeing. Australian & New Zealand Journal of Psychiatry, 51(12), 1198-1211.
[96] Jakobsen, J. C., Katakam, K. K., Schou, A., Hellmuth, S. G., Stallknecht, S. E., Leth-Møller, K., ... & Krogh, J. (2017). Selective serotonin reuptake inhibitors versus placebo in patients with major depressive disorder. A systematic review with meta-analysis and Trial Sequential Analysis. BMC psychiatry, 17(1), 58.
[97] Joseph, R., & Birchwood, M. (2005). The national policy reforms for mental health services and the story of early intervention services in the United Kingdom. Journal of Psychiatry and Neuroscience, 30(5), 362–365.
[98] McCrone, P., Craig, T.K., Power, P., Garety, P.A. (2010). Cost-effectiveness of an early intervention service for people with psychosis. Br J Psychiatry 196(5):377-82. doi: 10.1192/bjp.bp.109.065896.
[99] McGorry PD, Edwards J, Mihalopoulos C, Harrigan SM, Jackson HJ (1996). "EPPIC: an evolving system of early detection and optimal management". Schizophrenia Bulletin. 22 (2): 305–26. doi:10.1093/schbul/22.2.305. PMID 8782288.
[100] McGorry, P., Killackey, E., Elkins, K., Lambert, M., Lambert, T. (2003) Summary Australian and New Zealand clinical practice guideline for the treatment of schizophrenia (2003). Australasian Psychiatry, 11: 136-147. doi:10.1046/j.1039-8562.2003.00535.x
[101] Ellis, P., Hickie, I., Bushnell, J., Hirini, P., Stevens, S., Smith, D.A.R. (2004) Australian and New Zealand clinical practice guidelines for the treatment of depression. Retrieved from: https://www.ranzcp.org/Files/Resources/Publications/CPG/Clinician/Mood-Disorders-CPG.aspx
[102] Galletly, C., Castle, D., Dark, F., Humberstone, V., Jablensky, A., Killackey, E., Kulkarni, J., (...), Tran, N. (2015). Royal Australian and New Zealand College of Psychiatrists clinical practice guidelines for the management of schizophrenia and related disorders. Retrieved from: https://www.ranzcp.org/Files/Resources/Publications/CPG/Clinician/CPG_Clinician_Full_Schizophrenia-pdf.aspx
[103] Malhi, G.S., Bassett, D., Boyce, P., Bryant, R., Fitzgerald, P.B., Fritz, K., Hopwood, M., (...), Singh, A.B. (2015). Royal Australian and New Zealand College of Psychiatrists clinical practice guidelines for mood disorders. Retrieved from: https://www.ranzcp.org/Files/Resources/Publications/CPG/Clinician/Mood-Disorders-CPG.aspx
[104] Australian Federation of AIDS Organisation. About HIV. Retrieved from: https://www.afao.org.au/about-hiv/
[105] ASHM. (2014). Antiretroviral Guidelines: US DHHS Guidelines with Australian Commentary. Retrieved from: http://arv.ashm.org.au/arv-guidelines/introduction-to-the-australian-commentary
[106] The Kirby Institute. (2015). Results from world-first clinical trial support early treatment for HIV. Retrieved from: https://kirby.unsw.edu.au/news/results-world-first-clinical-trial-support-early-treatment-hiv
[107] Based on expert consultation
[108] World Health Organisation. (2009). Summary of Major Reommednations: 2009 ART Guidelines for Adults and Adolescents). Retrieved from: http://www.who.int/hiv/topics/treatment/risk-benefit-analysis-when-to-start.pdf
[109] Horberg, M. A., Hurley, L. B., Towner, W. J., Allerton, M. W., Tang, B. T.-T., Catz, S. L., … Quesenberry, C. P. (2012). Determination of Optimized Multidisciplinary Care Team for Maximal Antiretroviral Therapy Adherence. Journal of Acquired Immune Deficiency Syndromes (1999), 60(2), 183–190. http://doi.org/10.1097/QAI.0b013e31824bd605
[110] Canfell, K., Sitas, F., & Beral, V. (2006). Cervical cancer in Australia and the United Kingdom: comparison of screening policy and uptake, and cancer incidence and mortality. Medical Journal of Australia, 185(9), 482-486.
[111] See http://www.health.gov.au/internet/publications/publishing.nsf/Content/illicit-pubs-needle-return-2-toc~illicit-pubs-needle-return-2-app~illicit-pubs-needle-return-2-app-c

[112] ibid
[113] AHOD Annual Report 2012-2017
[114] The Kirby Institute. (2015). Results from world-first clinical trial support early treatment for HIV. Retrieved from: https://kirby.unsw.edu.au/news/results-world-first-clinical-trial-support-early-treatment-hiv
[115] ENCORE1 Study Group. (2014). Efficacy of 400 mg efavirenz versus standard 600 mg dose in HIV-infected, antiretroviral-naive adults (ENCORE1): a randomised, double-blind, placebo-controlled, non-inferiority trial. Lancet 383(9927):1474-1482. doi: 10.1016/S0140-6736(13)62187-X.
[116] Carpenter, C.C., Fischl, M.A., Hammer, S.M., Hirsch, M.S., Jacobsen, D.M., Katzenstein, D.A., Volberding, P.A. (1996). Antiretroviral therapy for HIV infection in 1996. Recommendations of an international panel. International AIDS Society-USA. JAMA.10;276(2):146-54.
[117] Dybul, M., Fauci, A.S., Bartlett, J.G., Kaplan, J.E., Pau, A.K., Panel on Clinical Practices for Treatment of HIV. (2002). Guidelines for using antiretroviral agents among HIV-infected adults and adolescents. Ann Intern Med 3;137(5 Pt 2):381-433.
[118] Roehr, B. (2018). David Cooper: brought HIV research and treatment to resource- poor settings. BMJ 361 doi: https://doi.org/10.1136/bmj.k1567
[119] KPMG analysis of McTernan, W. P., Dollard, M. F., & LaMontagne, A. D. (2013). Depression in the workplace: An economic cost analysis of depression-related productivity loss attributable to job strain and bullying. Work & Stress, 27(4), 321-338.
[120] Persson, J. and D. Song (2010), "The Land Transport Sector: Policy and Performance", OECD Economics Department Working Papers, No. 817, OECD Publishing, Paris. http://dx.doi.org/10.1787/5km3702v78d6-en
[121] Economics, L., 2010. The Economic Value of Australia's Investment in Health and Medical Research: Reinforcing the Evidence for Exceptional Returns.
122 Economics, A., 2003. Exceptional Returns: the Value of Investing in Health R & D in Australia. Australian Society for Medical Research.
123 Glover, M., Buxton, M., Guthrie, S., Hanney, S., Pollitt, A. and Grant, J., 2014. Estimating the returns to UK publicly funded cancer-related research in terms of the net value of improved health outcomes. BMC medicine, 12(1), p.99.
[124] Medical research – what is it worth?
[1] Universities Australia. (2018). Data snapshot.
[2] Science in Australia Gender Equity. (2016 August). Gender Equity in STEMM. Retrieved from: http://www.sciencegenderequity.org.au/gender-equity-in-stem/