Deloitte Access Economics

Returns on NHMRC funded Research and Development

Australian Society for Medical Research

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Glossary of acronyms

ABS	Australian Bureau of Statistics
AIHW	Australian Institute of Health and Welfare
ANZSRC	Australian and New Zealand standard research classification
ASMR	Australian Society for Medical Research
B/C	benefit / cost (ratio)
CPI	consumer price index
CVD	cardiovascular disease
DALY	disability adjusted life year
DEEWR	Department of Education, Employment and Workplace Relations
DIISR	Department of Innovation, Industry, Science and Research
DOHA	Department of Health and Ageing
DWL	deadweight loss
GBD	global burden of disease
GDP	gross domestic product
MD	muscular dystrophy
NAC	National Asthma Council
NHMRC	National Health and Medical Research Council
NIH	National Institutes of Health
OBPR	Office of Best Practice Regulation
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
ROI	return of investment
SEO	socioeconomic objective
SIDS	sudden infant death syndrome
US	United States
VSL(Y)	value of a statistical life (year)
WHO	World Health Organization
WTP	willingness to pay
YLD	years of life lost to disability
YLL	years of life lost to premature mortality

Foreword

Australian health and residential aged care expenditure is projected to increase from $85 billion to $246 billion (189%) in the period 2003 to 2033 (Goss, 2008). Health Research and Development (R&D) has the potential to enhance the longevity and quality of life for all Australians, and concomitantly slow the burgeoning health expenditure trajectory. This study estimates the economic benefit returned between 2040-2050 as a result of NHMRC investment in health R&D between 2000-2010 across the five diseases: cardiovascular disease (CVD, including stroke); cancer; sudden infant death syndrome (SIDS); asthma; and muscular dystrophy (MD), which collectively form approximately 40% of the burden of disease in Australia.

The past decade of investment through NHMRC has the potential to return considerable benefits, including:

Gains in wellbeing

- The aversion of 98,426 disability-adjusted life years (DALYs) valued at $6 billion

Avoidance of direct health expenditure costs

- The avoidance of $581 million in direct health system expenditure

Reduction in indirect costs

- The aversion of $385 million in indirect costs, including productivity losses incurred through premature mortality and morbidity related reductions in workforce participation

Commercialisation

- The estimated commercial benefit across the disease groups is $1.6 billion

The findings of this report suggest NHMRC funded R&D has the potential to avert a significant proportion of the burden of disease in Australia, which is borne primarily by individuals through morbidity and mortality, but also by society through increased demands on health services.

Dr Emma Parkinson-Lawrence

President

Australian Society for Medical Research

Executive summary

Almost two-thirds of the projected increase in Australian government spending to 2049-50 is expected to be on health (Commonwealth Government, 2010). Total health and residential aged care expenditure is projected to increase by 189% in the period 2003 to 2033 from $85 billion to $246 billion - an increase from 9.3% of gross domestic product (GDP) to 12.4% in 2032–33 (Goss, 2008). Moreover, disease and injury presents a socioeconomic burden from loss of longevity and quality of life for individuals and the community.

Investment in increasingly effective and efficient technologies has the potential to ameliorate some of this projected increase in health burden in Australia. In 2009, the NHMRC invested approximately $711 million on health research and development (R&D), equivalent to 0.23% of GDP, targeted in particular to diseases which pose a significant health burden to Australia.

This study estimates the economic benefits to Australian society of the NHMRC's contribution to health and medical research, by estimating wellbeing gains for specific diseases, namely cardiovascular disease (CVD, including stroke), cancer, sudden infant death syndrome (SIDS), asthma and muscular dystrophy (MD). These diseases collectively comprise approximately 40% of the total burden of disease in Australia (Begg et al, 2007), representing a significant health burden on Australian society and the health system. This study estimates the impacts of NHMRC funded R&D for these diseases between the years 2000 and 2010 on projected gains in health system expenditures, productivity gains and commercial returns for each disease in the years 2040-2050.

The outcomes are measured in terms of:

1. the net benefit (in $ million) – the sum of the discounted benefits minus the cost of the NHMRC expenditure streams;
2. the Benefit/Cost (B/C) ratio – benefits divided by costs; and
3. the ROI – the B/C ratio minus one, expressed as a percentage.

These metrics all represent slightly different ways of measuring the benefits derived from health R&D, taking into account the scale of the existing investment, i.e. they represent the net gains. For example, an ROI of 178% would mean that returns to the value of 178% of the original investment would be expected. Projected benefits are discounted to take into account society's preference to experience benefits in nearer rather than more distant years, resulting in the value of these gains diminishing over time.

NHMRC expenditure

To form the 'cost' side of this evaluation, NHMRC expenditure data were estimated annually for the period 2000 to 2010 and indexed to 2011 prices to account for inflation.

- From 2000 to 2010, NHMRC funding for CVD R&D showed a real increase from around $44 million in 2000 to $114 million in 2010, cancer R&D funding increased

from approximately $41 million to $168 million, asthma showed an increase in funding from $6 million to $20 million, MD R&D funding increased from nearly $2 million to $5 million, and finally SIDS experienced a decrease in funding from $0.6 million to $0.3 million. In total, NHMRC invested $2.2 billion across the five diseases between the years 2000 and 2010.

Gains in wellbeing

Wellbeing gains are estimated as the reduction in burden of disease and injury across a population, measured in disability adjusted life years (DALYs).

A dollar value can be placed on these gains using the concept of the value of a statistical life (VSL) from the willingness to pay (WTP) literature. A person's WTP, with their available income, to avoid a risk to their healthy life or to purchase a health gain can be translated mathematically into an estimate of the Value of a Statistical Life Year (VSLY). For the current study, a VSLY estimate of $168,166 was used, with a lower bound estimate of $66,821, in line with VSLY value recommended by the Department of Finance and Deregulation. Applying the VSLY to the total number of DALYs averted per year and discounting the values back to 2011 levels provides the value of gains in wellbeing in Australia for each year between 2040 and 2050.

However, only a proportion of these gains, in net present value (NPV) terms, can be attributed to Australian R&D, so the analysis depends critically on four parameters:

1. the proportion of gains attributable to R&D rather than other causes, such as improvements in environmental factors (for example, sanitation) or public policies (for example, health awareness or promotion programs);
2. the proportion of gains attributable to Australian health R&D rather than health R&D from overseas;
3. the proportion of gains attributable to NHMRC R&D rather than other Australian R&D; and
4. the time lag assumed between the mid-point of the R&D expenditure and the mid-point of the wellbeing gains, on average. This was estimated as an average of 40 years.

In wellbeing terms, NHMRC funded R&D between 2000 and 2010 is estimated to return a benefit between the years 2040 and 2050 of approximately:

- $4 billion for CVD;
- $2 billion for cancer;
- $2 million for SIDS;
- $60 million for asthma;and
- a net loss of wellbeing of -$0.3 million for MD.

This net loss for MD should be interpreted not in terms of a lack of effectiveness of recent R&D but rather that current investment levels are not sufficient to reduce the growth in burden of disease for this condition.

Gains to the health system

Gains from health R&D also include costs avoided due to less people using the health care system. Health system gains include costs avoided due to reduced expenditure on hospital services, nursing homes, out-of-hospital general practitioner and specialist medical services, imaging and pathology, prescribed and over-the-counter pharmaceuticals, allied health services and 'other' health care system costs (such as ambulance, aids and appliances and health administration).

The total value of discounted health system costs averted between 2040 and 2050 is approximately:

- $530 million for CVD;
- $162 million for cancer;
- $872 for SIDS;
- $6 million for asthma; and
- -$24,525 for MD.

The negative value of discounted health system costs averted for MD should not be interpreted as R&D leading to increasing costs, but rather the current R&D investment levels have not been sufficient to avert growing health care costs into the future for this disease.

It should be noted that the true value of avoided health system expenditures is not the dollar figure saved, but the increase in benefits that have occurred from using these resources elsewhere in the economy. This study does not estimate these benefits.

Productivity and other indirect gains

In addition to avoiding direct health system costs, an increase in wellbeing provides additional benefits to the economy and society by avoiding associated indirect costs, including: productivity gains from the avoidance of premature mortality and morbidity; avoided carer costs; avoided aids and home modifications costs; and avoided deadweight loss (DWL) associated with government transfers such as taxation revenue forgone and welfare and disability payments.

Estimates of the indirect costs avoided due to improved wellbeing from NHMRC funded R&D were calculated from previous Access Economics cost of illness studies. The total projected value of discounted indirect costs averted by NHMRC R&D between the years 2040 and 2050 is approximately:

- $402 million for CVD;
- $236 million for cancer;
- $0.1 million for SIDS;
- $42 million for asthma; and
- -$0.7 million for MD.

The major source of averted indirect costs was in productivity gains through the avoidance of premature mortality, as well as the increased employment participation and reduced absenteeism associated with the avoidance of morbidity.

Commercial returns

A large amount of NHMRC funded R&D has yielded valuable commercialisation benefits. In 2011, the value of commercialisation estimated from NHMRC R&D conducted since 1970-71 was $6.1 billion. Comparing this to NHMRC R&D expenditure over the same period ($8.5 billion) yields a commercialisation benefit to cost ratio of 0.72:1. That is, the financial benefits from commercialisation alone would almost be enough to recoup the dollars the NHMRC spends on research before assessing any of the health benefits.

Using this benefit to cost ratio to project the commercial returns for NHRMC R&D funded between 2000 and 2010 gave an estimated commercialisation value of approximately:

- $622 million for CVD;
- $831 million for cancer;
- $4 million for SIDS;
- $113 million for asthma; and
- $20 million for MD.

Total net benefits from NHMRC funded R&D

Two parameters were used to derive the net benefits from R&D:

- the proportion of total health system expenditures borne by individuals, which was estimated as 16.8% (AIHW, 2010); and
- the proportion of productivity losses borne by individuals, which was estimated as 80.4%, given an average personal income tax rate of 19.6% (Deloitte Access Economics, 2011).

As the benefits from improvements in wellbeing are derived from the VSL, and as individuals consider their expected after-tax future earnings and out-of-pocket health system expenditures when revealing their value for healthy life, the proportion of these costs borne by individuals were netted out of the estimated health system expenditure and productivity gains to avoid double counting.

The net benefit from NHMRC R&D over 2000 to 2010 was estimated as approximately:

- $4.39 billion for CVD;
- $1.96 billion for cancer;
- $0.7 million for SIDS;
- $35.4 million for asthma; and
- a net loss of $8.45 million for MD.

The benefit/cost ratios and ROIs can be seen for each disease in Table i.

Table i: Net benefit, B/C ratio and ROI for NHMRC funded R&D by disease

	CVD (inc. stroke)	Cancer	SIDS	Asthma	Muscular Dystrophy
Net Benefit ($m)	**4389.5**	**1958.2**	**0.7**	**35.4**	**-8.5**
Benefit / Cost ratio	6.1	2.7	1.1	1.2	0.7
ROI	509.0	169.9	11.6	22.7	-30.3

Source: Deloitte Access Economics calculations

The results of the sensitivity analysis indicate the 90% confidence interval for each estimate (net benefit, B/C ratios and ROIs) for each disease. These can be seen in Table ii.

Table ii: Sensitivity analysis and 90% confidence intervals for net benefits, benefit/cost ratios and ROIs

Output	Disease	Min	Mean	Max	5%	95%
Net benefit ($m)	CVD	2,265	4,617	7,994	3,147	6,204
	Cancer	913	2,072	3,736	1,348	2,853
	SIDS	0	1	2	0	2
	Asthma	-1	39	97	14	66
	MD	-9	-8	-8	-9	-8
Benefit/Cost ratio	CVD	3.6	6.4	10.3	4.7	8.2
	Cancer	1.8	2.8	4.2	2.2	3.5
	SIDS	0.9	1.1	1.4	1.0	1.3
	Asthma	1.0	1.3	1.6	1.1	1.4
	MD	0.7	0.7	0.7	0.7	0.7
Return on investment (ROI)	CVD	262.7	535.5	927.2	365.0	719.5
	Cancer	79.2	179.7	324.0	116.9	247.5
	SIDS	-6.5	13.5	42.3	1.0	27.1
	Asthma	-0.5	25.1	62.0	9.1	42.5
	MD	-32.1	-30.4	-29.2	-31.2	-29.6

Source: Deloitte Access Economics calculations

Conclusions

- A total of 98,426 DALYs are estimated to be averted in Australia between 2040 and 2050 relative to 2000 burden of disease levels for CVD, cancer, SIDS, asthma and MD combined, as a result of R&D investment between 2000 and 2010.
- The total value of the wellbeing gains for these diseases attributed to NHMRC R&D is estimated to be approximately $6 billion in 2011 dollars, with nearly $4 billion of health gains attributed to CVD R&D.
- The ROI is approximately 509% for CVD, 170% for cancer, 12% for SIDS, 22% for asthma and -30% for MD. As an example, this means that a dollar invested in Australian health R&D for CVD is estimated to return an average net health benefit valued at $5.02. Put another way, the Benefit/Cost ratio for CVD is 6.1, which means

that a dollar invested in Australian health R&D for CVD returns $6.00 in health benefits on average. B/C ratios for the remaining diseases were estimated at 2.7 for cancer, 1.1 for SIDS, 1.2 for asthma and 0.7 for MD.

- The 90% confidence intervals for the net benefits across the diseases suggest that the total combined net benefits from Australian R&D across the five diseases lie somewhere in the range of $4.7 billion to $9.2 billion if the VSLY is valued at $168,166, and between $1.9 billion to $4.1 billion if the VSLY is $66,821.
- Results from sensitivity analysis suggest that net benefits, ROI, and the B/C ratio are most sensitive to the proportion of health gains attributable to world R&D (assumed at 50% in the base case), indicating that changing the value of this parameter would have the most dramatic impact on the resulting estimates of net benefits. The proportion of health gains attributed to NHMRC R&D had the second highest sensitivity ranking, while Australia's contribution to world health R&D showed the lowest correlation to these disease research outputs, and it should be noted that conservative estimates were used for all of these parameters.
- NHMRC funded R&D from 2000 to 2010 in the area of CVD, cancer, SIDS, asthma and MD is estimated to avert a substantial proportion of the projected increases in Australia's health related expenses between the years 2040 and 2050. The combined estimated net benefits expected to be returned in this period include the aversion of 98,426 DALYs valued at $6 billion, the avoidance of $581 million in direct health system expenditure, and the aversion of $385 million in indirect costs, including productivity losses incurred through premature mortality and morbidity related reductions in workforce participation.

Implications

The diseases identified in this study (CVD, cancer, SIDS, asthma and MD) collectively form about 40% of the burden of disease in Australia, representing a significant burden on society and the health system. NHMRC funded R&D has the potential to avert a significant proportion of this burden, which is borne primarily by individuals through morbidity and mortality but also by society by increased demands on health services.

The magnitude of benefits attributed to NHMRC R&D for nearly all diseases examined in this study exceeds the original cost of NHMRC R&D funding. MD, however, shows a net loss, with future burden of disease and health costs associated with this illness exceeding the investment which has been channelled into MD R&D. The implication of this is not that the existent R&D has been ineffective, but rather that the R&D to date has not been of sufficient magnitude to reduce the projected future increases in disability associated with this disease for the Australian population.

1 Introduction

Deloitte Access Economics was commissioned by the Australian Society for Medical Research (ASMR) to examine the relationship between health research and development (R&D) and the future health and wellbeing of the Australian population. This report builds upon the earlier Access Economics reports (2003; 2008a; 2008b) examining the economic benefits of investment in medical research, but in this report the analysis considers R&D funding contributed by the National Health and Medical Research Council (NHMRC), the peak Australian health and medical research funding body, to specific disease areas. The current report examines the return on investment (ROI) for NHMRC R&D funding for particular diseases, comparing the R&D investment in the disease area against outcomes such as improved wellbeing, reductions in direct health expenditure and productivity gains.

1.1 Background

In 2003, Access Economics first developed a methodology to assess the historical ROI to health R&D in Australia over the period 1960-1999. The report was commissioned by the ASMR and was titled *Exceptional Returns: The Value of Investing in Health R&D in Australia* (Access Economics, 2003). The *Exceptional Returns* study estimated the life expectancy and quality of life gains experienced by Australians over the period, in terms of reductions in disability adjusted life years (DALYs), and placed a dollar value on these gains using the concept of the value of a statistical life (VSL) from the willingness to pay (WTP) literature. Only a proportion of these gains could be attributed to Australian R&D, so the analysis depended critically on two parameters:

- the proportion of gains attributable to R&D rather than other factors, such as improvements in environmental factors (for example, sanitation) or public policies (for example, health awareness or promotion programs); and
- the proportion of gains attributable to Australian health R&D rather than health R&D from overseas.

Sensitivity analysis was performed to account for potential uncertainty in relation to these two parameters. The dollar value of the gains attributable to health R&D was then estimated and compared to the annual expenditure on Australian health R&D (both public and private) estimated from Australian Bureau of Statistics (ABS) data.

A similar approach was adopted in a study that estimated the ROI for cancer R&D for the Cancer Institute of NSW (Access Economics, 2008c) and for an updated report on the ROI for Australian health R&D undertaken for the ASMR (Access Economics 2008a). Both studies revisited the two critical parameters from the Access Economics (2003) report, and made use of more recent estimates of the value of a statistical life year (VSLY) that Access Economics has calculated as part of a review of the VSL (Access Economics, 2008d) for Department of Education, Employment and Workplace Relations (DEEWR). They also incorporated more sophisticated sensitivity analysis to provide a confidence interval around the net benefit, ROI and benefit/cost (B/C) ratio findings.

A similar analysis was undertaken in 2008 for the NHMRC (Access Economics, 2008b), which used largely the same methodology as the 2008 ASMR report. However, this analysis solely examined the ROI of NHMRC funded R&D, and therefore developed parameters to determine the proportion of health benefits attributable to NHMRC funded R&D rather than the broader body of Australia R&D.

More recently, a United States (US) study by Manton et al (2009) examined the correlation between research investment across a number of the US National Institutes of Health (NIH) and age-adjusted mortality rates for relevant diseases over the six decades since the establishment of the Institutes. Publicly funded R&D is largely delivered within disease specific institutes in the US, such as the National Cancer Institute, the National Heart, Blood and Lungs Institute, the National Institute of Diabetes and Kidney Diseases, and the National Institute of Neurological Disorders and Stroke, enabling changing patterns in R&D investment in disease specific areas to be captured with a high degree of accuracy. The study found a consistent non-linear, temporal correlation between research funding and reductions in mortality rates across a range of diseases.

This current report examines the ROI of R&D investment by the NHMRC from 2000 to 2010, and in doing so, primarily draws on the methodology developed for the 2008 NHMRC report. However in concordance with the Manton et al (2009) study, the investigation of ROI from R&D is determined individually for a number of key diseases, namely:

- cardiovascular Disease (CVD; including stroke);
- cancer;
- asthma;
- sudden infant death syndrome (SIDS); and
- muscular dystrophy (MD).

These diseases constitute approximately 40% of the total burden of disease in Australia (Begg et al, 2007). While SIDS does not constitute a large burden of disease for the population as a whole, it has been estimated to account for as much as 5% of infant mortality in developing nations (Riccardo et al 2011; Rudan et al 2010).

MD is an illness with a relatively low burden of disease in Australia due to low prevalence, albeit in per capita terms (i.e. for the person experiencing MD) the burden is one of the highest of all conditions (Access Economics, 2007). MD is included in the analysis to provide an exploration of the ROI for a disease area that has experienced relatively few improvements in mortality or morbidity to date, although this may change in future with better understanding of genetics and genetic therapies.

The methodology for measuring the benefits arising from R&D mirrors the earlier 2008 NHMRC study, though with a particular focus on the ROI for specific diseases, and will examine projected health outcomes in terms of health and wellbeing gains, reductions in direct health care expenditure, and indirect benefits, such as productivity gains.

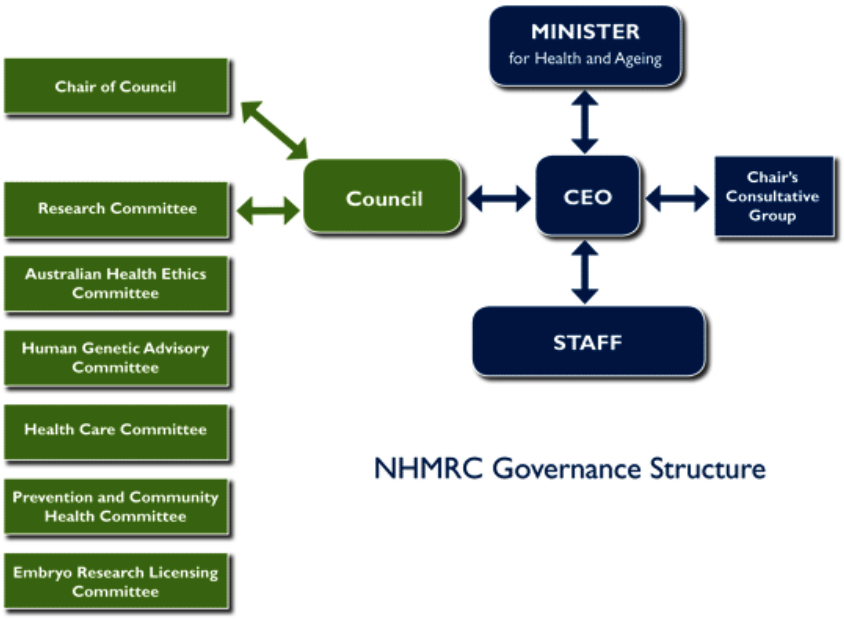
1.2 Roles and activities of the NHMRC

The NHMRC was established in 1936 and became an independent statutory agency on 1 July 2006, within the Australian Government's Health and Ageing portfolio. It is

Australia's peak body for supporting health and medical research, and is also responsible for developing health advice for the Australian community, health professionals and governments, and for providing advice on ethical behaviour in health care and in the conduct of health and medical research.

The governance structure for the NHMRC can be seen in Figure 1.1.

Figure 1.1:NHMRC governance structure



Source: http://www.nhmrc.gov.au/_files_nhmrc/file/about/org/nhmrc-governance-structure.pdf

The NHMRC Act (1992) provides four statutory obligations:

- raise the standard of individual and public health throughout Australia;
- foster the development of consistent health standards between the various states and territories;
- foster medical research and training and public health research and training throughout Australia; and
- foster consideration of ethical issues relating to health.

Under the NHMRC Act, the Health Minister must establish Principal Committees called the Research Committee and the Australian Health Ethics Committee, and may also establish such other Principal Committees the Minister thinks are necessary to assist Council to carry out any of its functions.

For the 2009-12 triennium, the Minister for Health and Ageing –the Hon Nicola Roxon MP, deemed that NHMRC would require the following six Principal Committees in addition to the NHMRC Council.

- The **Australian Health Ethics Committee** has as its primary functions to advise the Council on issues relating to health, and to develop and give the Council human research guidelines under subsection 10(2) of the NHMRC Act.
- The **NHMRC Research Committee** has as its primary to advise and make recommendations to the Council on the application and monitoring of the Medical Research Endowment Account, to monitor the use of assistance provided by the Account, and to advise the Council on matters relating to medical research and public health research, including the quality and scope of such research in Australia.
- The **NHMRC Licensing Committee** has prescribed functions under the national regulatory framework established by the *Research Involving Human Embryos Act 2002* and the *Prohibition of Human Cloning for Reproduction Act 2002*.
- The **Human Genetics Advisory Committee** has as its primary functions to provide ongoing advice on high-level technical and strategic issues in human genetics, and on the social, ethical and legal implications of human genetics and related technologies, to the Council. The Committee also provides national leadership in responding to new developments in these technologies.
- The **Health Care Committee** is a new Principal Committee in the 2009-12 triennium, and its primary purpose is to provide advice to the Council on a range of clinical matters in hospital and primary care settings.
- The **Prevention and Community Health Committee** is also a new Principal Committee in the 2009-12 triennium, and its primary purpose is to provide advice to the Council on issues in community and public health, as well as prevention of illness.

1.2.1 The Wills Review

To focus on the future role of health and medical research up to the year 2010, a Health and Medical Research Strategic Review was commissioned in March 1998 by the then Minister for Health, Dr Michael Wooldridge. The Review was conducted by a committee under the chairmanship of Mr Peter J Wills (AM). The report of the committee, entitled *'The Virtuous Cycle: Working together for health and medical research'* provided some key findings and recommendations for policy action in Australia, many of which have been implemented (Wills, 1998).

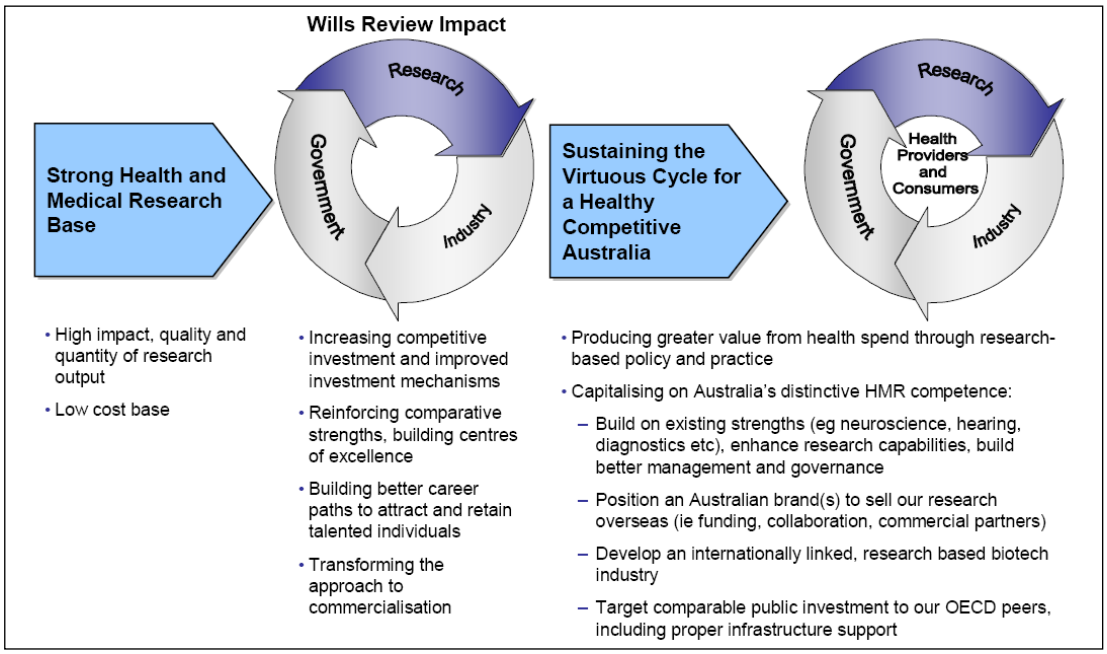
The final report contained 120 strategic recommendations for improving Australia's health and medical research workforce. Those recommendations, and the arguments in support of them, formed a compelling blueprint for change including the injection of an additional $614 million to the NHMRC for health and medical research by the Federal Government over the next six years. This cash injection doubled the Commonwealth's contribution to health and medical research channelled through the NHMRC.

The report noted that there is a potential 'virtuous cycle' between government, research bodies and industry where increased spending in one sector could lead to increased innovation and R&D in another area, thereby generating greater health benefits for all Australians.

In 2004 the Federal Government commissioned a review of the implementation, outcomes, and benefits of the Wills Review called the Grant Review (DoHA, 2004). The Grant Review recommended a number of actions required to sustain the 'virtuous cycle' between

government, research and industry. Figure 1.2 provides a broad overview derived from the Grant Review of the Wills Review impact and the necessary steps required to further improve investment returns from health and medical R&D in Australia.

Figure 1.2: Grant review vision for health R&D in Australia



Source: DoHA (2004).

The Grant Review noted that the 'virtuous cycle' was at risk if changes were not made to the structure of the health and medical research sector and additional investment from government was not made.

The Grant Review recommended a second stage increase in Federal Government funding over five years to follow the increase in funding derived from the Wills Review. The Review recommended a targeted investment by the Government of $1.8 billion per year in order to bring Australian government investment in health and medical R&D as a proportion of gross domestic product (GDP) in line with the average of the Organisation for Economic Cooperation and Development (OECD).

In addition, the Grant Review made several recommendations that focused on four areas to improve the health and medical research market, including research, industry, government and implementation. These are summarised in Table 1.1.

Table 1.1: Summary of Recommendations provided in the Grant Review

Area	Recommendation
Research	Appoint an independent NHMRC board, realign processes and improve resourcing
	Develop an investment program, improve governance, and increase investment
	Refine Project and Program Grants and Fellowships
	Leverage other investment sources to improve capabilities to secure additional investment from the private sector and philanthropy
Industry	Refine Development Grants and encourage further improvement in skills and awareness
	Combine resources to manage commercialisation and ensure all researchers have access to appropriate commercialisation skills and best practice techniques
	Attract $1 billion health research investment from overseas
	Establish a Commonwealth Government supported health and medical research venture fund and extend successful programs
Government	Restructure Research Infrastructure Block Grants and implement recommendations provided by the National Research Infrastructure Taskforce
	Invest in health and medical research priorities
	Develop a framework for institutional collaboration
Implementation	Form an Implementation Committee to focus on urgent actions and transition responsibility to the NHMRC

Source: DoHA (2004).

1.2.2 Expenditure on health R&D since the Wills Review

Following the Wills review, expenditure on health R&D increased significantly, from around $1.7 billion in 1998-99 to $2.8 billion in 2004-05 with an average growth rate of around 12% per year. The increase in health R&D was seen across all sectors – higher education (which undertakes nearly half of health R&D), the business and private non-profit sectors (accounting for approximately one quarter and one seventh, respectively, of health R&D), and the government sector (undertaking the least health R&D, albeit funding the most).

Importantly, since the Wills and Grant reviews there has been substantial change in NHMRC funding. Table 1.2 shows that annual NHMRC expenditure has increased 14.7% per annum on average, from $171 million in 2000 to $754 million in 2011. Total commitments (comprising actual and future awards) have risen similarly over the period, from $164 million to $757 million. The number of grants has also increased (from 1,885 to 4,205) along with the average size of the grant (from $90,807 to $179,479) for the same period.

Table 1.2: Total NHMRC expenditure from 2000-2011

Year	Commitment to new projects		New and continuing grants	
	No	*Commitment*	*No*	*Expenditure*
2000	676	$163,957,000	1885	$171,172,247
2001	902	$291,374,706	2093	$207,810,733
2002	887	$414,853,880	2420	$262,411,488
2003	896	$411,228,908	2554	$310,958,611
2004	939	$349,878,685	2757	$340,874,763
2005	1016	$605,384,823	2936	$409,700,077
2006	976	$484,572,249	3041	$447,092,940
2007	1217	$693,746,092	3409	$524,238,592
2008	1353	$668,497,597	3933	$622,252,138
2009	1321	$773,746,172	4225	$711,218,813
2010	1243	$767,230,258	4261	$744,739,119
2011	1254	$756,561,583	4205	$754,712,721
Total	**12680**	**$6,381,031,953**	**na**	**$5,507,182,242**

Source: NHMRC.

Funding across grant types has not been uniform (Chart 1.1).

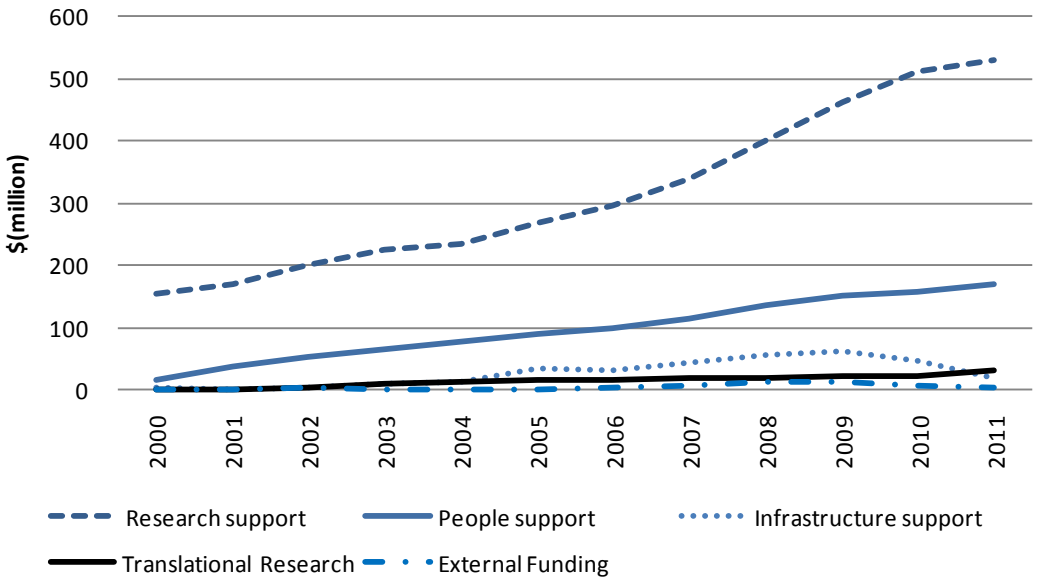
- The greatest increase in annual expenditure in absolute terms was in **research support**, rising from around $154 million in 2000 to $532 million in 2011, a total increase of $377 million (12% per annum on average).

- **People support** had the next highest increase in expenditure, increasing from $15 million in 2000 to $171 million in 2011 (29% per annum on average).

- **Translational research**, a new grant type introduced in 2002, had the third highest absolute increase in expenditure from $4 million in 2002 to $30 million in 2011 (30% per annum on average).

- **Infrastructure support** had the lowest absolute increase in expenditure, increasing from $2 million to $20 million (106% per annum on average).

Chart 1.1: NHMRC expenditure by grant type from 2000-2011



Source: NHMRC.

1.3 Structure of this report

In Chapter 2, the key diseases examined in this study are introduced, providing a background to the disease, contextual information on the policy context and current approaches to the disease, and an outline of epidemiological trends (such as mortality, incidence and prevalence).

In Chapter 3, estimates are provided for expenditure on health R&D in Australia, and in particular by the NHMRC. An overarching analysis of Australian and Commonwealth R&D spending is presented, and NHMRC expenditure around the key diseases is addressed and contrasted against growth in GDP, in nominal and in real terms (current prices).

In Chapter 4, the benefits to Australians from improved wellbeing are addressed, focussing on projected improvements in wellbeing across the key diseases. Projections on the aversion of burden of disease in 2040-2050 are contrasted with the burden of disease experienced in 2000, and these benefits are monetised in 2011 dollars to give an indication of the current value of these wellbeing gains. Also in Chapter 4, the net benefits arising from NHMRC R&D expenditure across the five disease categories are calculated, capturing net benefits, B/C ratio and ROI. Sensitivity analysis is subsequently performed around alternative values for key parameters utilised within the modelling.

Finally, in Chapter 6, conclusions and implications are discussed.

2 Epidemiology of key diseases

This section provides an outline of the key diseases under investigation in this report. For each disease – cardiovascular disease, cancer, asthma, SIDS and MD – there is first a discussion of the historical context of the disease in Australia, including policy approaches and general aetiology. Finally, epidemiological trends from the last two decades are canvassed to highlight any changes in the burden of disease in Australia and globally.

2.1 Cardiovascular disease

Cardiovascular disease is also known as 'circulatory disease' or as 'heart, stroke and vascular disease' and refers to all diseases and conditions of the heart and blood vessels. CVD often presents in the form of the following disease types:

- **Coronary heart disease,** also known as ischaemic heart disease, is the most common cause of sudden death in Australia (ABS, 2009). Coronary heart disease includes acute myocardial infarction (heart attack) and angina. The common underlying problem is atherosclerosis, involving plaque build up on the arterial lumen.
- **Stroke (or cerebrovascular disease)** is Australia's second largest killer attributable to CVD (ABS, 2009), and a leading cause of long term disability in adults. Stroke occurs when a blood vessel that carries oxygen and nutrients to the brain is either blocked by a clot (ischaemic stroke) or, less frequently, ruptures (haemorrhagic stroke). This can cause death, or damage part of the brain, which in turn can impair a range of functions such as movement of body parts, vision and communication.
- **Heart failure** is a major burden on society due to its high costs of care, lower quality of life and premature death (the third biggest CVD killer). It describes a pathologically complex condition where the heart functions less effectively to pump blood around the body. This results from a lifetime of 'insults' to the structural integrity and efficiency of the heart that impair or overload it, such as heart attack, high blood pressure or a damaged heart valve. Symptoms can include fatigue, breathlessness and fluid retention, and these symptoms are related to unmet metabolic demand, abnormal neurohormonal regulation and left ventricular dysfunction.
- **Peripheral vascular disease** refers to disease of the arteries outside the heart and brain, when plaque builds up in these arteries and reduces blood circulation, mainly affecting the legs and feet. It ranges from asymptomatic disease, through to pain on walking, to pain at rest and limb-threatening reduced blood supply that can lead to amputation.
- **Rheumatic heart disease** is the damage done to the heart muscle and heart valves by an attack of acute rheumatic fever, which is caused by Group A Streptococcus bacteria associated with infections of the throat and skin. It occurs mainly in children and young adults and may affect the heart valves, the heart muscle and its lining, the joints and the brain. Recurrences of rheumatic fever lead to cumulative heart damage but can be almost completely prevented by strict follow-up and monthly injections of penicillin. Poverty and overcrowding, poor sanitary conditions, lack of education and limited access to medical care for adequate diagnosis and treatment are recognised as contributing factors in Australia.

- **Congenital heart diseases** continue to contribute toward a significant proportion of mortality in infants less than one year old (ABS, 2009), with congenital complications resulting in mortality well into later childhood years. Congenital heart diseases include abnormalities of the heart, its valves or of blood vessels such as the aorta or pulmonary artery. Symptoms can include breathlessness or failure to attain normal development.

Known risk factors for CVD include risk profiles across genetic, behavioural and biomedical conditions. Social, economic, psychological and cultural factors can also affect health. Age, heredity and being male are key non-modifiable risk factors. Prevention of CVD involves reducing morbidity and mortality in people with and without previously diagnosed disease, known as primary and secondary prevention respectively. In the context of CVD, prevention relates to promoting healthy eating and regular physical activity, reducing salt and saturated fat intakes, quitting smoking, maintaining a weight in the healthy range and reducing high blood pressure and cholesterol levels.

In 1996, CVD was endorsed as a National Health Priority Area, due to the continuing high prevalence of CVD in Australia (DoHA, 2011a). During the 2004-05 financial year, around 11% ($5.9 billion) of total health funding was allocated to CVD (AIHW, 2010a). Tackling CVD through the implementation of population wide preventive health strategies is one of the key tasks of the newly formed Australian National Preventative Health Agency. Additionally, the National Partnership Agreement on Preventative Health[1] outlines a funding agreement between Australian Commonwealth and State and Territory Governments for the delivery of programs which aim to reduce the prevalence of lifestyle factors that increase the risk of CVD and other chronic diseases, such as smoking, obesity and inactivity.

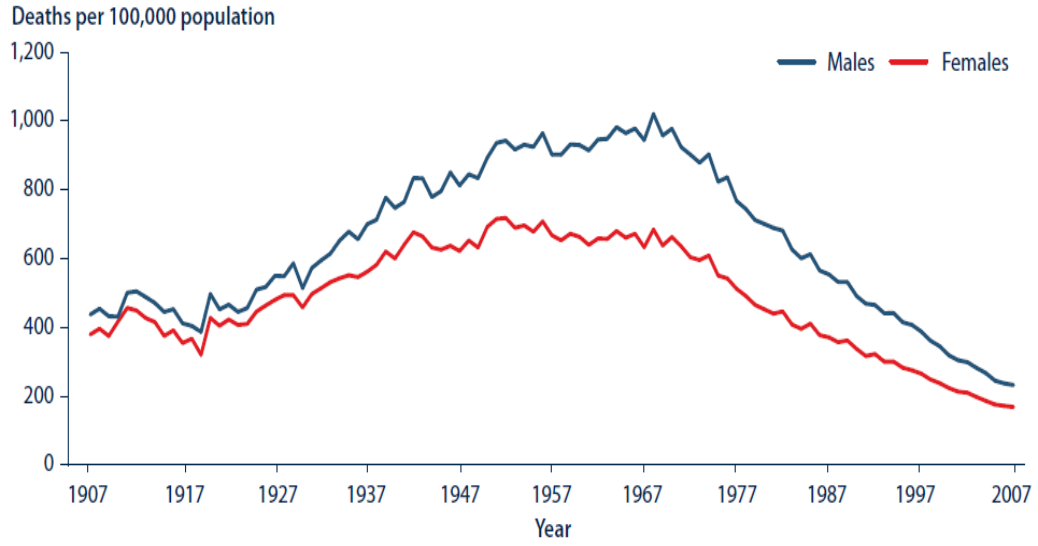
CVD remains a leading cause of mortality (AIHW, 2011) and disability in Australia (Begg et al, 2007), and is also the leading cause of mortality worldwide. The World Health Organization estimates that more than 17.1 million people died from CVD during 2004, representing around 29% of all global deaths (WHO, 2009b). Coronary heart disease (7.2 million deaths) and stroke (5.7 million deaths) contributed the greatest shares of global CVD mortality, with the greatest impact felt among low and middle income countries (WHO, 2009b).

In Australia, CVD continues to dominate the national health profile. One in 16 hospitalisations carry a principal diagnosis of CVD, while an additional one in ten admissions record CVD as an additional diagnosis (AIHW, 2011). Age-standardised rates for CVD hospitalisations in males were 1.6 times greater than females, at 2,599 per 100,000 population versus 1,651 per 100,000, during 2007–2008. Critically, CVD hospitalisation rates increase dramatically with age, with close to 78% of hospitalisations for CVD attributable to those aged 55 and older in 2007-2008 (AIHW, 2011).

CVD remains the principal cause of all deaths in Australia, responsible for 34% of mortalities in 2008 (AIHW, 2011). Death rates in males are higher in every age group cohort than females, although for those aged 85 or older, the difference in death rates between males and females dissipates.

[1] Accessible at: http://www.coag.gov.au/intergov_agreements/federal_financial_relations/docs/national_partnership/national_partnership_on_preventive_health.pdf

Chart 2.1: CVD mortality rates in Australia



Source: AIHW, 2011

Although mortality rates from CVD generally (Chart 2.1) and acute events specifically (heart attack and stroke) have been declining, the mortality burden of CVD remains considerable, and is becoming increasingly associated with periods of chronic disabling illness (notably heart failure).

2.2 Cancer

Cancer describes the uncontrolled growth of cells which lack normal regulatory mechanisms. Cancer cells typically display abnormalities in mechanisms which underlie routine cellular proliferation, differentiation and survival (Cooper, 2000).

Key risk factors for cancer include tobacco use, excess alcohol use, poor diet and physical inactivity. Some infections – such as hepatitis B virus, hepatitis C virus and forms of human papilloma virus – are known to give rise to cancer, and it is estimated that around 30% of cancer deaths are preventable (WHO, 2011).

In Australia, cancer is responsible for the greatest burden of disease (Begg et al, 2007). Cancer was declared a National Health Priority Area in 1996 (DoHA, 2011b). A targeted approach was taken toward eight cancers which carry the highest burden of morbidity and mortality in Australia (AIHW, 2008):

- lung cancer;
- colorectal cancer;
- melanoma;
- non-melanocytic skin cancer;
- prostate cancer;
- breast cancer;
- cervical cancer; and
- non-Hodgkin's lymphoma.

Cancer registries have been in operation since 1972, however, it was only since 1982 that adoption of these registries became universal across all Australian states, and inclusive of the territories by 1991 (NT) and 1994 (ACT) (AIHW, 2008).

In 2008, an estimated 7.56 million people died from cancer-related illnesses worldwide, with males representing over 55% of all mortalities (IARC, 2010). An additional 12.6 million cases of cancer were diagnosed during the same year (IARC, 2010), with the impact largely arising in low and middle income countries. Asia accounted for just under half of these cases (around 6.1 million), with the most prevalent forms of cancer identified as lung (873,063), stomach (727,565), liver (584,440) and breast (528,927) (O'Callaghan, 2011).

The impact of cancer on Australians' heath remains profound. During 2005 alone, over 100,000 new cases of cancer were diagnosed in Australia (AIHW, 2008). Cancer was second only to CVD as the leading cause of mortality in Australia, accounting for around 30% of deaths in 2009 (ABS, 2011). During 2009, the proportion of deaths attributable to cancer in males was estimated at 33%, whereas the proportion was closer to 27% in females. Mortality arising from cancer-related causes continues to account for a high proportion of deaths in Australia, with an ageing population and higher incidence in men and women aged 55 years or older (AIHW, 2008) contributing to its sustained prevalence.

2.3 Asthma

Asthma is a chronic inflammatory condition affecting the largest to the smallest airways. In susceptible individuals, this inflammation can cause recurrent episodes of wheezing, breathlessness, cough, and other symptoms, and is usually associated with widespread and variable airflow obstruction (Norris et al, 2008). The result is 'irritable' bronchial tubes that contract in response to many irritants, leading to increased susceptibility to bronchospasm.

Obstruction to the bronchioles is often reversible, and may occur spontaneously, or with treatment. In addition to bronchospasm and inflammation, some patients also experience airway re-modelling in the form of airway scarring and in loss of lung capacity (Olaguibel et al 2007), which leads to more severe and persistent disease.

While asthma is often diagnosed in childhood, asthma can develop at any time in life, with developmental aetiology arising from hereditary, epigenetic (North and Ellis 2011; Yang and Schwartz, 2011) and environmental factors (Clifford et al, 2011).

Asthma can be related to allergens (atopic, or extrinsic) or can be nonallergic (non-atopic, or intrinsic). Common stimuli which may precipitate an asthma attack include viral particles, exercise, air pollutants, tobacco smoke and a number of specific allergens (ACAM, 2008). Exercise-induced asthma may occur during or following exercise, although the mechanisms underlying it are not well understood.

The Thoracic Society of Australia and New Zealand first published a comprehensive asthma management plan in 1989. This was a world first in provision of national guidelines to tackling asthma. Shortly after this, the National Asthma Council (NAC) was developed, incorporating a number of health stakeholder groups, to champion the better management of asthma in Australia. Since 1999, asthma has been recognised as a National Health Priority Area by the Australian government (Briggs and Buchbinder, 2009).

Despite sustained efforts from the NAC and Government initiatives, current survey evidence suggests that people with asthma may still not be achieving effective management of their asthma. Common problems cited include over-reliance on reliever medication (ABS, 2009), the high incidence of regular symptoms, sleep disturbance, avoidance of exercise, reduced productivity and resistance to pharmacological interventions.

As asthma is both variable and episodic by nature, characterised by both exacerbation and remission, the main challenge for policy makers, health providers, clinicians and affected individuals going forward is to manage the disease chronically.

Due to asthma interventions and public health initiatives during the past two decades, mortality rates associated with asthma have halved, and hospital submission rates have been significantly reduced. Mortality attributable to asthma has fallen since 2000 from 454 to 397 (ABS, 2011). However, asthma remains a disease of substantial prevalence in Australia. The latest estimates from the ABS suggest that around 10% of the Australian population, or 2.05 million Australians, have asthma (ABS, 2009). The sustained prevalence of asthma in recent decades, and continuing morbidity, may be explained in part by both environmental and epigenetic changes (Dietert, 2011). Given dispersed environmental stimuli and allergens arising from industrialised processes and human activity, future management of asthma may continue to be challenging.

2.4 SIDS

SIDS has been described by Sawaguchi and Sawaguchi (2005) as:

> *"a syndrome that causes sudden death of an infant in which the demise of the victim cannot be anticipated by his prior health status or medical history and the cause of death cannot be determined from the circumstances surrounding the final moment or from the results of an autopsy".*

Epidemiological studies have identified a number of contributing factors which may, in part, explain the incidence of SIDS (Leach et al 1999; DiFranza and Lew, 1995; Mitchell and Milerad, 1999; Wilson et al, 2010), such as:

- higher incidence in males;
- low relative birth weight;
- short relative gestation time;
- neonatal delivery complications;
- maternal cigarette smoking;
- seasonal variation in incidence;
- sleeping position; and
- co-sleeping.

Peak mortality has also been observed between four and 16 weeks post partum. Neurobiological, genetic and the "triple risk hypothesis" – general vulnerability, age-specific risks and precipitating factors (among others) – have all been proposed to explain the

incidence of SIDS (Guntheroth and Spiers, 2002; Opdal and Rognum, 2004; Weese-Mayer et al, 2007).

In 1979, SIDS was first listed as a separate category in the International Classification of Diseases[2]. As a result, global recognition of the importance of this disease type is only quite recent. Globally, the incidence of SIDS accounts for as much as 5% of infant mortality in developing nations (Riccardo et al 2011; Rudan et al 2010).

The impact of SIDS-related infant mortality has been better addressed in first world countries. For example, in Sweden, the incidence of SIDS fell from 1.1 per 1000 live births (1992), to 0.41 (1995), and to as low as 0.25 since 2000 (Möllborg and Alm, 2010). Closer to home, the mortality rate attributable to SIDS in New Zealand in 2004 was around 62% lower than that recorded in 1994, at 0.8 per 1000 live births (WHO, 2009a). Simple changes, such as postural sleeping improvements (prone to supine position) and awareness campaigns have weighed-in heavily toward these ends (Nennstiel-Ratzel et al, 2010).

As reported by Wilson et al (2010), following the "Reducing the Risks of SIDS" campaign, infant mortality attributable to SIDS in Australia fell from 1.68 per 1000 live births in 1991 to 0.63 per 1000 live births by 2002. In 2009, there were 78 deaths (0.5 per 1000 live births) attributed to SIDS in Australia (ABS, 2011). The profound reduction in SIDS-related infant mortality in Australia has been abetted by successful national health promotion campaigns ("Reducing the Risk of SIDS", "SIDS and Kids Safe Sleeping"), with a focus on safe sleeping and SIDS prevention. Yet, despite the advancements in our understanding of SIDS, its aetiology, and the corresponding abatement in mortality attributable to ongoing awareness campaigns[3], a strong idiopathic component in the incidence of SIDS remains.

2.5 Muscular dystrophy

MD describes a diverse range of clinical and genetic conditions, which are associated with progressive muscle weakness and degeneration of voluntary skeletal muscle. The various forms of MD differ in terms of the extent and distribution of muscle weakness, age of onset, rate of progression and inheritance pattern. Onset of these progressive myopathies can manifest at any age, typically affecting physiological function across ambulation, posture, cardiac and respiratory function (McNally and Pytel, 2007).

A number of genetic components have been identified in the aetiology of MD, with classification including congenital MD, Becker MD, oculopharyngeal MD, distal MD (Udd, 2011), myotonic dystrophies (Ashizawa and Sarkar, 2011), Emery-Dreifuss MD (Puckelwartz and McNally, 2011), facioscapulohumeral MD (Statland and Tawil, 2011), Duchenne MD (Goyenvalle and Davies, 2011) and limb-girdle MD (Amato 2011). A molecular basis for the characterisation and delineation of these forms of dystrophy has been addressed through recent molecular and genetic bioassays (Bryne et al, 2003).

Duchenne MD is the most common form of MD, with a greater incidence observed in boys relative to girls. Onset of Duchenne MD is typically between three and five years, with

[2] The current World Health Organization International Classification of Diseases and Related Health Problems catalogue can be found at: http://apps.who.int/classifications/apps/icd/icd10online/

[3] The peak body for SIDS awareness in Australia is SIDS and Kids (www.sidsandkids.org).

severe impairment to voluntary muscle control observed by age 12. As Duchenne MD is an X-linked disorder, affected females have a 50% chance of reproductive transmission to subsequent generations. Facioscapulohumeral MD, in contrast, has its onset during adolescence. It affects distal muscular weakness of the face, arms, and legs, but also of the shoulders and chest, to varying degrees. Myotonic MD is particularly common during adulthood, and is physiologically typified by muscular spasms, cardiac and endocrine abnormalities and cataracts.

In Australia, people with MD are typically in need of ongoing care, which may be provided in the community by families or in formal care facilities. Depending on the person's location and community, access to services differs on an individual and geographic basis.

As of 2005, there was an estimated total of 3,457 Australians with MD, of whom 56% were male (Access Economics, 2007). Moreover, 82% of children with MD aged 0-14 years were boys. Most people in Australia with MD have Duchenne MD, limb-girdle MD or myotonic MD, collectively accounting for more than 60% of Australians with MD. The most recent statistics from the AIHW showed that inpatient hospital separations for MD increased from 131 in 1998-99 to 178 in 2007-08 (AIHW National Hospital Morbidity Database).

Morbidity and mortality from MD includes pulmonary complications, cardiac involvement and mental retardation. The relative risk of mortality for MD is very high (424 times the population risk for males and 149 times for females), with 290 deaths from MD estimated in 2005. Of these deaths, 133 (35%) were children aged under 15 years.

3 Expenditure on health R & D

This section presents estimates of expenditure on R&D in Australia. It first describes the methodology for extrapolation of Australian and NHMRC R&D expenditure, and then reviews Australian R&D expenditure by source, scope and group. Finally, this section looks at the expenditure undertaken by the NHMRC in health R&D, and compares the trend in expenditure with Australian health R&D in general, and proportionate to Australian GDP.

3.1 Methodology

3.1.1 Australian expenditure

Since the time of our previous reports (Access Economics, 2008a; 2008b), the ABS has altered their reporting of Australian R&D expenditure data. Australian expenditure on health R&D is no longer provided as estimates derived from public and private (profit and non-profit) institutions; instead, only direct source funding is provided, with provision across socio-economic objective (SEO) to four digits. For example, granularity for determination of R&D funding by sector and source of funding cannot be derived.

Subsequently, Australian expenditure data are based on the Department of Innovation, Industry, Science and Research (DIISR) portfolio budget statement summaries of government support for science, research and innovation, through the budget and other appropriations (DIISR, 2011). Overall R&D funding is available by portfolio activity, and overarching SEO.

Additionally, Commonwealth R&D funding was obtained from the ABS, with top-level field of research delineation available through biannual reporting (ABS, 2010a). For years where Commonwealth R&D funding data were unavailable, an average value was extrapolated from the previous and subsequent years.

3.1.2 NHMRC expenditure

Annual NHMRC R&D expenditure data from 1964 is available in hardback form via annual reports on grant allocations from the Medical Research Endowment Fund. These data were provided to Deloitte Access Economics by ASMR. However, while these annual reports provide a comprehensive list of grant allocations to individual projects over this historical period, they do not classify projects according to the nature of the underlying scientific investigation, nor according to the specific disease being targeted.

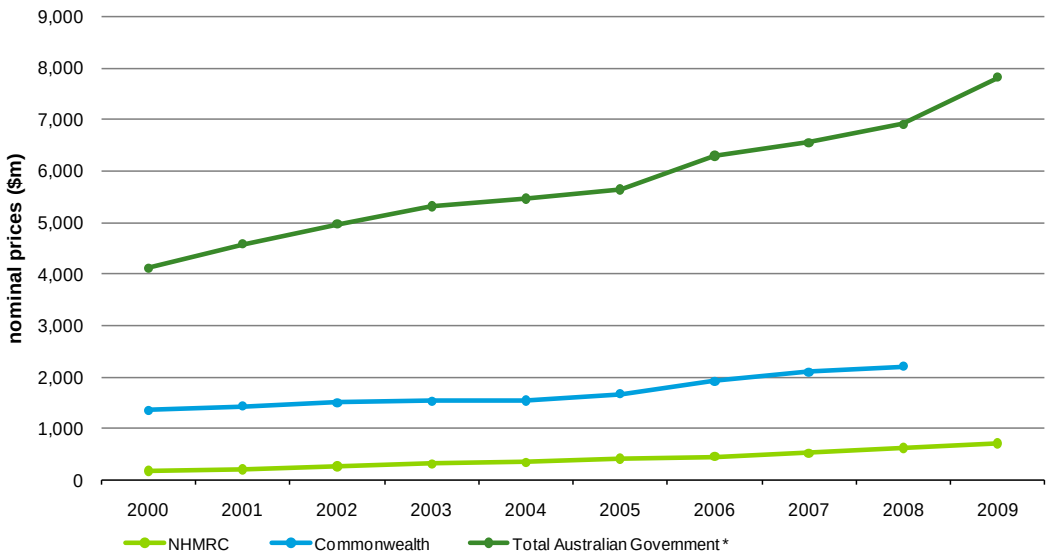
As such, and to avoid erroneous attribution of grant funding to specific diseases, the current study drew on a recent ten year period (2000-2010) of NHMRC funding data, which enables grant allocations targeting specific diseases to be reliably quantified.

3.2 Australian expenditure on health R&D

3.2.1 Comparison of NHMRC and total Australian R&D spending

Chart 3.1 shows how NHMRC expenditure for R&D increased significantly, from around $170 million in 2000 to $711 million by 2009, or around 316%. Commonwealth R&D expenditure and total Australian Government R&D expenditure (inclusive of research, science and innovation) also increased. Commonwealth R&D funding increased steadily to approximately $1.7 billion in 2005, then jumped sharply to $1.92 billion in 2006, and further to $2.2 billion by 2008 – an increase of 63.2% on 2000. Likewise, total Australian R&D funding increased steadily to approximately $5.65 billion in 2005, and then jumped to $6.3 billion in 2006, and again to $7.82 billion by 2008, an increase of around 90% on 2000.

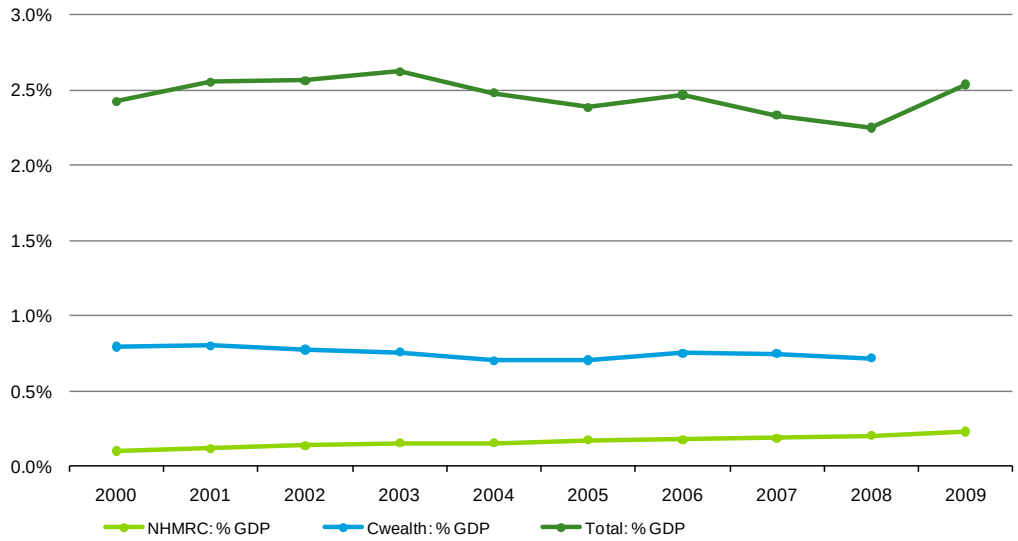
Chart 3.1: Australian R&D expenditure by source, nominal prices ($m)



Source: DIISR, 2009-2011; ABS, 2010a and Deloitte Access Economics calculations. * includes: research, science and innovation.

Although total Australian R&D expenditure increased nominally during the decade, as a proportion of GDP, both Commonwealth and total Australian R&D expenditure remained largely unchanged (Chart 3.2). As a percentage of GDP, Commonwealth R&D funding hovered in the range of 0.7% to 0.8% GDP, dipping slightly from 0.79% in 2000 to 0.72% by 2008. Likewise, total Australian R&D expenditure sat in a range of 2.4% to 2.5% of GDP, rising slightly from 2.43% of GDP in 2000, up to 2.54% of GDP by 2009. In contrast, NHMRC R&D funding increased steadily throughout the decade, rising from 0.10% of GDP in 2000, to 0.17% by 2005, and finally to 0.23% by 2009.

Chart 3.2: Australian R&D expenditure proportion of nominal GDP, (%)



Source: DIISR, 2009-2011; ABS, 2010a and Deloitte Access Economics calculations. * includes: research, science and innovation.

3.3 NHMRC expenditure on health R&D

3.3.1 Classification

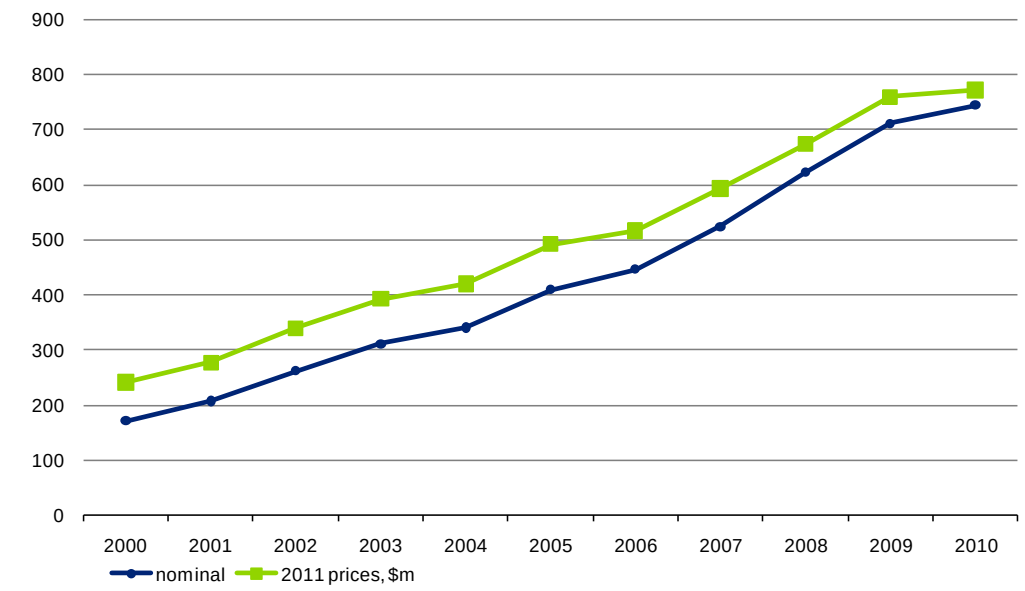
Expenditure on health R&D used within this study is based on the NHMRC grant funding dataset (NHMRC, 2010). NHRMC funding datasets are based upon textual identifiers and programmatic information provided by individual research project chief investigators through the application process. The NHMRC applies subjective criteria for the determination of individual projects by disease group and therapeutic area, and is guided by an internal review process. For specific therapeutic areas, the databases are mined by relevant keywords across selected fields of research and grant types. The search strategy applied by the NHMRC for the therapeutic areas described within this report is outlined in Appendix A, at Table A.1.

3.3.2 Expenditure by therapeutic area

During the past decade, NHMRC funding for R&D has risen considerably, both in nominal and real terms (Chart 3.3Chart 3.3). In nominal terms, during the period from 2000 to 2010, total NHMRC R&D funding increased dramatically, rising almost 335% from $ 171.2 million (2000), to $409.7 million (2005) and $744.7 million by 2010 (Chart 3.3, Table 3.1).

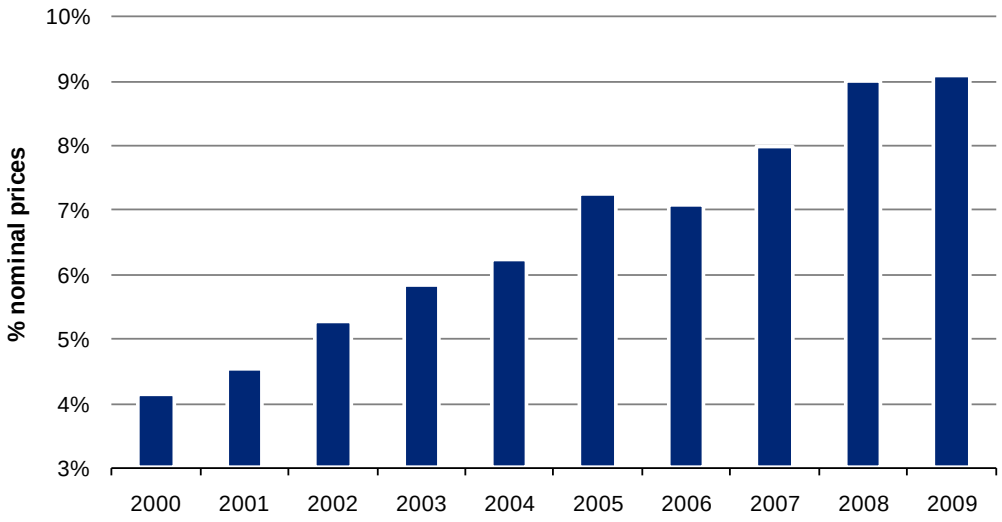
In real terms, with funding amounts indexed to 2011 prices, a similar increase in NHMRC funded R&D has been observed, with growth at almost 220% during the same timeframe. In 2011 prices, NHMRC funding increased from $241.9 million (2000), to $492.25 million (2005) and $771.6 million by 2010 (Chart 3.3). Commensurate with this, there has been an increase of total NHMRC R&D funding as a proportion of total Australian Government support for science, research and innovation (Chart 3.4).

Chart 3.3: NHMRC R&D total expenditure, nominal and 2011 prices ($m)



Source: NHRMC, 2010.

Chart 3.4: NHMRC R&D as proportion of total Australian R&D expenditure, nominal prices



Source: NHRMC, 2010; DIISR, 2009-11. Total Australian expenditure includes: research, science and innovation.

NHMRC funding for therapeutic areas addressed in this study varied widely during the decade from 2000 to 2010 (Table 3.1). In both nominal and real terms (2011 prices), funding for CVD , asthma, cancer and MD research increased by over 350%; however, funding for SIDS research has not shown consistent increases over this period. Year-on-

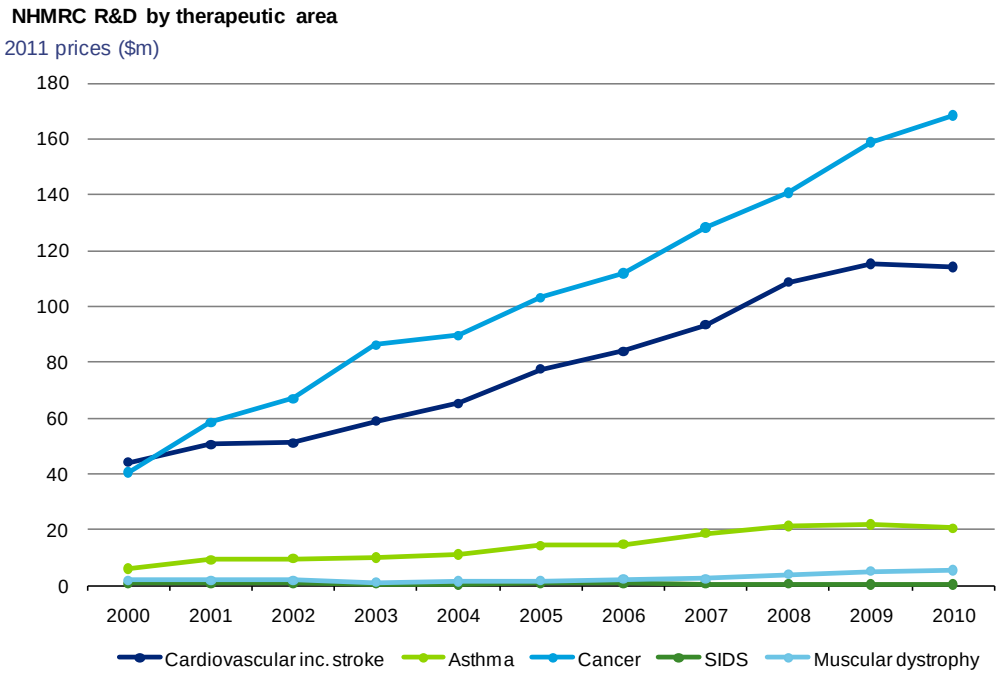
year funding relationships are presented schematically in Chart 3.5 (2011 prices), with relative funding for cancer and CVD research showing demonstrably greater gains.

Table 3.1: NHMRC R&D by therapeutic area, nominal prices ($m)

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Nominal prices	Cardiovascular	31.14	37.89	39.45	46.65	52.94	64.54	72.55	82.43	100.20	108.00	110.05
	Asthma	4.21	6.83	7.40	7.79	8.93	11.81	12.70	16.48	19.56	20.46	19.73
	Cancer	28.64	43.83	51.62	68.25	72.81	85.79	96.71	113.35	129.97	148.84	162.58
	SIDS	0.44	0.52	0.60	0.40	0.21	0.56	0.64	0.43	0.36	0.26	0.28
	MD	1.23	1.30	1.32	0.88	1.09	1.40	1.83	2.02	3.57	4.68	5.12
	Total all R&D	171.17	207.81	262.41	310.96	340.87	409.70	447.09	524.24	622.25	711.22	744.74
2011 prices	Cardiovascular	44.00	50.49	51.12	58.87	65.19	77.55	83.83	93.32	108.54	115.31	114.01
	Asthma	5.95	9.10	9.60	9.82	11.00	14.19	14.68	18.66	21.19	21.84	20.44
	Cancer	40.46	58.41	66.89	86.12	89.65	103.08	111.75	128.32	140.79	158.91	168.43
	SIDS	0.62	0.69	0.78	0.50	0.26	0.68	0.74	0.49	0.39	0.28	0.29
	MD	1.73	1.74	1.72	1.10	1.34	1.68	2.11	2.28	3.86	5.00	5.31
	Total all R&D	241.87	276.93	340.03	392.38	419.74	492.25	516.63	593.47	674.04	759.35	771.57

Source: NHMRC, 2010; ABS, 2010b and Deloitte Access Economics calculations.

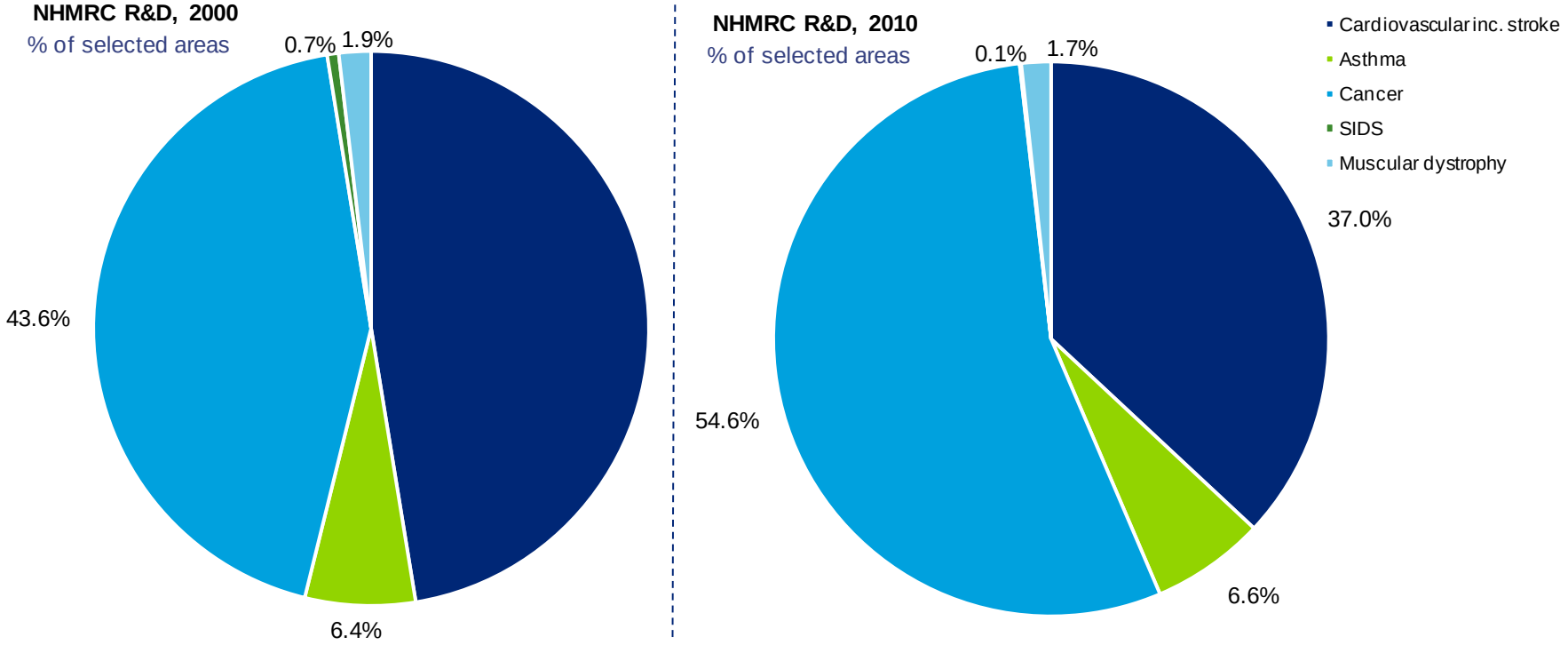
Chart 3.5: NHMRC R&D by therapeutic area, 2011 prices ($m)



Source: NHRMC, 2010; ABS, 2010b and Deloitte Access Economics calculations.

As a proportion of NHMRC R&D funding to these representative therapeutic areas, in 2011 prices, cancer-related funding grew substantially as a share of overall funding, while SIDS funding declined proportionately to the greatest extent (Chart 3.6). Growth in NHMRC funded R&D grew in greatest proportion for cancer research, followed by asthma research, MD research, CVD research, with SIDS funded research trailing. Collectively, NHMRC R&D funding for these select therapeutic areas grew from 38.7% of total R&D funding in 2000, to around 42% of total R&D funding by 2010.

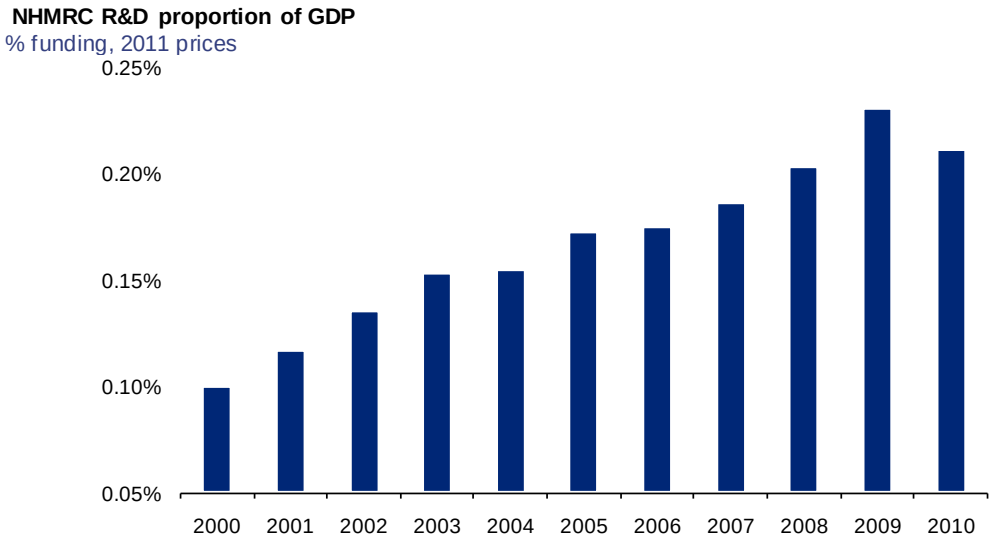
Chart 3.6: NHMRC R&D funding by selected therapeutic area proportions, 2011 prices



Source: NHMRC, 2010.

In Chart 3.7, NHMRC R&D funding was calculated as a proportion of GDP in 2011 prices, with year-on-year changes estimated relative to that of 2000 expenditure. It is evident that there have been a number of upward intermittent "surges" in the proportion of GDP allocated to NHMRC R&D (cf. 2002-3, 2005, 2009). However a consistent year-on-year upward linear trend in funding relative to GDP is apparent.

Chart 3.7: NHMRC R&D funding proportion of GDP; 2011 prices



Source: NHMRC, 2010; ABS, 2010b; ABS, 2010c and Deloitte Access Economics calculations.

4 Net benefits from NHMRC R & D

4.1 Methods for quantifying gains in wellbeing

In order to measure the gains in wellbeing over time, this study has used a framework known as a 'burden of disease' analysis. This was originally developed by the World Bank in its global burden of disease (GBD) study to inform global health planning (Murray and Lopez, 1996) and has subsequently been widely used and improved in a number of Australian and international settings.

Burden of disease analysis aims to calculate the size and impact of health problems derived from disease and injury across a population. It uses measured incidence, prevalence, duration, mortality and morbidity to quantify a summary measure of population health known as disability adjusted life years (DALYs). The method for estimating DALYs is outlined in Figure 4.1.

Figure 4.1:Method for estimating DALYs

Estimation of DALYs

DALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (YLL) in the population and the years of healthy life lost due to disability (YLD) for incident cases of a health condition. This can be represented by:

DALY = YLL + YLD

As a DALY incorporates loss of life and loss of non-fatal healthy life, it is a summary measure of the loss of 'perfect health' from different diseases and injuries. For each new case of a health condition, the number of years of healthy life lost is obtained by multiplying the average duration of the condition (to remission or death) by a severity weight that quantifies the equivalent loss of healthy years of life due to living with the health condition. The severity weight is based on a social value and ranges between zero and one, with one being the most severe disability (equivalent to death). Years lost due to disability can therefore be represented as follows:

YLD = I*D*L

Where I is the number of incident cases in the reference period, D is the disability weight (in the range 0–1) and L is the average duration of disability (measured in years). With discounting at rate r to account for positive time preference (i.e. valuing healthy life today more than healthy life in the distant future), the formula for calculating YLD becomes:

YLD = I*D* [1 - exp(- rL)] / r

Source: Access Economics, 2008a, 2008b

The burden of disease and injury approach and the use of DALYs was initially adopted and applied in Australia by the AIHW to determine the burden of disease and injury in Australia (see Mathers et al (1999) and Begg et al (2007)). It is worth noting that in contrast to the GBD methodology the Australian studies adjusted the YLD estimates for comorbidities between mental disorders and physical disorders at older ages, and did not use age weights to give preference to young and mid-adult years.

In order to ensure the net benefit estimates from NHMRC funded R&D are comparable to the burden of disease studies undertaken by the AIHW, projections of DALYs between 1993 and 2023 from the most recent report on the burden of disease and injury in Australia (Begg et al, 2007) have been used, as well as DALYs from the earlier burden of disease report (Mathers et al, 1999) in particular for SIDS, asthma and MD. The methodology that was used to project DALYs by Begg et al (2007) is discussed in the next section.

4.1.2 Estimating past, present and future wellbeing in Australia

The method used by Begg et al (2007) to estimate the past, present and future DALYs in Australia between 1993 and 2023 has been outlined in previous Access Economics reports (2008a, 2008b) and so won't be reproduced in detail here.

This method transforms estimates of burden of disease and injury in the past, present and future into a set of standardised rate ratios. These rate ratios represent the growth rate of DALYs after the effect of population ageing has been removed. The standardised rate ratios used to estimate DALYs between 1993 and 2023 for males and females by cause are shown in Table 4.1. Growth was projected from an initial starting point in 2003 so the ratio for 2003 represents the base from which the future and past rate ratios were estimated (ratios for 1993 were 'back-cast').

As data on the growth rate of DALYs were only available for four time periods (1993, 2003, 2013, and 2023), linear projections were used to fill in the data gaps, and to project the growth rate forward to 2050. Furthermore, Begg et al (2007) mapped changes in burden for disease and injury classification groups, whereas this study examines diseases which may only comprise one disease within the disease classification group, namely SIDS, asthma and MD (which are contained within the ill-defined conditions, chronic respiratory disease, and nervous system and sense organ disorders classification groups respectively). Section 4.1.3 outlines how DALYs were projected for these diseases.

Table 4.1: Standardised ratio of DALYs, 1993 to 2023

	Males				Females			
	1993	2003	2013	2023	1993	2003	2013	2023
Infectious and parasitic diseases	0.93	1.00	1.02	0.99	0.99	1.00	0.93	0.85
Acute respiratory infections	0.67	1.00	1.00	1.00	0.61	1.00	1.00	1.00
Maternal conditions	0.00	0.00	0.00	0.00	1.09	1.00	1.03	1.02
Neonatal causes	1.32	1.00	0.80	0.68	1.00	1.00	0.82	0.71
Nutritional deficiencies	1.12	1.00	1.03	1.02	1.03	1.00	0.99	0.98
Malignant neoplasms	1.20	1.00	0.85	0.70	1.16	1.00	0.88	0.74
Other neoplasms	1.03	1.00	0.83	0.68	0.94	1.00	0.89	0.81
Diabetes mellitus	0.87	1.00	1.15	1.32	0.89	1.00	1.18	1.40
Endocrine and metabolic disorders	1.88	1.00	1.08	1.03	0.89	1.00	1.16	1.31
Mental disorders	1.03	1.00	1.01	0.99	0.99	1.00	1.01	1.01
Nervous system and sense organ disorders	0.96	1.00	1.02	1.03	0.96	1.00	1.03	1.05
Cardiovascular disease	1.56	1.00	0.69	0.48	1.51	1.00	0.74	0.53
Chronic respiratory disease	1.22	1.00	0.83	0.73	1.04	1.00	0.96	0.93
Diseases of the digestive system	1.01	1.00	0.81	0.71	1.03	1.00	0.85	0.75
Genitourinary diseases	0.97	1.00	0.97	0.96	0.97	1.00	0.98	0.95
Skin diseases	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99
Musculoskeletal diseases	0.98	1.00	1.03	1.05	0.97	1.00	1.02	1.02
Congenital anomalies	1.11	1.00	0.84	0.74	1.19	1.00	0.84	0.72
Oral conditions	0.99	1.00	1.02	1.03	0.98	1.00	1.01	1.02
Ill-defined conditions	1.70	1.00	0.83	0.73	1.31	1.00	0.93	0.89
Injuries	1.16	1.00	0.91	0.79	1.08	1.00	0.89	0.76
All causes	**1.18**	**1.00**	**0.90**	**0.81**	**1.11**	**1.00**	**0.93**	**0.87**

Source: Begg et al (2007).

One issue with projecting total DALYs is the changing composition of the Australian population. Higher incomes, improved health care, healthier lifestyles, and decreased fertility are resulting in population ageing. As the total population prevalence and incidence of disease and injury is closely linked with ageing, the expected changes in the Australian population need to be taken into account when estimating total DALYs for a population. Within this study, DALY growth rates (as represented by the standardised ratio of DALYs) were multiplied by population projections (at the five year age cohort level and by gender) derived from the Access Economics Demographic Model. This provided a total DALY estimate by age, gender and cause for each year between 2000 and 2050.

4.1.3 Total gains in wellbeing by disease

Total gains in wellbeing can be represented by the reduction in DALYs from a base case. In this study, the base case was total DALYs for 2000, which was constructed by 'back-casting' total DALYs from 2003 across age, gender and cause using the standardised ratio of DALYs displayed in Table 4.1.

While standardised ratios of DALYs are available for CVD and cancer (malignant neoplasms), they are not available for SIDS, asthma and MD at the specific disease levels. To address this, standardised ratios for their disease classification groups were used, and a number of transformations were undertaken to narrow down the projected DALY changes for the disease classification groups so that they could be applied to the specific diseases. The process is described in more detail below.

SIDs is one of two conditions comprising the 'Ill-defined conditions' group, the other condition being chronic fatigue syndrome (Begg et al, 2007). In 2003, SIDS accounted for approximately 33% among men and 14% among women of the total DALYs assigned to the 'Ill-defined conditions' group. Asthma is classified as a chronic respiratory disease, and in 2003 it accounted for approximately 30% among men and 39% among women of the total DALYs associated with chronic respiratory diseases. MD is classified as one of the neurological and sense disorders, and within this disease classification it accounted for approximately 0.6% of the DALYs among men and 0.2% of the DALYs among women in 2003.

For SIDS, asthma and MD, the DALYs assigned to the specific conditions as a proportion of the DALYs attributed to their disease classification group in 1996 (from Mathers et al, 1999) and in 2003 (from Begg et al, 2007) were used to develop a logarithmic trend line, by disease and gender. A logarithmic trend line was used as it is a more conservative and realistic method for estimating rates of change over the long term compared to linear trends. The proportion of DALYs attributed to each of the specific diseases in 2003 was halved (based on observation of the downward trend between 1996 and 2003) to create a value for the proportion of DALYs attributed to the disease in 2050, and a logarithmic trend line was then fitted to the 1996, 2003 and 2050 values. This trend line was then 'back-cast' to 1993 and used to project DALY gains through to 2050, and the generated values for the trend line were used to replace the original values. DALY gains for these diseases were estimated as a proportion of the total gains in wellbeing for their disease classification group. Annual estimates of DALYs for the overarching disease classification groups were derived using the standardised ratios displayed in Table 4.1, and using linear projections to impute values from 2000 through to 2050.

The total aversion of DALYs per annum was then calculated by subtracting the DALYs at 2000 levels from projected DALYs up to 2050 for each of the key diseases. The gains in wellbeing for CVD, cancer, asthma, SIDS and MD in 2003, 2013 and 2023 are shown in Table 4.2.

The aversion of DALYs generally increases out into the future for males and females for each of the key diseases, apart from MD. This suggests that, despite population increases and ageing, total DALYs for CVD, cancer, asthma, and SIDS are expected to be less than 2000 levels overall. However, for MD the aversion of DALYs is negative for males and females in the future. This can be interpreted as an increase in the burden of disease due to an increase in incidence and the 'at risk' population.

Table 4.2: DALYs averted relative to 2000, by cause and gender

Disease	Males			Females		
	2003	**2013**	**2023**	**2003**	**2013**	**2023**
CVD	42,743	162,212	308,730	33,932	118,463	234,289
Cancer	15,776	72,903	160,297	11,382	50,056	114,027
SIDS	1,461	1,417	1,370	143	193	185
Asthma	2,301	8,399	11,893	388	1,702	2,869
MD	-15	-35	-46	-3	-10	-16

The gains in wellbeing by cause (projected total number of DALYs averted) between 2000 and 2050 are shown in Chart 4.1 to Chart 4.5.

These are the annual projections of DALYs through to 2050 minus the DALYs for 2000 and have been used to calculate the total value of gains in wellbeing, from which the net benefits from NHMRC funded R&D in Australia are derived.

Chart 4.1: DALYs averted, CVD, 2000 to 2050

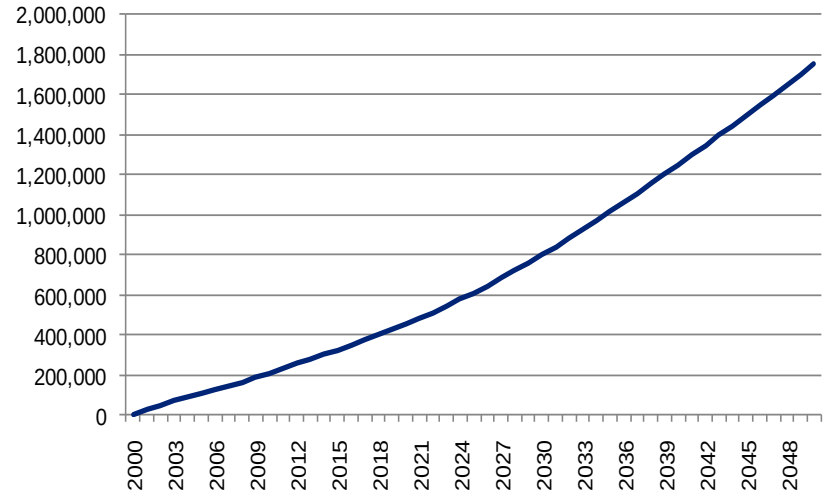


Chart 4.2: DALYs averted, cancer, 2000 to 2050

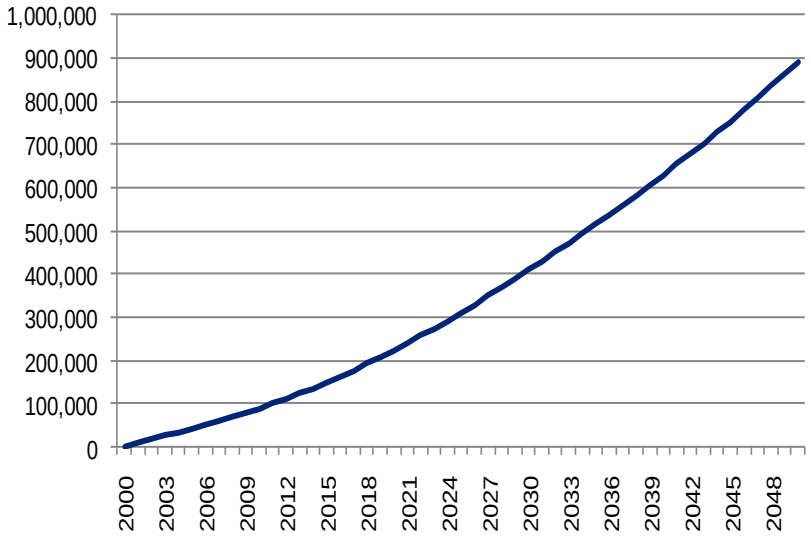


Chart 4.3: DALYs averted, SIDS, 2000 to 2050

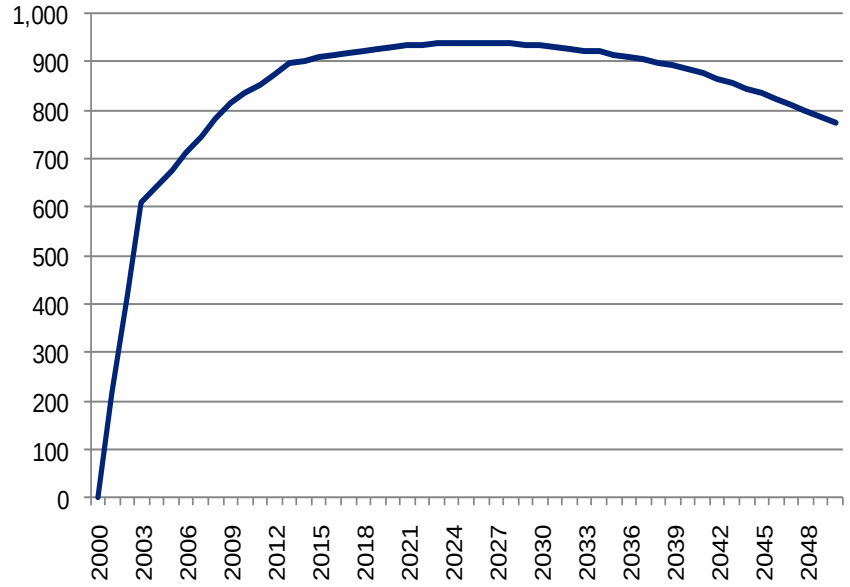


Chart 4.4: DALYs averted, asthma, 2000 to 2050

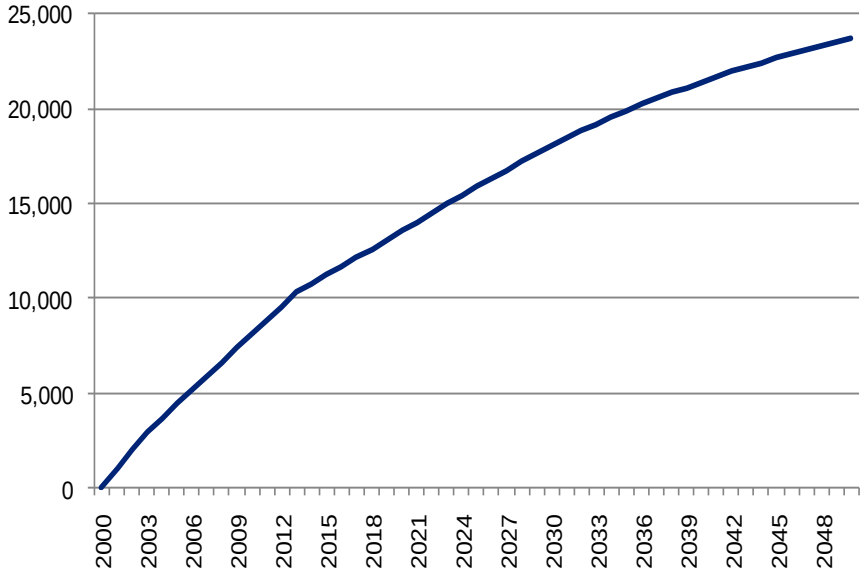
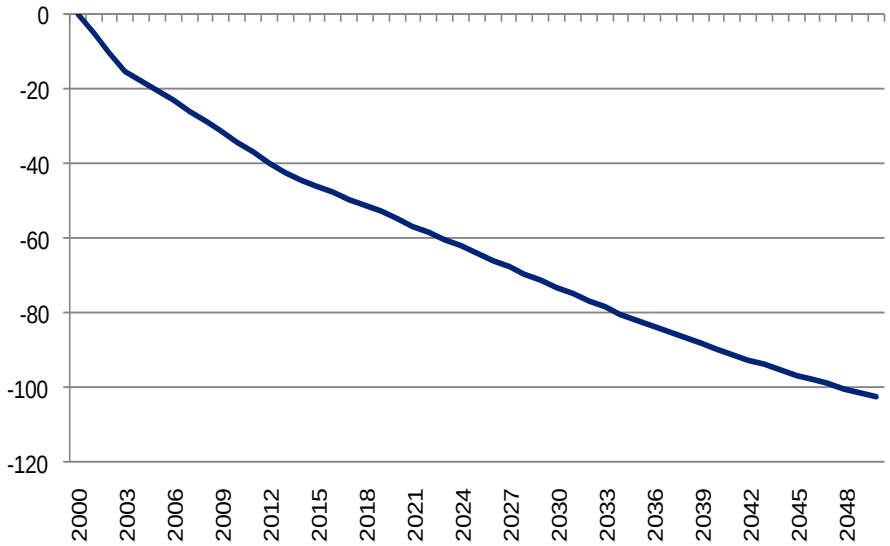


Chart 4.5: DALYs averted, MD, 2000 to 2050



4.1.4 The value of gains in wellbeing

The gains in wellbeing presented in Section 4.1.3 are represented as DALYs avoided. However, to determine the net benefits from NHMRC funded R&D, gains in wellbeing need to be monetised so they can be compared to the cost of producing those gains. The value of gains in wellbeing was calculated by multiplying the total number of DALYs averted per year by the value of a statistical life year (VSLY).

In the past, many economists and policy makers argued that it was not possible to place a value on human life. Despite the difficulties in measurement, most economists and public policy makers recognise that, given the scarcity of resources for public projects and the consequent need for efficient allocation, if such valuations are not made explicitly then they will be made implicitly through decisions about which projects proceed and the funding accorded to competing projects.

The terminology 'statistical' life evolved in an attempt to distinguish the value of the life of an anonymous or unknown individual from the life of a known or particular person, since identified lives are sometimes perceived to be of more value than unidentified ones.[4] While there are different definitions based on different approaches to measurement that could be discussed in more detail, it is more important to note that the value of a unit (year) of healthy life is the relevant variable for decision making.

The VSL(Y) has been measured using different approaches including traditional productivity approaches and 'willingness to pay' (WTP) approaches.

Productivity approaches are based on the expected earnings of the individual (lost production).

[4] We note that in a policy setting, anonymous valuation may not always be the correct perspective from which to make an assessment – e.g. when target populations are small. The terminology may thus not be appropriate.

- Frictional approaches are appropriate to measure productivity losses in the short term or in situations of a relatively large unemployment pool.
- Human capital approaches are appropriate in the longer term in economies like Australia operating at near full employment.

However, the loss of human life is viewed as more than earnings, incorporating both the value of unpaid work and the utility value of leisure. As such, the human capital valuation is a lower bound on the VSLY.

To take account of the value of unpaid work and leisure, a hybrid or mark-up approach has been adopted in some cases where the value is estimated as 30% or 40% of the value of earnings. Other early approaches to valuing life included the discounted consumption approach, the implicit value approach, the insurance value approach and the court award approach.

Willingness to pay (WTP) approaches to valuing human life have been the focus of the literature on the economics of valuing life since the 1960s. WTP assumes that a person's utility depends on their income and their health, although the complexities of the interactions are not always taken into account. The person's WTP, with their available income, to avoid a risk to their healthy life (including a certain risk) can then be translated mathematically into an estimate of their VSL/VSLY. There are two empirical methods of determining VSL/VSLY using WTP:

- stated preference valuation (contingent valuation or choice modelling) methods; and
- revealed preference (hedonic) valuation methods.

When data can be sufficiently measured, revealed preference studies are generally considered superior to measure individual WTP as they are based on real world empirical, binding market transactions. Compensating (hedonic) wage studies, for instance, use information on people's job choices to estimate WTP for job risk changes.

In the Access Economics (2008b), the estimate of the VSLY was drawn from the results of a meta-analysis of estimates from 244 'western' studies undertaken by Access Economics (2008d). Based on the results of this analysis, a 'gross' VSLY of $266,843 was used, with $164,553 used as a lower bound and $360,238 used as an upper bound.

However, more recently the Office of Best Practice Regulation (OBPR), in the Department of Finance and Deregulation, has issued a Best Practice Regulation Guidance Note on the use of VSL (Office of Best Practice Regulation, 2008). As part of this guidance it is noted that WTP is the appropriate way to estimate the value of reductions in physical harm, in the form of a VSL. Based on international and Australian evidence, the OBPR recommend that a credible estimate for the VSL is $3.5 million and $151,000 for a VSLY (in 2007 dollars). Adjusting this value to account for inflation gives a VSLY of $168,166 in 2011 dollars.

To ensure consistency and comparability with the results of other ROI or cost-benefit analyses undertaken in Australia, this report uses the VSLY estimate recommended by the OBPR. As a result, this analysis of the economic impacts of health R&D on the health and wellbeing of Australians may be more conservative with respect to the potential monetised benefit gains, compared to previous analysis undertaken by Access Economics on this subject.

Applying this VSLY to the total number of DALYs averted per year for each of the key diseases and discounting the values back to 2011 levels enables estimation of the net present value of these wellbeing gains. Projected benefits are discounted to take into account society's preference to experience these benefits in nearer rather than more distant years, resulting in the value of these gains diminishing over time. The estimation of the total value of gains in wellbeing in Australia between 2000 and 2050 can be seen in Chart 4.6 to Chart 4.10. These represent the annual value of gains in wellbeing expected to result from all impacts on health, not just Australian R&D.

Chart 4.6 to Chart 4.10 demonstrate that the annual value of gains in wellbeing are expected to be larger for males than for females across all of the key diseases. This is primarily due to the expected larger decrease in the burden of disease for all of the key diseases (CVD, cancer, SIDS, asthma, and MD) for males when compared to females. For all of the key diseases, the larger increase in DALYs averted for males is a function of a larger rate of decrease from a larger DALY base.

For both males and females the annual value of discounted gains in wellbeing increase at a decreasing rate, i.e. the growth in gains does not occur at a linear or constant rate instead the magnitude of annual gains diminishes over time. For CVD and cancer, while total gains in wellbeing increase close to a linear rate (especially after 2023 where a linear growth was used to project DALYs out to 2050), the discount rate means the increase in the VSLY is non-linear, resulting in a non-linear distribution of monetised wellbeing gains. For SIDS, asthma and MD, a logarithmic trend line was used to project DALYs between 1996, 2003 and 2050, hence the growth in wellbeing for these diseases increases at a logarithmic rate, while discounting similarly has a non-linear affect on the rate of change in monetised wellbeing gains.

Chart 4.6: Annual value of discounted gains in wellbeing for CVD, by gender, 2000-2050

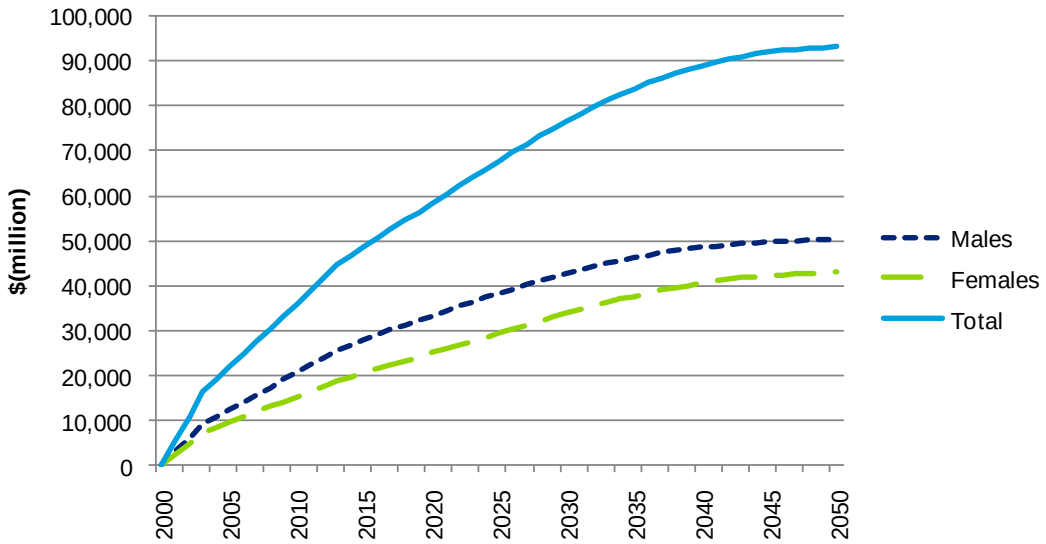


Chart 4.7: Annual value of discounted gains in wellbeing for cancer, by gender, 2000-2050

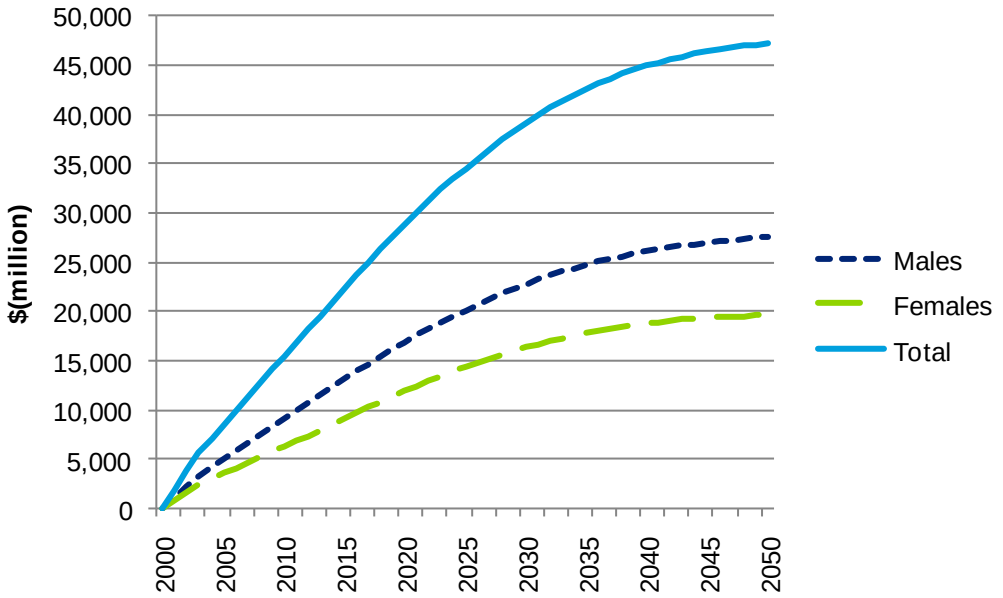


Chart 4.8: Annual value of discounted gains in wellbeing for SIDS, by gender, 2000-2050

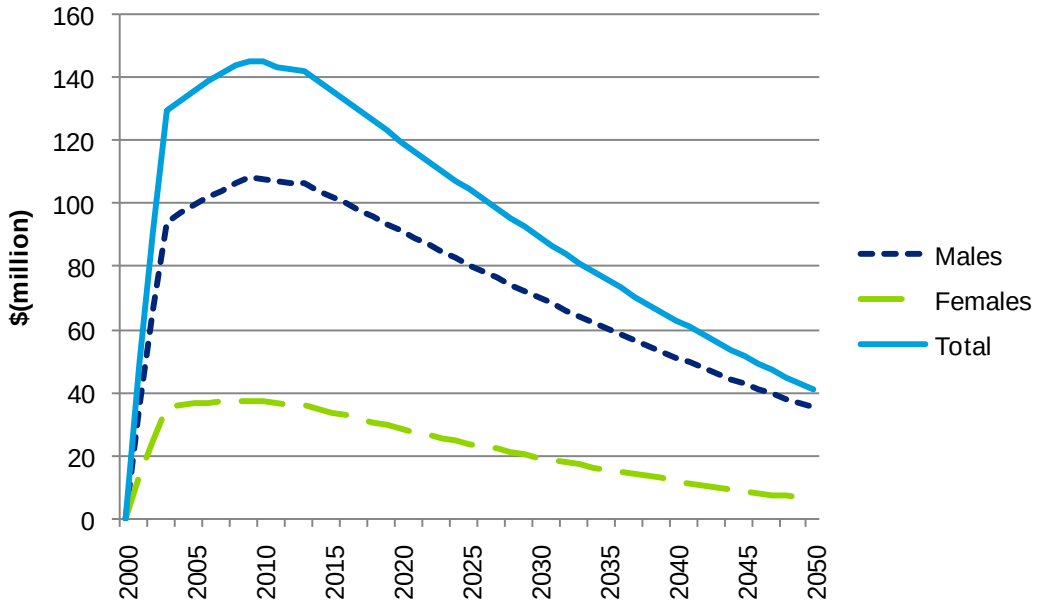


Chart 4.9: Annual value of discounted gains in wellbeing for asthma, by gender, 2000-2050

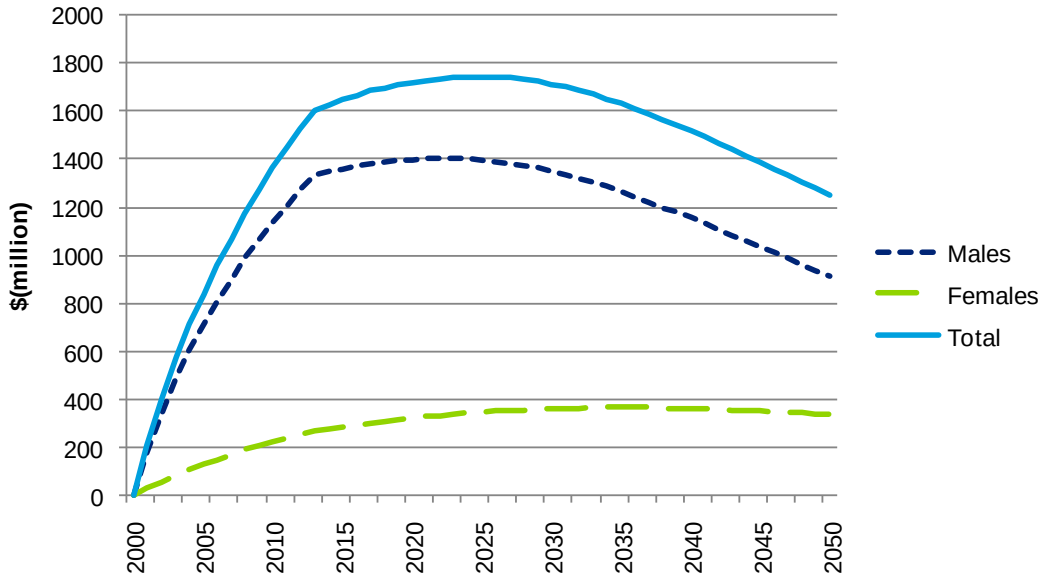
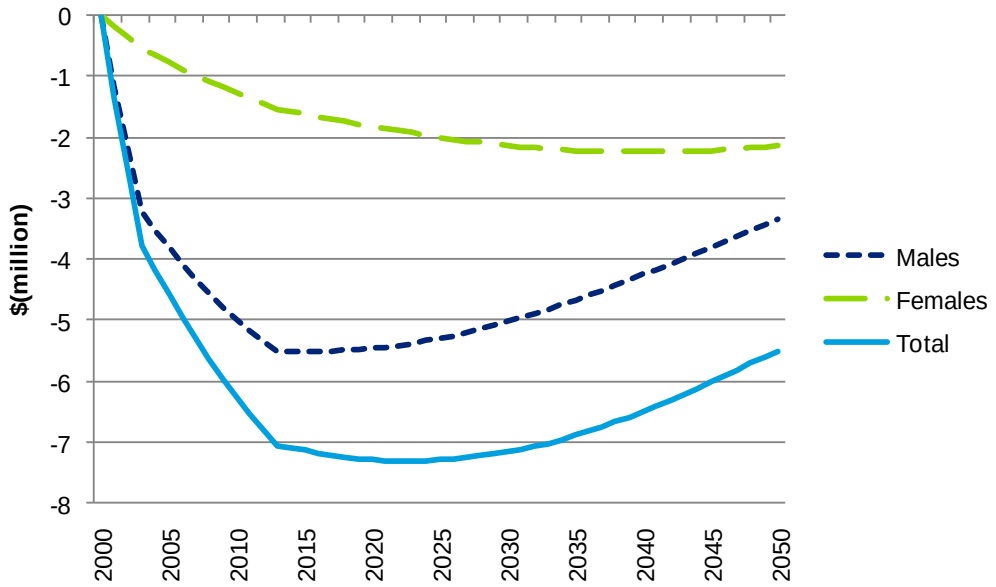


Chart 4.10: Annual value of discounted gains in wellbeing for MD, by gender, 2000-2050



4.2 Methodology for attributing gains to NHMRC R&D

Investment in health R&D to develop new technologies and methods has one primary goal in mind – to improve the health and wellbeing of individuals. However, determining the

impact of NHMRC funded health R&D on the wellbeing of individuals over time is a difficult task due to the many confounding factors that impact health. To ensure these confounding factors are removed and only the impacts of NHMRC funded health R&D are derived, the following five steps were undertaken.

Health scenarios were established 'with R&D' and 'without R&D'. The 'with R&D' scenario is the current and expected wellbeing scenario faced by Australia. The 'without R&D scenario' is the wellbeing scenario that would have occurred if Australian health R&D was not undertaken. For the purposes of this study it was assumed that DALYs per capita were those of 2000 – the year that the first R&D expenditure data were available.

1. **The impact of NHMRC funded R&D was estimated**. The impact that NHMRC funded R&D has had on the wellbeing of Australians was calculated by multiplying the proportion of health gains attributable to world R&D by the proportion of world R&D that is contributed by NHMRC funded R&D.
2. **The net benefit stream was modelled**. The VSLY was multiplied by the expected gains in Australia's wellbeing as a result of NHMRC funded R&D to derive a monetary value for the benefits of NHMRC funded R&D. The NHMRC's expenditure on R&D was then subtracted to calculate a net benefit.
3. **The economic evaluation measures were calculated.** These included the net benefits, ROI and B/C ratio.
4. **A sensitivity analysis was undertaken**. A Monte Carlo simulation was used to test the sensitivity of the economic evaluation measures to variation in key model inputs.

A major issue in calculating the net benefits of health R&D is the treatment of time lags between health R&D expenditure and gains in wellbeing. The very nature of scientific investigation is that its results and timeframes are uncertain, and successes are cumulative. In pharmacological research, timeframes are somewhat more predictable, but such developmental research tends to build on public sector basic research that involves greater risks and externalities.

How can such lags be captured? In Access Economics (2003), we retrospectively compared the estimated gains in any year with the research spend in that same year. This provided an estimate that did not capture the lag between R&D and its benefits, but was a conservative proxy. For this study, as in the Access Economics 2008 studies (2008a; 2008b) it was decided that in order to provide more realistic estimates of the return from R&D, the lag between expenditure and gains in wellbeing should be captured.

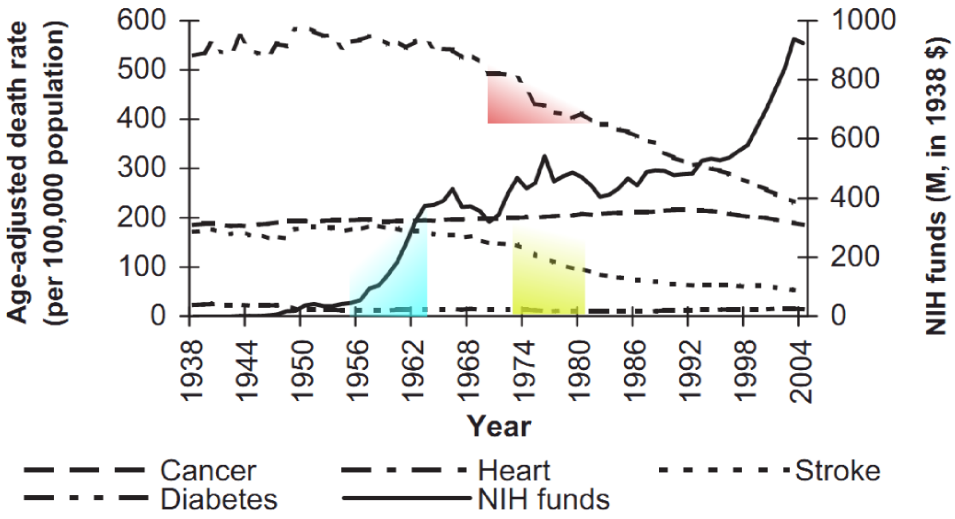
However, the lag before returns begin, and the period over which benefits last, are both uncertain. In any year, benefits reflect many different previous R&D investments from earlier years, and it is extremely difficult to allocate benefits over a stream of years to investments over a corresponding earlier stream of years. Therefore, in order to calculate the net benefits for NHMRC funded R&D, some simplifying assumptions were made.

For the current study, it was assumed that the total benefits from NHMRC funded R&D undertaken in one year are lagged across 40 years. That is, the benefits that are projected to be experienced across 40 years are used as a proxy for the benefits expected from R&D undertaken 40 years prior. The R&D expenditure in 2000 was therefore compared with the projected wellbeing gains in 2040. Similarly, the expenditure in 2001 was compared with

the projected wellbeing gains in 2041 and so on. This was continued up to 2010 where the NHMRC measured expenditure data finishes. The economic evaluation measures were calculated by comparing the total projected wellbeing gains associated with total expenditure between 2000 and 2010, which were both adjusted to 2011 prices using a discount rate of 3%.

Furthermore the approach taken in this study drew on a recent study by Manton and colleagues (2009), which examined relationships between NIH funding and change in causal age-adjusted mortality rates. In this study, 10 year-lagged R&D funding directed towards particular diseases was assessed against the disease specific mortality gains over a historical period of approximately six decades. A conceptual overview of the study is presented in Chart 4.11. Across the disease groups presented, there were no *immediate* responses of any significance. However, progressive temporal responses, apparent through a decrease in age-adjusted mortality rates, were observed. Indicative decreases are observed for both heart disease (magenta shading) and stroke (yellow shading), beginning around 13 and 18 years following incipient increases in NIH funding, respectively. The temporal relationship between wellbeing gains and increases in health R&D funding varied across the diseases.

Chart 4.11: Manton et al (2009) study methodological overview – NIH funding by mortality rate and cause



Source: adapted from Manton et al, 2009. Shaded colours highlight trends in NIH expenditure (up; cyan), cardiovascular mortality rates (down; magenta) and stroke mortality rates (down; yellow).

The study by Manton et al (2009) provides a useful conceptual basis for examining R&D funding directed towards particular disease groups against health and wellbeing gains made over a number of subsequent decades within those diseases. Hence in the current study we will examine R&D investment for CVD, cancer, SIDS, asthma and MD, against health and wellbeing gains, direct expenditure and indirect costs made over a 40 year period for these diseases.

4.3 Modelling parameters

Only a portion of wellbeing gains can be attributed to NHMRC funded R&D as there are other factors that impact health that are not related to R&D, such as improved income, education programs, better food and improved environment. Health R&D undertaken outside Australia has also had a significant impact on the health of Australians so this impact must be removed if a true representation of the benefits from NHMRC funded R&D is to be made.

Consequently, modelling the net benefits for Australian health R&D critically depends on the following parameters:

- the proportion of health gains attributed to world health R&D rather than other factors that impact health;
- the contribution of Australian and NHMRC health R&D to the total health gains attributable to world health R&D; and
- the proportion of Australian R&D health gains derived from NHMRC funded R&D.

These parameters are discussed below.

4.3.1 Proportion of health gains attributed to world health R&D

In our 2008 reports, Access Economics (2008a; 2008b) used the base case assumption that health R&D is responsible for 50% of the improvements in healthy lifespan. This was based on research quoted in Hatfield et al (2000), who estimated that 33% of total health gain related to a reduction in mortality and morbidity from cardiovascular disease is the result of medical research, while a share of the remaining 67% can be linked to research since gains attributed to changes in public policy and individual behaviour depend on research-derived information. However, benefits from research in some areas are less immediately apparent, particularly if research and higher medical expenditure may have little impact on mortality or morbidity, such as in the case of musculoskeletal conditions (Hanney et al, 2004).

Several papers have been written about the issue of how to attribute health gains to R&D. Buxton et al (2004), for instance, reviewed key studies related to the impact of health research – including the Access Economics (2003) study – concluding that estimating the economic value to societies of health research is complex as it involves multiple issues such as identifying and valuing the relevant research inputs, accurately ascribing the impact of the research and appropriately valuing the attributed economic impact. Weiss (2007) argued that in order to calculate the clinical return on an investment in medical research, three outcomes need to be measured: awareness, implementation and patient benefit, but the ability to provide that information is limited at present. However, no better estimate of the actual percentage of health gains attributable to total R&D has been made.

Consequently the base case assumption of 50% can still be seen as appropriate given the complexity of the issue and the lack of alternative estimates. This parameter was also retained in Access Economics' recent studies for the Cancer Institute NSW (Access Economics, 2008c).

4.3.2 Proportion of world R&D attributable to Australian and NHMRC R&D

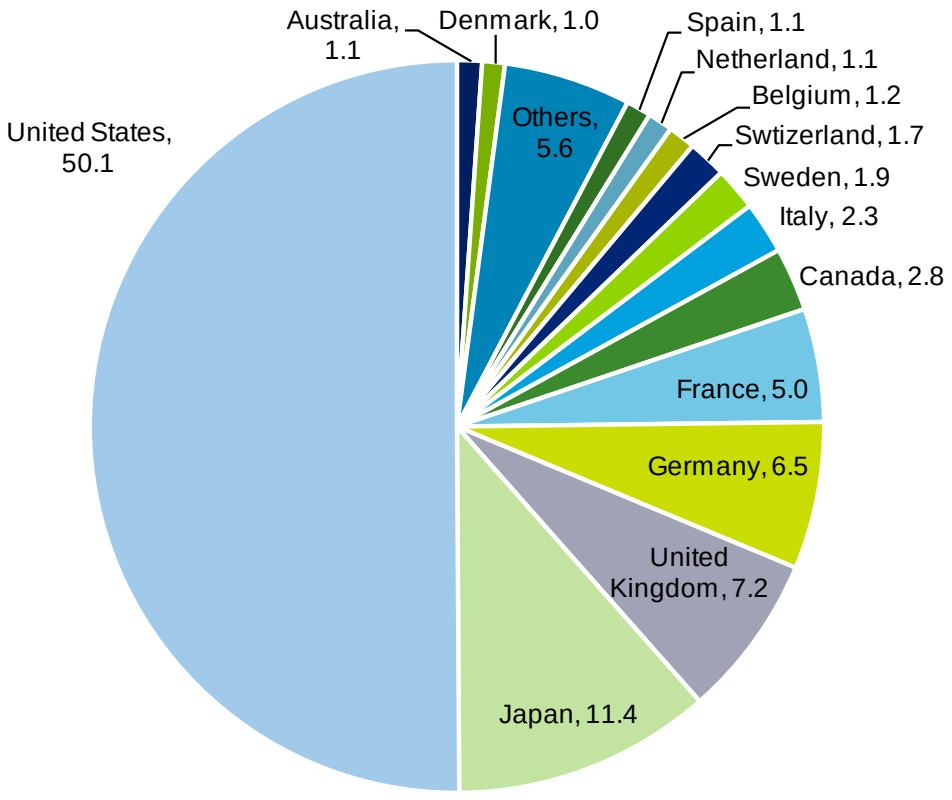
There is no denying that the majority of Australia's health gains have come from R&D undertaken within Europe and North America. This is shown by the amount of resources used to undertake health R&D in these regions, and the number of journal articles that are created from this research.

However, Australia has also made considerable achievements in health R&D. Wills (1998) concluded that, with 0.3% of the world's population, Australia produces about 2.5% of the world's health R&D output. Australian scientists have received seven Nobel prizes for Medicine or Physiology, while the impact of our health R&D ranks consistently in the top eight countries across a range of fields.

Inputs into R&D: Australian and NHMRC share of global R&D expenditure

Burke and Monot (2006) estimated global health research spending to be US$125.8 billion in 2003. This estimate is based on various data sources including OECD data (2001; 2007). The OECD estimates global overall R&D spending in 2003 to have been around US$645 billion. Approximately 20% of the total global R&D expenditure is estimated to have been for health research which would amount to US$129 billion. Looking at country shares, Burke and Monot (2006) estimate Australia's health R&D expenditure to be 1.1% of global health R&D expenditure (Chart 4.12).

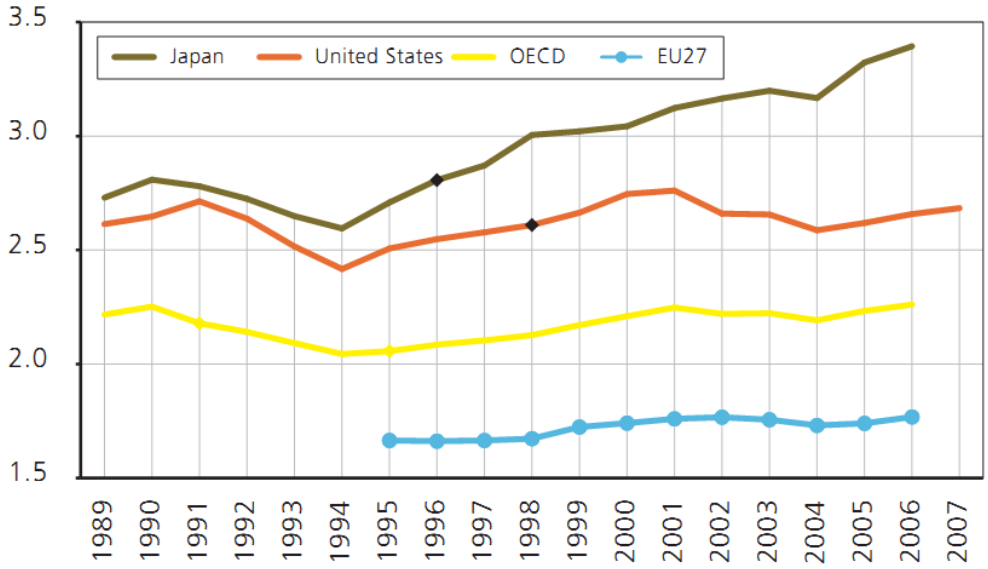
Chart 4.12 Global distribution of R&D for health expenditure, 2003 (%)



Source: Burke and Monot, 2006

Landriault and Matlin (2009) show that gross national expenditure on R&D across OECD countries tracks at around 2.2% to 2.5% of GDP (Chart 4.13). Similarly, Australian expenditure on total R&D tacks very closely to that of the US (Chart 4.14).

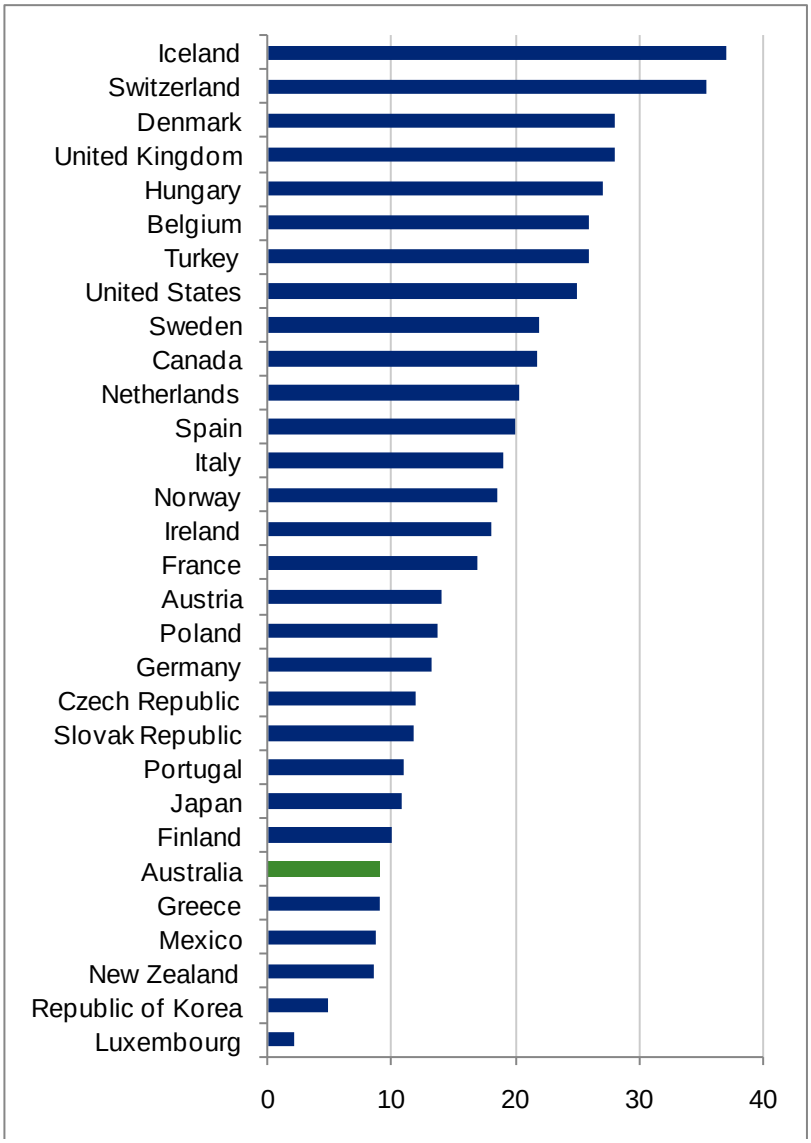
Chart 4.13: Gross expenditure on R&D: proportion of GDP (%)



Source: Landriault and Matlin, 2009.

Expenditure on health R&D as a proportion of total R&D, however, displayed a significant discrepancy across OECD countries, of between 2% and 37% (2005 data; Chart 4.14). As discussed in Section 3.3, NHMRC expenditure on health R&D constitutes around 9% of total Australian R&D expenditure (Chart 3.4). Although NHMRC R&D health expenditure is not wholly representative of total Australian health R&D, these data suggest that Australian health R&D would sit within the bottom half of OECD countries for this R&D expenditure metric.

Chart 4.14: OECD countries (2005) and Australian (2009) national health R&D: proportion of total R&D (%)



Source: Adapted from Landriault and Matlin, 2009; Deloitte Access Economics calculations.

However, expenditure data simply provides information on the inputs into health R&D, rather than the efficacy of such investments with respect to health outcomes. As such, it is not particularly useful in measuring the extent to which a country might contribute in terms of R&D outputs. Consequently, it is problematic to use expenditure data to measure the contribution of Australia's R&D to wellbeing because it is R&D outputs such as quantity and quality of R&D that matters. For this task, bibliographic (reference and citation) evidence is superior, as it gives an indication of the significance and magnitude of the research findings generated from R&D expenditure.

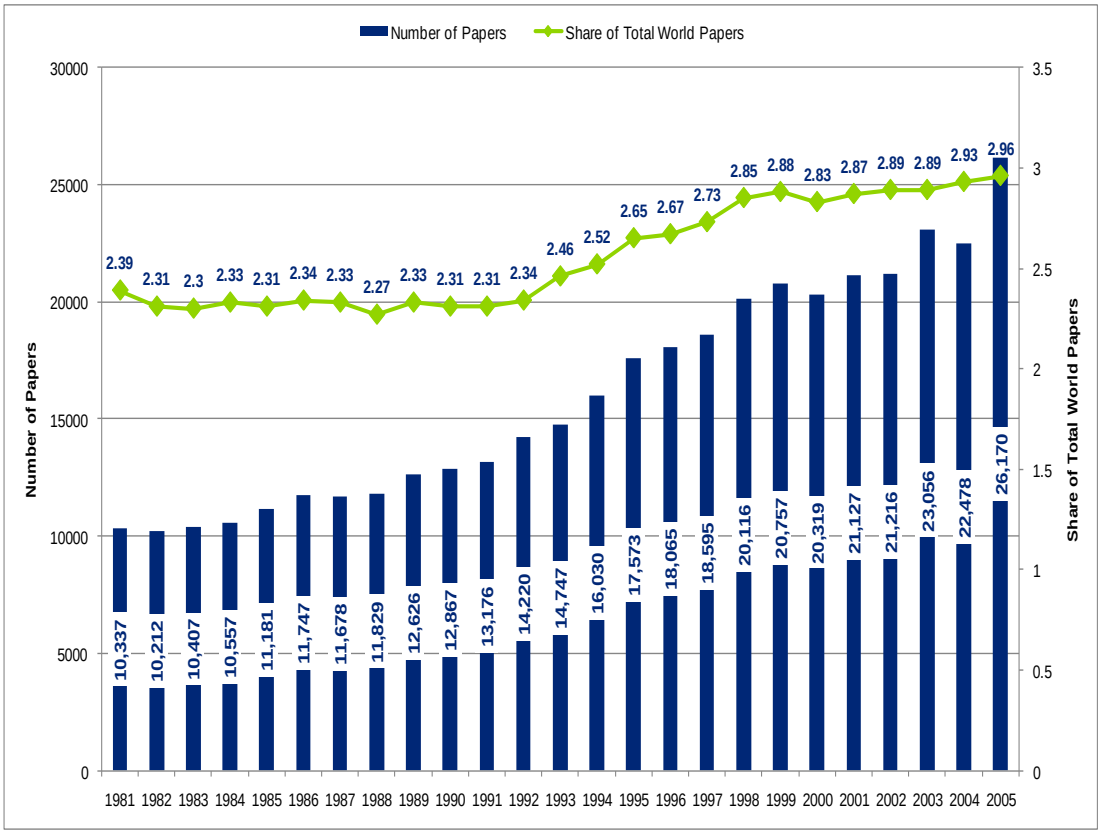
Outputs from R&D: Australian and NHMRC share of publications

Bibliometric analysis involves the use of publication and citation data in the assessment of research performance (Pollitt et al, 2011). In this report, bibliometrics has been applied to

Australian research output generally, and specifically, to research supported by NHMRC funding.

The total number of Australian research publications rose steadily from 10,363 in 1981 to 26,170 in 2005. Australia's share of total world research publications stayed steady at around 2.3% until the early 1990s when it experienced an upward trend, rising to 2.96% in 2005 (Chart 4.15). With this share, Australia ranked eleventh in the world and ninth among OECD countries. In 2005, Australia's citation impact was 1.19 times the worldwide average. From 1981 to 2005, Australia's citation impact was generally above the world average, but dipped below that average on eight occasions between 1987 and 1997 (DEST, 2006).

Chart 4.15: Australia's number and share in research publications, 1981-2005



Source: DEST, 2006.

The cohort of publications most relevant to this report are those which fall under clinical science (also referred to as clinical medicine), as the five disease groups under investigation all fall under this overarching umbrella[5]. Bibliometric analysis undertaken by Butler and colleagues (Butler and Biglia, 2001; Butler, 2003; Butler et al, 2005; Butler and Henadeera,

[5] The Web of Science journal sets analysed within the 2009 Butler and Henadeera manuscript include: andrology; anesthesiology; cardiac and cardiovascular systems; clinical neurology; dermatology and venereal diseases; emergency medicine and critical care; endocrinology and metabolism; gastroenterology and hepatology; geriatrics and gerontology; hematology; infectious diseases; medicine, general and internal; obstetrics and gynaecology; oncology; ophthalmology; orthopedics; otorhinolaryngology; pathology; pediatrics; peripheral vascular disease; psychiatry; psychology; radiology, nuclear medicine and medical imaging; rehabilitation; rheumatology; respiratory system; transplantation; surgery; urology and nephrology; tropical medicine.

2009) found that the Australian global proportion of clinical science publications has increased steadily during the period 1996 through 2006, increasing from 2.72% (1996-2000) to **3.14%** (2002-2006) (Table 4.3).

Approximately one quarter (26.1%) of Australian biomedical research resulting in peer-reviewed journal publications is funded through the NHMRC (Butler and Henadeera, 2009). In step with Australian observations, publications in the clinical sciences arising from NHMRC funding have increased by 29.32% as a proportion of global publications, to 0.79% (2002-2006). These data are presented schematically in Chart 4.16.

NHMRC funded research **within the clinical sciences** discipline has displayed continued strength, with key observations including (Butler and Henadeera, 2009):

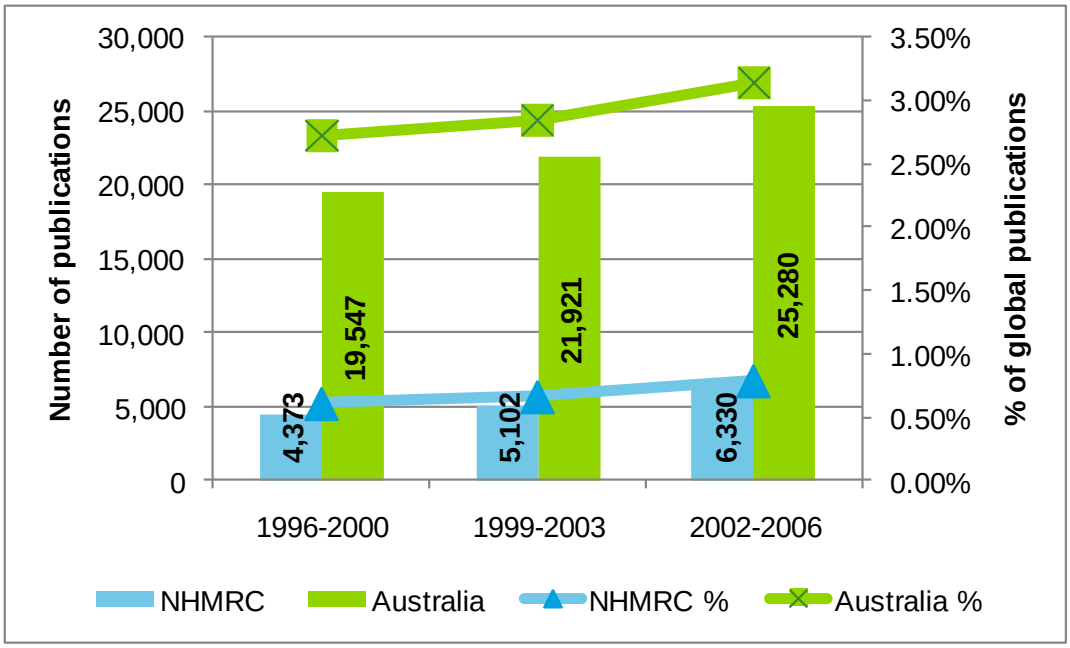
- A citation impact of 1.60 and 1.25 relative to global and Australian publications respectively (2002-2006);
- A journal impact factor of 1.93 relative to global publications (2002-2006);
- Contribution towards **25.04%** of Australian publication output in 2009, an increase of 1.7% on 1999-2003;
- Growth reaching almost 45% in publication output over the period of 1996-2000 (4,373) to 2002-2006 (6,330); and
- A 28.43% increase in citations per publication, from 6.75 (1996-2000) to 8.67 (2002-2006) (Table 4.3).

Table 4.3: Clinical sciences: publications, citations and Australian/global proportion

	1996-2000	1999-2003	2002-2006
Publications			
NHMRC	4,373	5,102	6,330
Australia	19,547	21,921	25,280
Global	719,302	771,671	805,135
Publications: proportion of Australia			
NHMRC	22.37%	23.27%	**25.04%**
Publications: proportion of global			
NHMRC	0.61%	0.66%	0.79%
Australia	2.72%	2.84%	**3.14%**
Citations			
NHMRC	29,528	43,568	54,895
Australia	93,902	131,231	175,022
Global	3,347,630	4,155,300	4,893,290

Source: Butler, 2003; Butler et al, 2005; Butler and Henadeera, 2009.

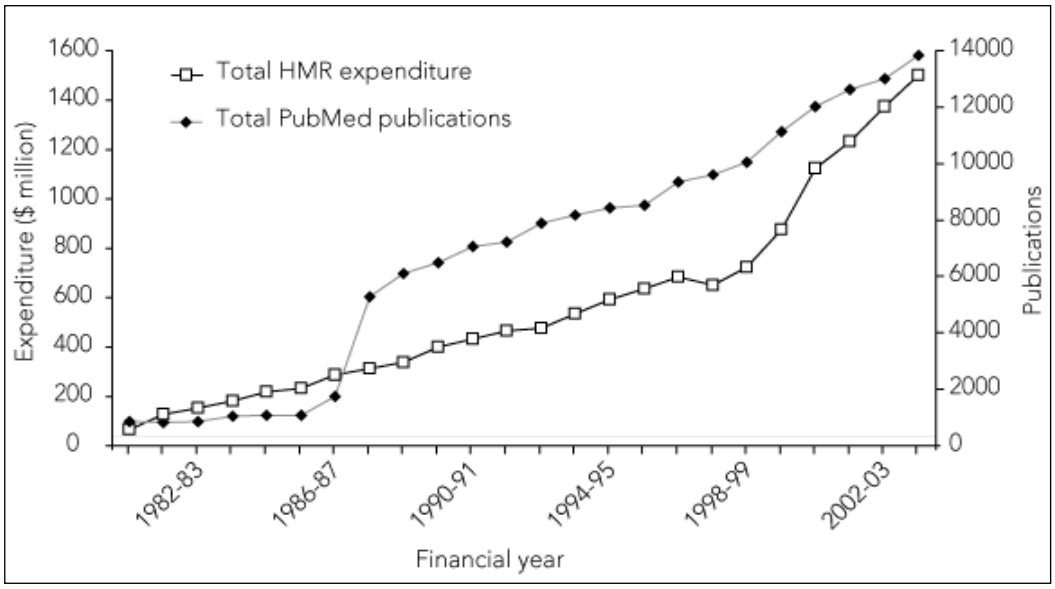
Chart 4.16: Clinical sciences: publications, and global proportion



Source: Butler, 2003; Butler et al, 2005; Butler and Henadeera, 2009.

Mendis and McLean (2006) estimate that Australian PubMed publications increased from 844 in 1980-81 to 13,836 in 2003-04 during a time when Australian health and medical research funding increased from $66 million to $1,503 million. This is shown in Chart 4.17.

Chart 4.17: Australian PubMed publications and health and medical research expenditure, 1980-81 to 2003-04



Source: Mendis and McLean, 2006.

Given that the majority of health R&D undertaken in Australia is clinical and that recent health R&D funding has increased in Australia (which is expected to translate into more

outputs), the proportion of world R&D attributable to Australian R&D has been estimated at **3.14%** (Table 4.3), which is in line with DEST (2006).

4.3.3 Proportion of Australian R&D health gains derived from NHMRC funded R&D

The share of publication method was used to determine the proportion of NHMRC funded R&D, as was the case for Australian funded R&D. The proportion of NHMRC funded R&D within Australian R&D was derived from the proportion of NHMRC funded publications in the clinical sciences, compared to total Australian funded publications in the clinical sciences for 2002-2006. This equated to **25.04%** (Table 4.3).

A case exists to use the number of citations that publications receive as a means of determining the proportion of health wellbeing gains which can be attributed to NHMRC health R&D (which would equate to 31.36%; Table 4.3), as citations indicate not only the magnitude of research output but go some way to measuring its significance or influence on the broader research field. For the current study the proportion of publications was used to ensure the proportion of health gains attributed to NHMRC funded R&D was conservative and unlikely to overstate the relationship.

The impact of NHMRC funded R&D has on publication output is somewhat varied over the discrete research fields and disciplines. NHMRC accounts for over one-quarter of all Australian biomedical research. In four biomedical sub-fields, the NHMRC is linked to more than one-third of the total Australian output (Butler and Henadeera, 2009): immunology (44.6%), neurosciences (40.2%), biochemistry and cell biology (37.8%) and medical physiology (33.7%). Publications linked to NHMRC demonstrate, in aggregate, a very strong citation performance with a citation rate 50% above the world rate for biomedicine.

Given that the focus is on five specific diseases within the field of clinical sciences, calculation of the health gains attributable to NHMRC R&D will use the publication proportions from the clinical sciences rather than biomedicine.

4.4 Benefits from NHMRC funded R&D

There are many different types of benefits resulting from NHMRC funded R&D. First and foremost is the increase in wellbeing resulting from improved health outcomes now and in the future. From these health gains there are associated benefits, including the avoidance of direct health system expenditure and the avoidance of indirect costs (such as productivity loss, other financial costs associated with reduced wellbeing, and deadweight loss). In addition, there are commercial gains that result from NHMRC funded R&D. These are discussed below.

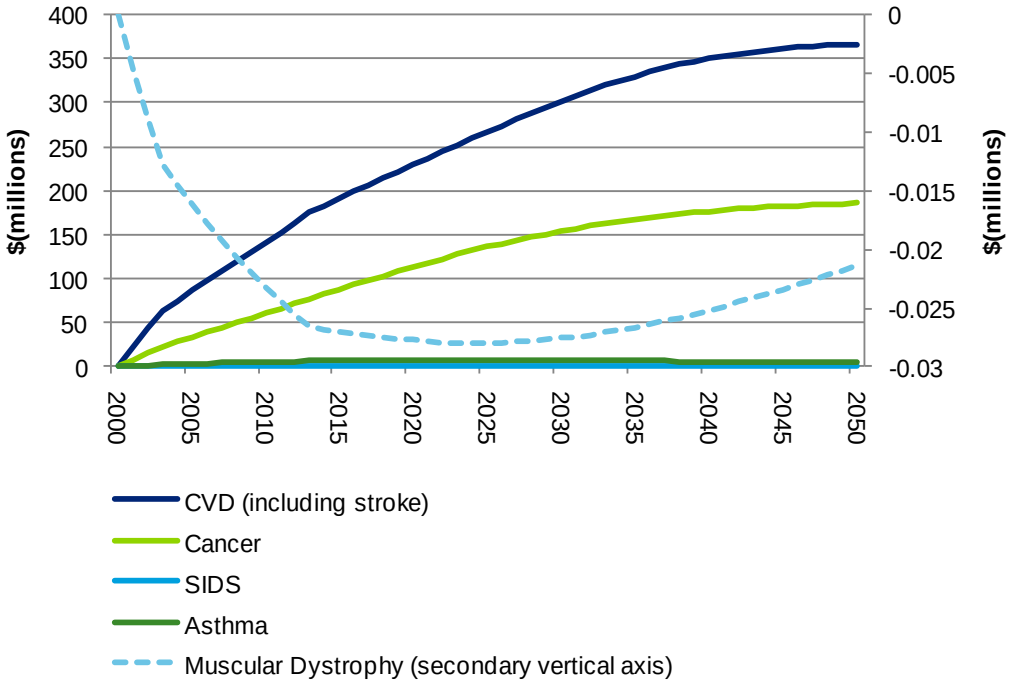
4.4.1 Value of gains in wellbeing

The value of wellbeing gains from NHMRC funded R&D performed between 2000 and 2010 is estimated to be approximately $4 billion for CVD, $2 billion for cancer, $3.3 million for SIDS, $60 million for asthma, and -$259,987 for MD. While the majority of these diseases are expected to enjoy wellbeing gains into the future compared to burden of disease levels

in 2000, MD is expected to result in increasing levels of disability into the future, thereby generating a negative value of wellbeing returns.

The estimated annual benefit stream from gains in wellbeing is shown in Chart 4.18. It shows that benefits have been increasing since 2000 but at a decreasing rate. For example, annual benefits tend to flatten out at around 2040. Although gains in wellbeing are expected to continue beyond 2040, the logarithmic trend line used to generate future DALY values for SIDS, asthma and MD, in addition to discounting the wellbeing gains for all diseases, tends to reduce the annual rate of increase over time.

Chart 4.18: Value of wellbeing gains from NHMRC funded R&D, 2000 to 2050



The average annual cost of NHMRC R&D from 2000 to 2010 and the average wellbeing gains between 2040 and 2050 were compared to derive an average annual cost per DALY averted for those diseases which demonstrated a net benefit from NHMRC funded R&D. These are listed below[6]:

- Between 2000 and 2010 the average annual cost of R&D for CVD was $78.4 million, and an average of 5885 DALYs were averted each year, with an approximate average annual cost of $13,015 to avert one DALY (in 2011 prices). A 10% increase in annual NHMRC funding would enable the aversion of an additional 740 DALYs due to CVD every year, the equivalent of $124 million in wellbeing gains.
- Between 2000 and 2010 the average annual cost of R&D for cancer was $104.8 million, and an average of 2972 DALYs were averted each year, with an approximate average annual cost of $34,230 to avert one DALY (in 2011 prices). A 10% increase in NHMRC

[6] These scenarios are extrapolating health gains based on marginal changes to average annual R&D investment levels between 2000 and 2010. Scenario testing on a more significant scale would require testing of the shape of the relationship between R&D investment and health outputs, which this study did not examine.

funding for cancer R&D would lead to gains of approximately 396 DALYs avoided, the equivalent of $66.6 million in wellbeing gains.

- Between 2000 and 2010 the average annual cost of R&D for SIDS was $0.5 million, and an average of 3 DALYs were averted each year, with an average approximate annual cost of $161,299 to avert one DALY (in 2011 prices). A 10% increase in annual funding for SIDS would lead to an additional 0.4 DALYS avoided for this disease every year.
- Between 2000 and 2010 the average annual cost of R&D for asthma was $14.2 million, and an average of 89 DALYs were averted each year, with an approximate average annual cost of $158,344 to avert one DALY (in 2011 prices). If there were a 10% increase in annual NHMRC R&D funding for asthma, it would enable an additional 8 DALYs per year to be avoided.

4.4.2 Value of avoiding direct (health system) expenditure

Gains from health R&D are not only confined to the expected gains in wellbeing, they also include costs avoided due to less expenditure within the health care system. These avoided direct financial costs include:

- the costs of running hospitals and nursing homes (for example, buildings, labour costs, and consumables);
- out-of-hospital services and other professional services (for example, general practitioner and specialist medical services, imaging and pathology);
- prescribed and over-the-counter pharmaceuticals (for example, expenditure made through the Pharmaceutical Benefits Scheme and private medication purchases);
- allied health services (for example, community and public health services, and dental);
- further health research and development; and
- 'other' health care system costs (for example, ambulance, aids and appliances and health administration).

The AIHW collects recurrent health care system expenditure data on disease and injury in Australia. It allocates expenditure across disease and injury using a top-down approach, where total costs of a program are allocated by disease. This is in contrast to the alternative bottom-up approach, where cost of a condition is calculated by multiplying the number of people with that condition by the average cost of impact. A top-down approach is preferred for cost allocation across an entire health care system because it ensures the sum of expenditure parts will always equal total expenditure.

The most recent analysis of health system expenditure on disease and injury in Australia was released by AIHW in 2010 and represents health care expenditure for 2004-05 (AIHW, 2010a). The database is a comprehensive national accounting of health system costs across diseases and health system functions.

To ensure consistency, the disease groups used in the disease expenditure estimates are based on the diseases that are used in the burden of disease study. This means that health expenditure data derived from the AIHW are also consistent with the disease and injury classifications used to calculate wellbeing gains within this study, however there are some minor variations within disease and injury classifications, with the 'ill-defined conditions' classification being a case in point.

While 'ill-defined conditions' refers to SIDS and chronic fatigue syndrome in the disease and injury classifications which are used to calculate wellbeing gains, in the health expenditure data it includes a much broader range of conditions, including those that are unable to be classified under other disease and injury classifications, such as treatment for signs and symptoms where the cause is unknown. Hence, the resulting health expenditure estimate for SIDS, even when attenuated according to the proportion of burden of disease it comprises in the 'ill-defined conditions' disease classification group, is significant overestimate.

For this reason the direct health expenditure costs associated with SIDS were estimated using the average health system expenditure associated with males and females 0-4 years of age, drawn from AIHW analysis of health care expenditure on disease and injury in 2004-05. These amounts were multiplied by the most recently available data on the incidence of SIDS (ABS, 2011). It should be noted that this approach assumes that all cases of SIDS would be transported to hospital, resuscitated and admitted. Information on the proportion of SIDS cases that are subject to resuscitation, transportation, admittance to hospital and length of stay in hospital is not available, so any further adjustments to deflate this estimate are not possible, and therefore it should be interpreted with caution.

Estimates of the direct health system costs avoided due to improved wellbeing from NHMRC funded R&D were calculated using health system expenditure on disease and injury estimates provided by AIHW, and the DALYs avoided from NHMRC funded R&D calculated within this study. The first step was to estimate the proportion of health expenditure by disease and injury for 2004-05 based on AIHW (2010a). These proportions were then applied to total health expenditure in 2005 to calculate expenditure per DALY for each disease and injury for 2005. Indexation was then applied to the 2005 expenditure per DALY estimates for each disease to convert them to 2011 prices , and they were then multiplied by the DALYs avoided from NHMRC funded R&D to provide a total value of direct health system costs avoided. As these avoided costs are not expected to occur until sometime in the future, they were discounted back to 2011.

The value of avoided direct health care system costs as a result of health R&D funded by the NHMRC is shown in Table 4.4. The greatest avoided cost is within cardiovascular disease at around $530 million, or approximately $53 million per year of NHMRC R&D investment. This is followed by cancer, with $161.8 million, or approximately $16.8 million per year per of NHMRC R&D investment. For SIDS the direct health care system avoided costs was approximately $872, or $87 per year of NHMRC R&D investment, and Asthma was associated with $6.2 million direct health care system costs avoided, or $0.6 million avoided per year of NHMRC R&D investment.

In Table 4.4, MD shows a negative number of direct health expenditure avoided (-$23,951). Negative numbers can be interpreted as an expected increase in direct health system costs as a result of an expected increase in the prevalence of disease. However, this does not mean that NHMRC funded health R&D in this area has not been effective. Rather, it indicates that current R&D levels are not sufficient to meet the expected increase in disease.

The value of avoided health system costs represents the minimum value of direct benefits derived from NHMRC funded R&D. As the public and private sectors have avoided payment for health related expenditures that would have otherwise occurred, the true value of

avoided health system expenditures is not the dollar figure saved, but the increase in benefits that have occurred from using these resources elsewhere in the economy. This study does not estimate these benefits.

Table 4.4: Value of avoided health care system costs due to NHMRC funded R&D between 2000 and 2010

Disease	Direct health expenditure avoided ($)
CVD	530,204,269
Cancer	161,811,841
SIDS	872
Asthma	6,167,701
MD	-23,951

Source: Deloitte Access Economics

4.4.3 Value of avoiding indirect costs

In addition to avoided direct health system costs, an increase in wellbeing provides additional benefits to the economy and society through avoiding associated indirect costs. These include:

- productivity gains from the avoidance of premature mortality and increased employment participation and/or reduced absenteeism associated with the avoidance of morbidity;
- avoided carer costs measured as the value of care services that would have otherwise been provided by informal (unpaid) carers and not captured in the direct health care system costs;
- other avoided costs not captured through the direct health system costs, such as aids and home modifications; and
- avoided deadweight loss (DWL) associated with government transfers such as taxation revenue forgone and welfare and disability payments.

To elaborate on productivity losses, which are usually the greatest cost associated with disease after the value of the loss of wellbeing, disease and injury can have an impact on economic productivity through three primary channels. These comprise:

- reduced productivity per worker at work due to the impacts of ill health, such as reduced functional, physical, mental and cognitive health;
- temporary reduction in the size of the labour force (total number of hours worked) due to absenteeism; and
- permanent reduction in the size of the labour force due to premature retirement and premature mortality within working age.[7]

Figure 4.2 provides a diagrammatic representation of the different types of productivity (income) losses that can occur for an individual due to a loss in wellbeing. At the lowest

[7] Within this study it was assumed that working age is between 15 and 65 (inclusive).

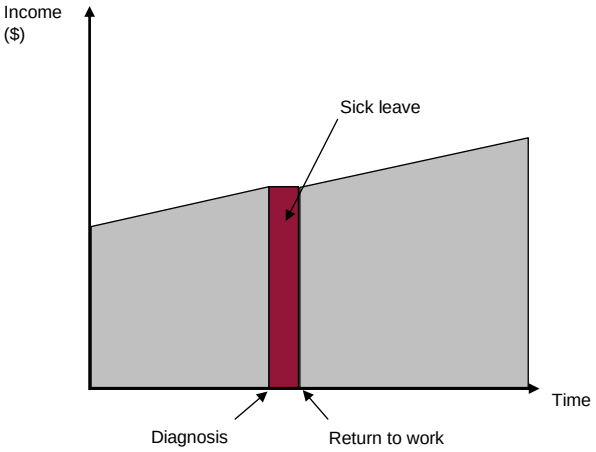
end of the productivity loss scale is a loss equal to the time taken for sick leave. This is shown in the top two panels of Figure 4.2. A moderate loss in productivity will occur when an individual experiences a loss in wellbeing that leads to sick leave and a permanent disability that reduces their productivity once they have returned. This is shown in the middle left panel of Figure 4.2. Large productivity losses will occur if a loss in wellbeing leads to a permanent disability that causes the individual to take early retirement, or leads to premature mortality within working age. Both these situations are shown in the last two panels respectively.

It should be noted that a loss in productivity by an individual will only be equal to a loss in productivity to the economy under fairly strict conditions. These are:

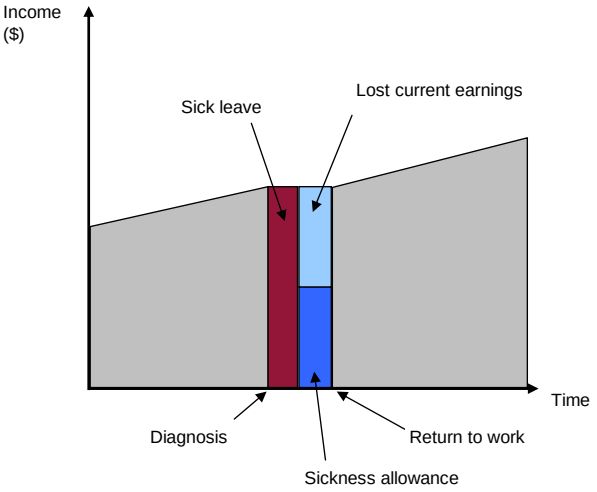
- the economy is at full employment so any reduction in hours worked due to sickness, or any permanent reduction in labour force participation through early retirement or death, cannot be replaced by employing or increasing hours of other workers; and
- the income of an individual is proportional to the total value added to production.

Figure 4.2: Diagrammatic representation of productivity losses

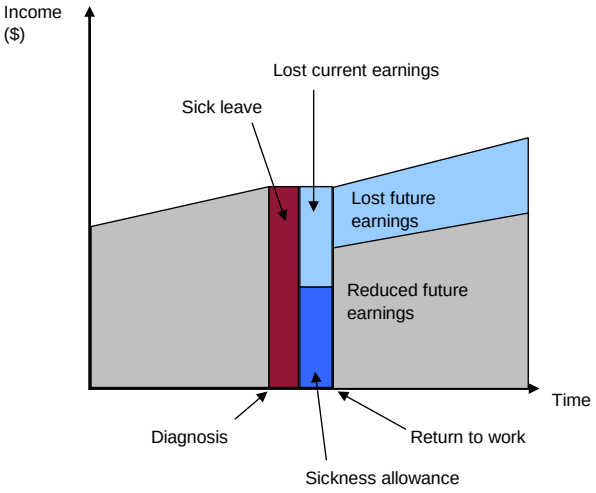
Minimal Productivity Loss - Covered Entirely by Sick Leave



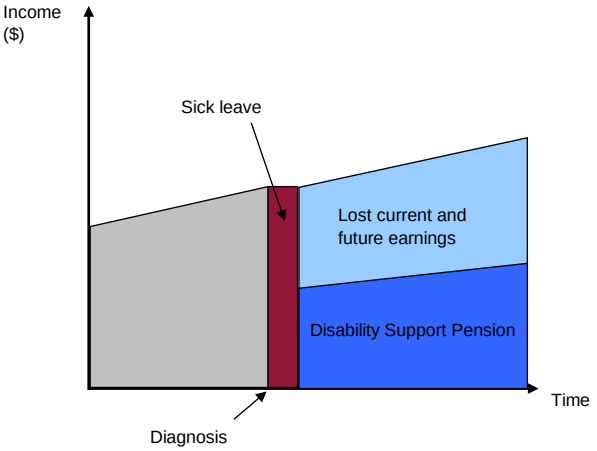
Minimal Productivity Loss - Covered Partially by Sick Leave



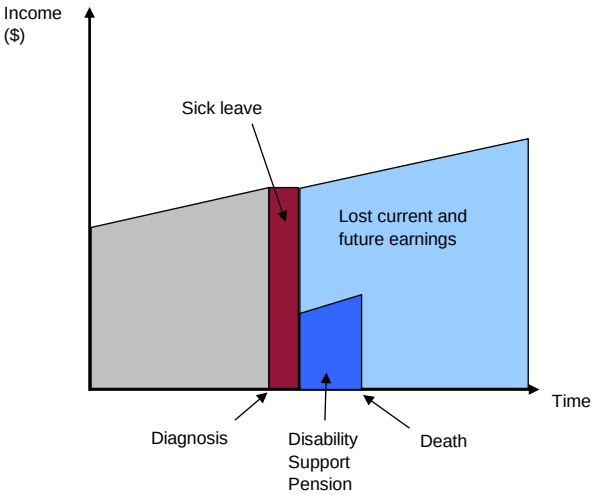
Moderate Productivity Loss - Reduced Rate of Future Earnings



Significant Productivity Loss - Permanent Disability



Significant Productivity Loss - Death



The first condition is likely to fluctuate over time as the economy moves into, and out of, full employment. Thus a reduction in labour when labour is scarce will have a greater impact on productivity than when labour is abundant. Although Australia is currently at full employment it is impossible to determine the scarcity of labour into the long term future when NHMRC R&D is still expected to impact wellbeing. However, given demographic ageing and current immigration and workforce policy, it is reasonable to assume that the long term goal of government will remain keeping the economy at full employment, so this is the assumption that has been used in calculating productivity losses. This means that a temporary or permanent reduction in working hours due to illness cannot be replaced by another worker, so it represents a loss in productivity to the Australian economy.

The second condition will only occur if there is a perfect labour market such that the marginal benefit from an additional hour of work (the value added) is equal to the marginal cost (the wage). In reality, the labour market is far from perfect for a number of reasons, for example asymmetric information within the market and labour market restrictions imposed by government regulation and natural labour market barriers. In addition, synergy created between labour and other factors of production such as capital and land means a reduction in working hours will also impact the productivity of other factors of production. Consequently the value of productivity from labour will be larger than the wage provided to an individual so using lost income from illness as a proxy for lost productivity is expected to underestimate the true value.

A full economic analysis on the impact of reduced productivity on the welfare of society would take into consideration flow-on effects to the economy, such as an increase in the price of labour due to a reduction in labour supply, the increase in the price of goods and services due to a higher labour cost, and the reduced demand for these goods and services due to the higher price and reduced incomes. This would require the use of a general equilibrium model, which is outside the scope of this study.

As such, the value of avoided lost productivity and the associated costs, such as funeral costs, carer costs, out-of-pocket costs (for example, aids and modifications, travel) and deadweight loss, have been derived from estimates previously made within burden of disease analyses previously undertaken by Access Economics over a range of conditions.

However, there is an imperfect mapping from the conditions previously investigated and the conditions investigated within this report, so some assumptions were made. For CVD, cancer, and MD previously established estimates were available from Access Economics studies (The shifting burden, 2004; The cost of cancer in NSW, 2005; The costs of Muscular Dystrophy, 2007).

For asthma, estimates arising from a previous Access Economics study on the cost of allergic disease (Access Economics, 2007) were used as proxies for the indirect costs associated with asthma. For SIDS, no previous estimates of indirect costs were available, so indirect costs had to be calculated. The two sources of indirect costs estimated for SIDS were funeral costs brought forward and productivity losses. Productivity losses were calculated by applying the standardised death rate for SIDS (ABS, 2009) to the average lifetime earnings, adjusted for the average participation rate, and discounted at a rate of 7%.

The cost per DALY (in 2011 prices) used for each condition are shown in Table 4.5. Although disease specific estimates for indirect costs were available for the majority of the diseases , for asthma these estimates are based on proxies for allergic disease and therefore may underestimate the true avoided costs.

To derive the value of avoided indirect costs for each cause, the cost per DALY was multiplied by the expected number of DALYs avoided due to NHMRC funded R&D, which was then discounted back to 2011 prices. These are shown for each condition in Table 4.5.

Overall, for each disease the largest magnitude of indirect costs expected to be avoided through NHMRC funded R&D relate to productivity losses (74% of indirect costs). This was followed by other financial costs (which includes funeral costs, carer costs, aids and modifications, travel, other out-of-pocket costs, legal costs, and government programs not accounted for in direct health system costs) comprising approximately 17% of total indirect costs, and finally deadweight losses which comprised approximately 9% of total indirect costs.

Table 4.5: Cost per DALY, by condition (2011)

	Productivity loss	Other financial costs	Deadweight loss
	$ per DALY	$ per DALY	$ per DALY
CVD	9,288	6,455	1,319
Cancer	15,285	1,157	3,411
SIDS	5,488	152	0
Asthma	99,852	4,664	13,961
MD	269,598	150,805	48,406

Source: Deloitte Access Economics

Table 4.6 shows the total indirect costs for diseases expected to be avoided as a result of NHMRC funded R&D. CVD had the greatest magnitude of indirect costs avoided at $402 million, followed by cancer with $236 million. Asthma had approximately $43 million in indirect costs avoided, while SIDS has $0.1 million.

Table 4.6:Value of avoided indirect costs between 2040 and 2050, attributable to NHMRC funded R&D between 2000 to 2010

Disease	$m
CVD	402.0
Cancer	236.1
SIDS	0.1
Asthma	42.5
MD	-0.7

Source: Deloitte Access Economics

While most of the diseases have a positive value for the expected avoidance of indirect costs, MD has a negative value. This can be interpreted as an expected increase in indirect

costs as a result of an expected increase in the prevalence of disease. However, this does not mean that NHMRC funded health R&D in this area has not been effective. Rather, it indicates that current R&D levels are not sufficient to meet the expected increase in disease and, consequently, there is an expected increase in indirect costs.

4.4.4 Value of commercial gains from NHMRC funded R&D

While improved health outcomes is the NHMRC's main goal in funding research, a large amount of this research has yielded valuable commercialisation benefits. The market value of Australian life science[8] companies is dominated by a handful of large, older companies all of which have developed products based on NHMRC research support. While these benefits are large, some of the breakthrough products have had lengthy research support from the council. Thus, in order to estimate the benefit to cost ratio of commercialisation, it is necessary to estimate the value of NHMRC support back to those early research times, and the current commercial value resulting from that support.

Most Australian biotech companies are young and still in the process of developing their research. Average time from discovery to product is around six years, and roughly three quarters of companies are set up before they have a marketable product. A survey of Biotech companies undertaken by Research Australia (2004) found that they had an average age of 7.88 years, with an age range of 0.1-22 years. While these young companies have been supported by the NHMRC, most of the benefits of commercialisation are yet to be reaped. The value of NHMRC support for products still in the development pipeline is included in this analysis, although the uncertainties surrounding the development paths of current 'pre-product' companies preclude estimating future commercialisation benefits. Consequently this retrospective analysis may under-estimate the B/C ratio of existing and previous NHMRC support.

4.4.5 Benefits of NHMRC-supported commercialisation

Research Australia (2004) found that 33% of Australian biotech companies have received funding from the NHMRC for their research. As these findings were based on 400 companies, it implies that around 133 companies were developing products derived from NHMRC supported research.

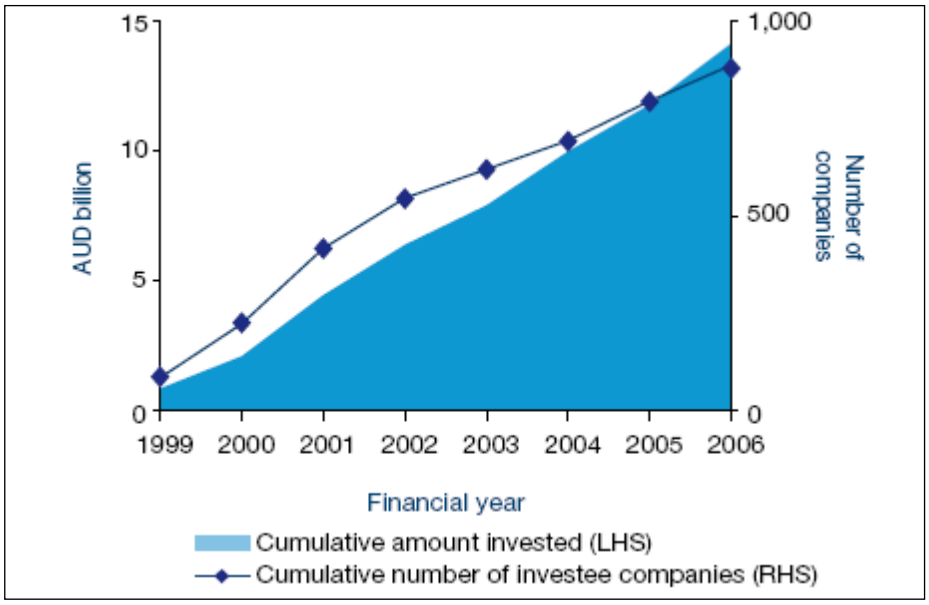
The majority of the market value of life science companies comes from those who are publicly listed. PriceWaterhouse Coopers (PWC) (2009, 2010) reports that the market capitalisation of Life Science companies listed on the Australian Securities Exchange averaged across the 2009-10 financial year was $35 billion. However this is expected to be an underestimate of the total market value as only around 35% of biotech companies are listed (Research Australia, 2004). The rest are private companies, whose commercialisation is almost universally (94%) funded by private equity / venture capital (PE/VC)[9]. PWC (2006) reports that there are more PE/VC supported firms in the health care sector than any other industry in Australia. Consequently the number of firms across all sectors that are supported by PE/VC has also grown rapidly since 2001.

[8] "Life Sciences" is composed of "Pharma/Biotech" and "Medical Devices". The NHMRC advises that its funded research contributes to both these sectors (and that the boundaries between the two can be indistinct).

[9] Other sources of funding include various government programs and pharmaceutical companies.

Figure 4.3 shows the growth of private equity and venture capital funding in Australia between 1999 and 2006. In 2006, PWC reported that the value of PE/VC invested in health companies in June 2006 was $434 million. The value of PE/VC investments in health companies has grown considerably in recent years and the ABS (2011) reports that in 2009/10 the value of PE/VC funds invested in biotech, pharmaceuticals and health was $1.396 billion.

Figure 4.3: Growth of private equity and venture capital funding in Australia



Source: PriceWaterhouse Coopers (2006).

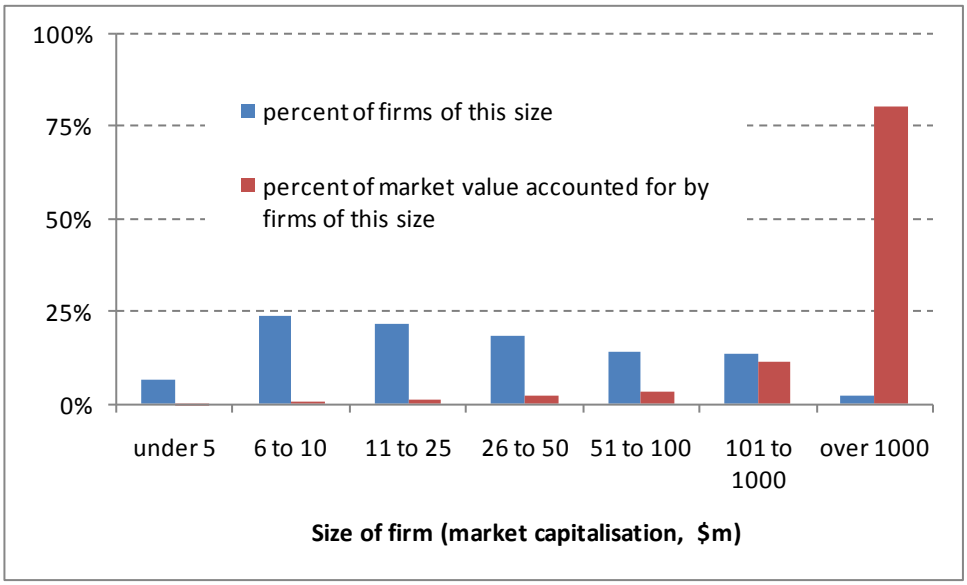
Failure rates among firms funded by venture capital can be very high and it is expected that a considerable number of these start-ups will collapse. However, the amount of money invested in a biotech firm is effectively the market value of that firm's commercialisation, even if no useful products ever result. A parallel with this corollary is that the amount of money shareholders are prepared to invest in a listed firm is its market value today, even if the firm later collapses.

Combining the listed and unlisted firms, and converting their value in 2009-10 to 2011 prices, brings the total value of commercialised Australian health research to $36.9 billion. Multiplying this total by the proportion of biotech companies that have received NHMRC funding (33%) implies that the value of companies formed using NHMRC-funded research (whether in part or completely) is around $12.2 billion. In essence, this represents the market value of the discounted future stream of revenue from life science products currently being produced (or expected to be produced) by these companies as a result of NHMRC funding.

Of course this may overstate the value of NHMRC input as it is likely that companies have received funding from elsewhere. However, it may also understate the value of NHMRC funding. This is because the top three companies (Cochlear, ResMed and CSL) account for around 80% of this total market capitalisation (Chart 4.19), and the flagship products of all three, including the bionic ear, continuous positive airway pressure (CPAP) devices for sleep

apnoea, and Gardasil[10] respectively have been supported by the NHMRC. On balance, it is considered that the estimate of one-third of market capitalisation being ultimately derived from NHMRC funded research may be conservative.

Chart 4.19: Distribution of Australian Biotech firms by size and market value



Source: PriceWaterhouseCoopers (2008)

While ground-breaking new products[11] like Gardasil could not have happened but for the underlying basic research, there is also a great deal of subsequent effort needed during the following development and commercialisation phases. To account for this, the commercial value of products was apportioned in equal shares to the R&D and to other factors that impact commercialisation success, for example marketing, regulatory approval processes, and supply chain development. Thus, of the $12.2 billion worth of commercialisation developed from NHMRC-funded research discoveries, $6.1 billion has been attributed to R&D and $6.1 billion to 'everything else'.

4.4.6 Cost of NHMRC funding

The commercialisation benefits of NHMRC funded R&D needs to be compared against the cost of funding. There are two criteria that need to be determined here, including what proportion of the NHMRC's total annual funding should be included as an R&D cost, and how many years of funding should be used.

[10] Gardasil is not its only major product, however in the first year of Gardasil being released, CSL's profit increased by $91 million (36%), most of which has been attributed to Gardasil royalties ($81 million) and profits from $143 million of Australian Gardasil sales (http://www.csl.com.au/docs/358/504/1H08%20ASX%20release%20FINAL.pdf)

[11] A "product" need not be physical. Research Australia found that while sale of goods and services accounted for the largest share of revenue (44%) for biotech companies, licensing intellectual property was a close second (43%).

At a minimum, the research cost should include the total present value of all funds the NHMRC has supplied to these firms since it started supporting them. However, over that period, the NHMRC would have also funded a large amount of research that never led to any commercial benefits. This type of funding also needs to be included in the analysis as an R&D cost.

As CSL, ResMed and Cochlear account for over three-quarters of the total market value of life science companies, it could be argued that the relevant years to be included as an R&D cost are those since the NHMRC began funding their flagship products (eg, 1985 for Gardasil). Conversely, it could be argued that R&D the NHMRC has supported in earlier years also contributes to the value of products currently on the market, as well as those that did not make it to market. Consequently it is important to account for the latter to avoid underestimating costs. In Section 4 of this report it was assumed that the total health benefits of NHMRC funded R&D undertaken in one year is experienced over 40 years. To ensure methodological consistency, the same average lag period is adopted here. That is, it assumed that the benefits of commercialisation in 2011 are the result of R&D undertaken since 1970-71.

It could be argued that the benefits of commercialisation accrue earlier than health benefits because of the preventive nature of many products. For example, Gardasil took around 20 years from the first NHMRC grant to the first vaccines being sold. At this point, the benefits of commercialisation are accrued in the form of increased share prices[12] but most of the health benefits will not be incurred until nearly 40 years[13]. However, in the interests of being conservative and consistent, the occurrence of health and commercial benefits has been treated as contemporaneous since many products have immediate health benefits and the period of commercial benefits (like health benefits) extends long into the future.

Data for NHMRC funding are not available as far back as 1968, although budget allocations for its medical research program are. From years when funding data are available (from 1993-94 onwards), the NHMRC is highly efficient in converting budget appropriations into research grants. On average, 95% of program outlays are actual research funding, and only 5% is administration. This ratio has been applied to program allocations from 1970-71 to 2009-10. To ensure benefits and costs are measured in the same units, research expenditure was converted to 2011 prices using CPI data. The total value in today's dollars of NHMRC research funding since 1970-71 is $8.5 billion, as shown in Table 4.7 along with nominal and real expenditure.

Thus, in 2011, the estimated value of commercialisation developed from NHMRC funded R&D was $6.1 billion, and the amount of associated funding is estimated at $8.5 billion. This yields a commercialisation benefit to cost ratio of 0.72:1. That is, the financial benefits from commercialisation alone would be enough to recoup almost three quarters of the dollars NHMRC spends on research, before any of the health benefits are assessed.

[12] For most companies, this would be the point of an initial share market float.

[13] The average age for contracting cervical cancer is 50 years; the target group for the National Immunisation Program are thirteen year olds.

Table 4.7: NHMRC medical research funding appropriation, July 1970 to June 2010

Year	$m(nominal)	CPI	$m(real)
1970-71	$ 2,296,408	9.75	$21,726,571
1971-72	$ 2,573,781	9.12	$22,769,605
1972-73	$ 3,368,000	8.60	$28,081,782
1973-74	$ 4,780,000	7.62	$35,316,009
1974-75	$ 8,030,000	6.52	$50,789,564
1975-76	$ 5,211,000	5.78	$29,191,885
1976-77	$ 10,295,000	5.07	$50,635,047
1977-78	$ 11,714,000	4.63	$52,601,034
1978-79	$ 13,175,000	4.28	$54,724,451
1979-80	$ 14,000,000	3.88	$52,747,788
1980-81	$ 18,698,000	3.55	$64,426,290
1981-82	$ 25,648,000	3.22	$80,033,979
1982-83	$ 29,754,000	2.89	$83,272,082
1983-84	$ 37,979,000	2.70	$99,466,724
1984-85	$ 44,182,200	2.59	$110,976,824
1985-86	$ 51,236,000	2.39	$118,714,161
1986-87	$ 58,952,000	2.19	$124,947,425
1987-88	$ 64,635,000	2.04	$127,621,339
1988-89	$ 68,748,000	1.90	$126,468,100
1989-90	$ 80,426,000	1.76	$136,965,478
1990-91	$ 90,955,000	1.67	$147,134,994
1991-92	$ 98,579,000	1.64	$156,495,024
1992-93	$ 105,148,901	1.62	$165,230,522
1993-94	$ 111,272,000	1.59	$171,722,896
1994-95	$ 117,318,000	1.54	$175,410,495
1995-96	$ 131,161,000	1.48	$188,138,288
1996-97	$ 139,076,000	1.46	$196,920,747
1997-98	$ 148,029,123	1.46	$209,641,244
1998-99	$ 166,003,858	1.44	$232,057,927
1999-00	$ 156,847,607	1.41	$214,160,333
2000-01	$ 185,207,079	1.33	$238,628,830
2001-02	$ 262,663,109	1.29	$329,029,257
2002-03	$ 332,688,000	1.25	$404,258,055
2003-04	$ 412,709,000	1.22	$489,957,077
2004-05	$ 414,579,688	1.19	$480,455,399
2005-06	$ 436,833,950	1.16	$490,556,028
2006-07	$ 614,491,000	1.12	$670,496,987
2007-08	$ 644,000,000	1.09	$679,617,041
2008-09	$ 617,837,000	1.05	$632,222,569
2009-10	$ 703,065,000	1.03	$703,065,000

Total	**$8,446,674,852**

Source: NHMRC

4.4.6.2 Commercial benefits from NHMRC funded R&D between 2000 and 2010

The rate of return calculated over the last 40 years can be applied against the cost of NHMRC research from 2000 to 2010 in order to add estimated commercialisation benefits to the health benefits resulting from that period. Total funds provided by the NHMRC for research and development for each disease is as follows: $ 862.2 million for CVD; $1.2 billion for cancer, $5.7 million for SIDS, $156.5 million for asthma and $27.9 million for MD. Multiplying this by 0.72 gives an estimated **commercial benefit of around $621.7 million for CVD, $831.2 million for cancer, $4.1 million for SIDS, $112.8 million for asthma, and $20.1 million for MD** for NHMRC funded R&D between 2000 to 2010.

The commercialisation returns to research conducted after 1992 may be higher than returns on research conducted in the 1960s and 1970s because prior to the mid-nineties, commercialisation was a matter which was not contemplated by the majority of medical researchers (Research Australia, 2004). Evidence of this can also be seen in the age of biotech companies, with an average age of approximately 8 years in 2004 (Research Australia, 2004). DoHA (2004) attributes this mostly to a cultural change ushered in by the Wills review report.

The estimated value of commercialisation should be used with caution. There is uncertainty regarding whether the value of commercialisation represents a true increase in welfare to Australians or a transfer of welfare from consumers to producers. For example, if all new products produced using NHMRC funded R&D were sold only in Australia, there would be no net increase in welfare from commercialisation benefits because it is simply a transfer of surplus from consumers to producers. What people gain in welfare from better health is reduced by the loss in consumption of alternative goods and services. This will even be the case if products are subsidised by the government (for example, through the Pharmaceutical Benefits Scheme) because, rather than consumers paying for the product, it will be taxpayers. The value of commercialisation will only represent an increase in welfare to Australians to the extent that products are sold internationally and the surplus is repatriated back to Australian investors, such as shareholders or the government.

4.5 Total net benefits from NHMRC funded R&D

Summaries of the benefits derived from NHMRC funded R&D between 2000 and 2010 are provided in Table 4.8 to Chart 4.21Table 4.13. These data include actual and expected benefits derived from:

- Improvements in wellbeing;
- Avoided direct health system costs;
- Avoided indirect costs, such as:
    - Productivity loss

- Other financial costs, including funeral costs, carer costs, aids and modifications, travel, legal costs, other out-of-pocket costs and Government programs not accounted for in direct health system costs.
- Deadweight loss; and

- Commercialisation of NHMRC funded R&D.

A summation of net benefits, the B/C ratio and ROI metrics arising from NHMRC funded R&D are reported across the five diseases under investigation in Table 4.8. It can be seen that investment into health R&D for CVD has returned the greatest net benefits, with net benefits of $4.39 billion, followed by cancer with an expected net benefit of around $1.96 billion. The net monetary benefit related to asthma R&D is $35.5 million, while SIDS R&D has a considerably lower net benefit of $0.1 million. MD R&D is estimated to show a net loss (-$8.4 million).

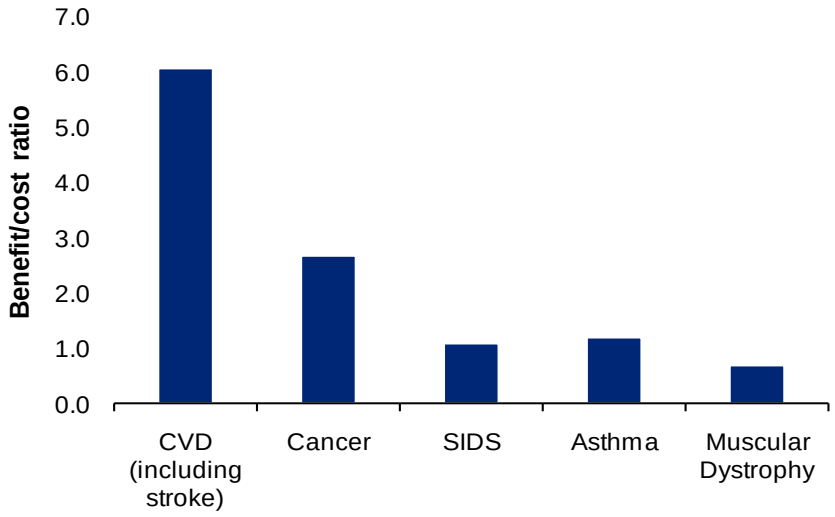
In rank order from highest to lowest, ROIs for R&D are for CVD (509), cancer (169.9), SIDS (11.6), Asthma (22.7), and MD (-30.3). Benefit/cost ratio and ROI data are presented schematically in Chart 4.20 and Chart 4.21, respectively.

Table 4.8: Net benefit, B/C ratio and ROI for NHMRC funded R&D by disease

	CVD (inc. stroke)	Cancer	SIDS	Asthma	Muscular Dystrophy
Net Benefit ($m)	**4389.0**	**1958.2**	**0.7**	**35.5**	**-8.4**
Benefit / Cost ratio	6.1	2.7	1.1	1.2	0.7
ROI	509.0	169.9	11.6	22.7	-30.3

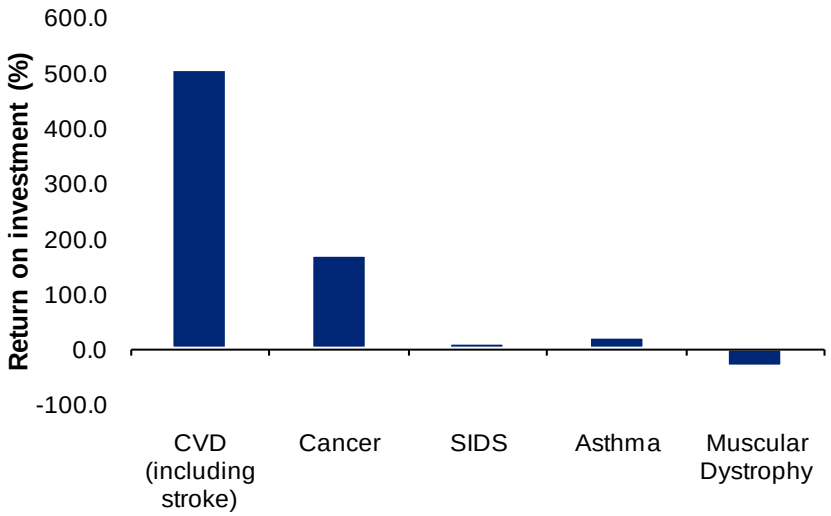
Source: Deloitte Access Economics Calculations.

Chart 4.20: Benefit / cost ratio for average 40 year lagged benefits from NHMRC funded R&D by disease



Source: Deloitte Access Economics Calculations.

Chart 4.21: Return on investment (ROI) in average 40 year lagged benefits from NHMRC funded R&D by disease



Source: Deloitte Access Economics calculations.

A breakdown of the benefits and costs and estimated average annual benefits from NHMRC funded R&D are provided for each of the disease in Table 4.9 to Table 4.13. As the benefits from improvements in wellbeing are derived from the VSL, and as individuals consider their expected after-tax future earnings and out-of-pocket health system expenditures when revealing their value for healthy life, these costs were netted out of the total benefits to avoid double counting.

Parameters used in the derivation of net benefits from NHMRC funded R&D by disease include:

- The individual component of health system expenditures, which was estimated as 16.8% (AIHW, 2010b); and
- The individual component of productivity losses, which was estimated as 80.4%, given an average personal income tax rate of 19.6% (Deloitte Access Economics, 2011).

4.5.2 Cardiovascular disease

Net benefits arising from NHRMC funded R&D for CVD during 2000 to 2010 are estimated at around $4.39b, with realisation during 2040 to 2050 (Table 4.9). The predominance of these benefits will be found from improvements in wellbeing (75.5%), followed by those found in commercialisation (11.8%). Without commercialisation, avoidance of direct health system costs will come to represent 9.5% of benefits.

4.5.3 Cancer

NHRMC funded R&D for cancer during 2000 to 2010 is estimated to generate around $1.96b in net benefits, with realisation during 2040 to 2050 (0). The benefits arising from this research are estimated to split predominantly between improvements in wellbeing (64.3%) and commercialisation (26.7%). Without commercialisation, net improvements in wellbeing will come to represent around 88% of benefits.

4.5.4 SIDS

The net benefit resulting from NHMRC funded R&D for SIDS is expected to be approximately $0.66 million (Table 4.11). The key driver for the realisation of these benefits are wellbeing gains (35.1%:Table 4.11), which when commercialisation is excluded, rises as a proportion to around 99%. Commercialisation benefits are otherwise expected to contribute 64.6% of net benefits.

4.5.5 Asthma

Net benefits attributable to NHMRC funded R&D for asthma during 2000 to 2010 are estimated to amount at around only $35 million (0). This result is, perhaps, partly attributable to Australia's past successes in tackling asthma during the last two decades, resulting in significant reductions in asthma-associated mortality. The greatest driver of realised benefits in 2040-50 is gains in wellbeing (31.4%: 0), which rises to 76.2% of gains once commercialisation is excluded.

4.5.6 MD

NHMRC funded R&D for MD during 2000 to 2010 is estimated to return a net loss of around $8.4 during 2040-2050 (Table 4.13). This outcome is expected due to an increase in incidence or risk factors for MD, despite the best efforts from health R&D.

Table 4.9: Cardiovascular disease (inc. stroke) – Benefits from NHMRC funded R&D, 2000 - 2010

Type of benefit	Gross (2011 $m)	Net (2011 $m)	Annual (2011 $m)	% total inc. commercial'n	% total exc. commercial'n
Net improvements in wellbeing	3,962.3	3,962.3	264.2	75.5	85.6
Avoided direct health system costs	530.2	441.1	29.4	8.4	9.5
Avoided productivity loss	218.8	42.9	2.9	0.8	0.9
Avoided 'other' financial costs	152.1	152.1	10.1	2.9	3.3
Avoided deadweight loss	31.1	31.1	2.1	0.6	0.7
Value of commercialisation	621.7	621.7	41.5	11.8	-
Total benefits of NHMRC funded R&D	5,516.2	5,251.2	340.1	100%	100%
Total costs of NHMRC funded R&D	862.2	862.2	57.5		
Total net benefits:	4,653.9	4,388.9	292.6		

Source: Deloitte Access Economics calculations.

Table 4.10: Cancer – Benefits from NHMRC funded R&D, 2000 - 2010

Type of benefit	Gross (2011 $m)	Net (2011 $m)	Annual (2011 $m)	% total inc. commercial'n	% total exc. commercial'n
Net improvements in wellbeing	2,000.5	2000.5	133.3	64.3	87.7
Avoided direct health system costs	161.8	134.6	9.0	4.3	5.9
Avoided productivity loss	128.6	25.2	1.7	0.8	1.1
Avoided 'other' financial costs	89.3	89.3	6.0	2.9	3.9
Avoided deadweight loss	31.1	31.1	2.1	1.0	1.4
Value of commercialisation	831.2	831.2	55.4	26.7	-
Total benefits of NHMRC funded R&D	3,242.5	3,111.9	207.4	100%	100%
Total costs of NHMRC funded R&D	1,152.8	1,152.8	76.9		

Total net benefits:	2,089.7	1,959.2	130.6		

Source: Deloitte Access Economics calculations.

Table 4.11: SIDS – Benefits from NHMRC funded R&D, 2000 - 2010

Type of benefit	Gross (2011 $m)	Net (2011 $m)	Annual (2011 $m)	% total inc. commercial'n	% total exc. commercial'n
Net improvements in wellbeing	2.2	2.2	0.2	44.3	99.1
Avoided direct health system costs	0.0008	0.0008	0.00005	<0.1	0.03
Avoided productivity loss	0.06	0.001	0.001	0.22	0.5
Avoided 'other' financial costs	0.002	0.002	0.0001	<0.1	<0.1
Avoided deadweight loss	0.006	0.006	0.0004	0.1	0.3
Value of commercialisation	4.1	4.1	0.3	55.27	-
Total benefits of NHMRC funded R&D	6.4	6.4	0.4	100%	100%
Total costs of NHMRC funded R&D	5.7	5.7	0.4		
Total net benefits:	0.71	0.66	0.04		

Source: Deloitte Access Economics calculations.

Table 4.12: Asthma – Benefits from NHMRC funded R&D, 2000 - 2010

Type of benefit	Gross (2011 $m)	Net (2011 $m)	Annual (2011 $m)	% total inc. commercial'n	% total exc. commercial'n
Net improvements in wellbeing	60.3	60.3	4.0	31.3	76.2
Avoided direct health system costs	6.1	5.1	0.3	2.7	6.5
Avoided productivity loss	36.0	7.0	0.5	3.6	8.9
Avoided 'other' financial costs	1.7	1.7	0.1	0.9	2.1
Avoided deadweight loss	5.0	5.0	0.3	2.6	6.3
Value of commercialisation	112.8	112.8	7.5	58.9	-

Total benefits of NHMRC funded R&D	211.7	191.9	12.8	100%	100%
Total costs of NHMRC funded R&D	156.5	156.5	10.4		
Total net benefits:	65.3	35.5	2.3		

Source: Deloitte Access Economics calculations.

Table 4.13: MD – Benefits from NHMRC funded R&D, 2000 - 2010

Type of benefit	Gross (2011 $m)	Net (2011 $m)	Annual (2011 $m)	% total inc. commercial'n	% total exc. commercial'n
Net improvements in wellbeing	-0.3	-0.3	-0.02	-1.3	38.8
Avoided direct health system costs	-0.02	-0.02	-0.001	-0.1	3.0
Avoided productivity loss	-0.4	-0.08	-0.05	-0.4	12.2
Avoided 'other' financial costs	-0.2	-0.2	-0.02	-1.2	34.8
Avoided deadweight loss	-0.07	-0.07	-0.005	-0.4	11.2
Value of commercialisation	20.1	20.1	1.3	103.5	-
Total benefits of NHMRC funded R&D	19.1	19.4	1.3	100%	100%
Total costs of NHMRC funded R&D	27.9	27.9	1.86		
Total net benefits:	-8.8	-8.4	-0.6		

Source: Deloitte Access Economics calculations.

4.5.7 Sensitivity analysis

The results reported in Section 4.5 are estimates of the net benefits, ROI and B/C ratios generated from NHMRC funded R&D over the period 2000 to 2010. As they are point estimates based on uncertain inputs into the model, the accuracy of the estimates cannot be determined from these results alone. In order to incorporate the uncertainty of inputs into the model, a sensitivity analysis was undertaken.

The sensitivity analysis investigated how the net benefits, ROI and B/C ratio changed with different assumptions regarding inputs used within the model. This provides an indication of how confident we are in the results presented in Section 4.5. The inputs that were investigated included:

- VSLY – Simulation 1: $66,821 (2011 prices) and Simulation 2: $168,166 (2011 prices);
- proportion of health gains attributed to world health R&D ;
- contribution of Australian health R&D to the total health gains attributable to world health R&D; and
- proportion of Australian R&D health gains derived from NHMRC funded R&D.

Two simulations were run around discrete values for the VSLY, taking into account a lower bound and upper bound for this parameter. We chose to perform sensitivity analysis around these discrete VSLY valuations as the values here are often provided through exogenous determination[14].

Within these individual simulations, for each of the remaining inputs, a probability distribution was placed around the most likely value, which was utilised in the baseline modelling (Section 4.5). The probability distributions account for uncertainty by describing the probability of the input taking on a certain value. For example, the "proportion of health gains attributed to world health R&D" estimate used within the model was 50%, which represents the most likely value. As this is only an estimate, the true value may be some other number, either higher or lower than the estimate used in the model. The probability distribution attaches a probability to these other numbers.

The probability distributions used within the sensitivity analysis were constructed based on the most likely lower and upper bounds for each of the inputs and the most likely type of probability distribution for that input. These are shown in Figure 4.4, and were equivalent across discrete VSLY simulations. For these inputs, a triangular distribution was used.

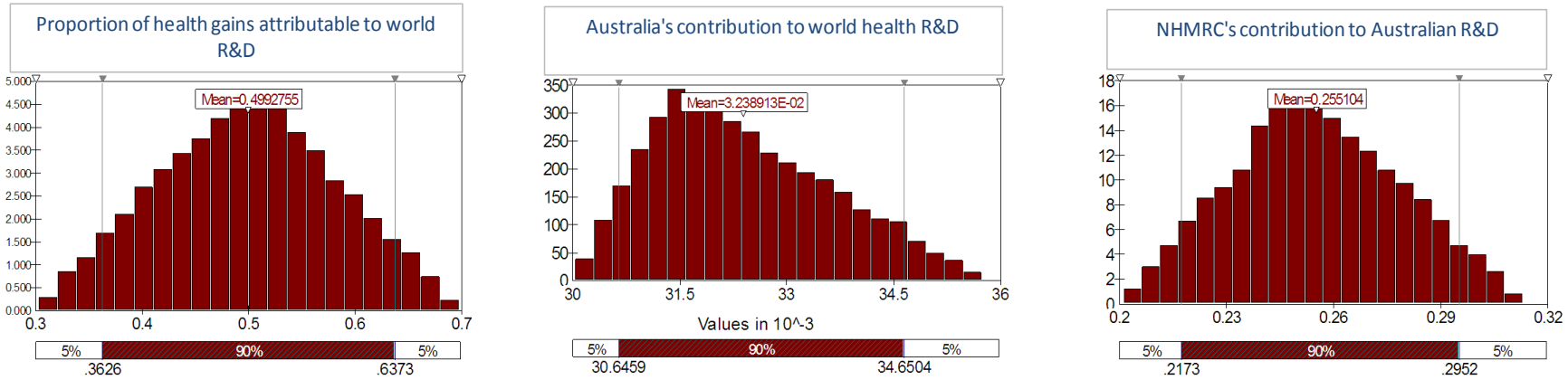
The sensitivity analysis was undertaken using a Monte Carlo simulation[15]. This simultaneously drew a random number for each input from their distribution and

[14]For example, the OBPR arm of the Department of Finance recommends that a VSLY equivalent to $151,000 (2008 prices) be utilised in BoD analysis; www.finance.gov.au/obpr/docs/ValuingStatisticalLife.rtf.

[15] Monte Carlo simulation is a well known technique used to determine the sensitivity of model outputs from key model inputs. It iteratively replaces numbers attached to key parameters (inputs) with random numbers drawn from a specified distribution, where the type of distribution, the upper and lower bounds on the distribution, and the number of iterations are chosen by the analyst. The Monte Carlo simulation provides a distribution around chosen outputs (such as the return on investment) from which sensitivity of outputs to inputs can be determined. The program used to undertake the Monte Carlo simulation was @Risk4.5.

recalculated the net benefit, ROI and B/C ratio. This process was repeated 10,000 times to provide 10,000 different estimates. From these estimates, worst case and best case scenarios were developed, along with the most likely scenario.

Figure 4.4: Distribution of key inputs used within the sensitivity analysis



Source: Deloitte Access Economics.

4.5.8 Results of sensitivity analysis

The results from the simulation are presented in Table 4.14 where VSLY was set to $66,821 (2011 prices) and in Table 4.15 where VSLY was set to $168,166 (2011 prices). These data are presented by minimum, mean (most likely), and maximum net benefit ($m), B/C ratio and ROI, generated from the simulation. The tables also show the 90% confidence intervals for each estimate, which is represented by the last two columns.

Distributions of the aforementioned key outputs from sensitivity analysis are presented across disease and VSLY simulation in Figure 4.5, Figure 4.6 and Figure 4.7. The graphs show the shape of the distributions around the simulation mean, including 90% confidence interval.

Substantial variation between best and worst case scenarios was generated in the sensitivity analyses (Table 4.14, Table 4.15). Some salient overarching observations include:

- Consistently across CVD and cancer: positive net benefits, B/C ratios and ROI were estimated in both simulations, which remained true for best and worst case scenarios.
- The net benefits and ROI for asthma were more sensitive to changes in the VSLY, with the lower bound VSLY estimate ($66,821) producing negative net benefits and ROIs in the best and worst case scenarios.
- Across both simulations and for all scenarios, MD was estimated to return a net loss and sub-parity B/C ratios.
- The probability of actually realising the best and worst case scenarios described in the sensitivity analyses is extremely small and should therefore be viewed with caution. Instead it is best to look at the confidence intervals to determine where the true estimates are likely to lie. The confidence intervals reveal the probability (90%) that the real net benefits, B/C ratio and ROI lies between their confidence interval bounds. For example, Table 4.14 (with VSLY estimated at $66,821) shows that even though there is large uncertainty surrounding the inputs, there is a 90% chance that the interval for the net benefits from NHMRC R&D in CVD ($1.41 billion, $2.89 billion) contains the true net benefits. Similarly, for CVD there is a 90% chance that the B/C ratio for NHMRC R&D lies somewhere between 2.6 and 4.4 and the ROI lies somewhere between 160.7% and 335.3%.
- The 90% confidence intervals for the net benefits across the diseases suggest that the total combined net benefits from Australian R&D across the five diseases lie somewhere in the range of $4.7 billion to $9.2 billion if the VSLY is valued at $168,166, and between $1.9 billion to $4.1 billion if the VSLY is $66,821.

Table 4.14: Results of sensitivity analysis: VSLY=$66,821

Output	Disease	Min	Mean	Max	5%	95%
Net benefit ($m)	CVD	916	2,118	3,797	1,406	2,887
	Cancer	233	810	1,615	468	1,179
	SIDS	-1	-1	0	-1	0
	Asthma	-22	1	33	-12	16
	MD	-9	-8	-8	-8	-8
Benefit/Cost ratio	CVD	2.1	3.5	5.4	2.6	4.3
	Cancer	1.2	1.7	2.4	1.4	2.0
	SIDS	0.8	0.9	1.0	0.8	0.9
	Asthma	0.9	1.0	1.2	0.9	1.1
	MD	0.7	0.7	0.7	0.7	0.7
Return on investment (ROI)	CVD	106.3	245.7	440.3	163.1	334.8
	Cancer	20.2	70.2	140.1	40.6	102.2
	SIDS	-19.7	-11.2	0.7	-16.2	-5.7
	Asthma	-13.8	0.9	21.3	-7.8	10.2
	MD	-31.2	-29.8	-28.8	-30.4	-29.2

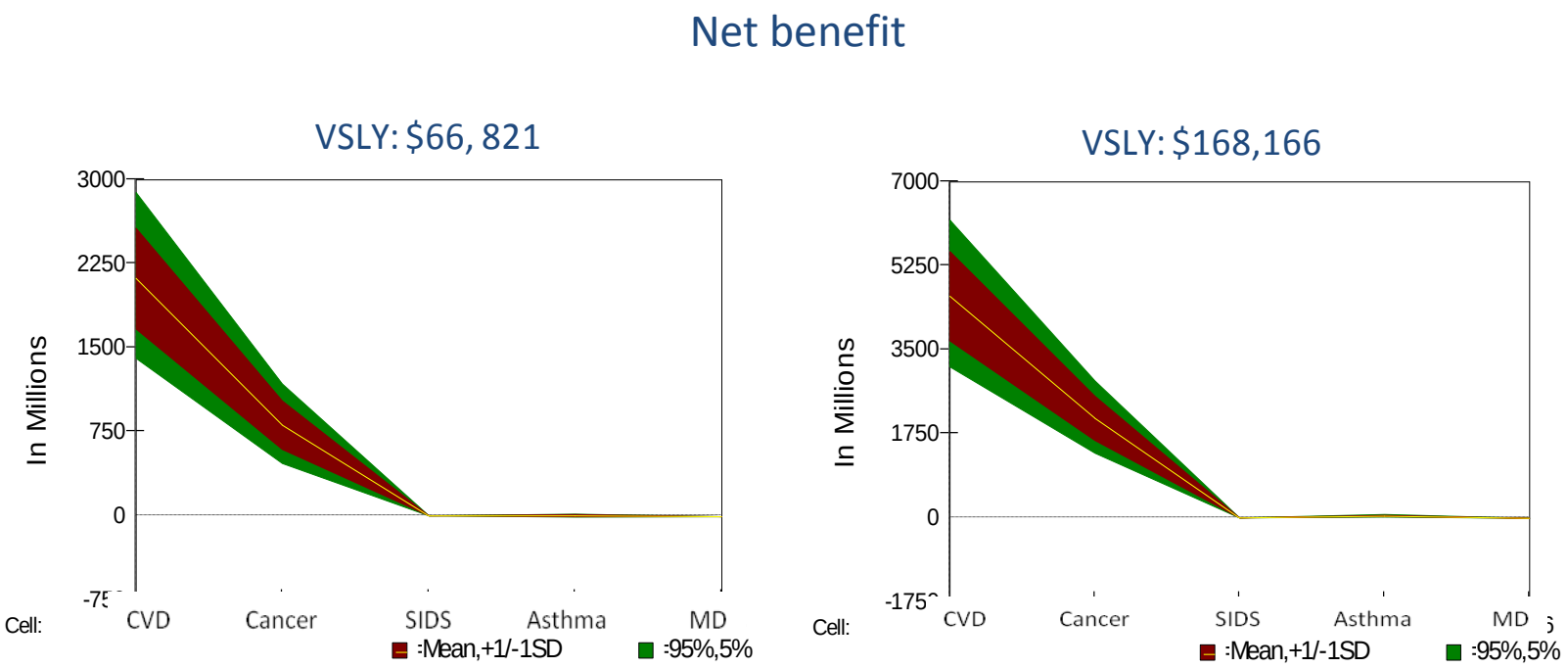
Source: Deloitte Access Economics

Table 4.15: Results of sensitivity analysis: VSLY=$168,166

Output	Disease	Min	Mean	Max	5%	95%
Net benefit ($m)	CVD	2,265	4,617	7,994	3,147	6,204
	Cancer	913	2,072	3,736	1,348	2,853
	SIDS	0	1	2	0	2
	Asthma	-1	39	97	14	66
	MD	-9	-8	-8	-9	-8
Benefit/Cost ratio	CVD	3.6	6.4	10.3	4.7	8.2
	Cancer	1.8	2.8	4.2	2.2	3.5
	SIDS	0.9	1.1	1.4	1.0	1.3
	Asthma	1.0	1.3	1.6	1.1	1.4
	MD	0.7	0.7	0.7	0.7	0.7
Return on investment (ROI)	CVD	262.7	535.5	927.2	365.0	719.5
	Cancer	79.2	179.7	324.0	116.9	247.5
	SIDS	-6.5	13.5	42.3	1.0	27.1
	Asthma	-0.5	25.1	62.0	9.1	42.5
	MD	-32.1	-30.4	-29.2	-31.2	-29.6

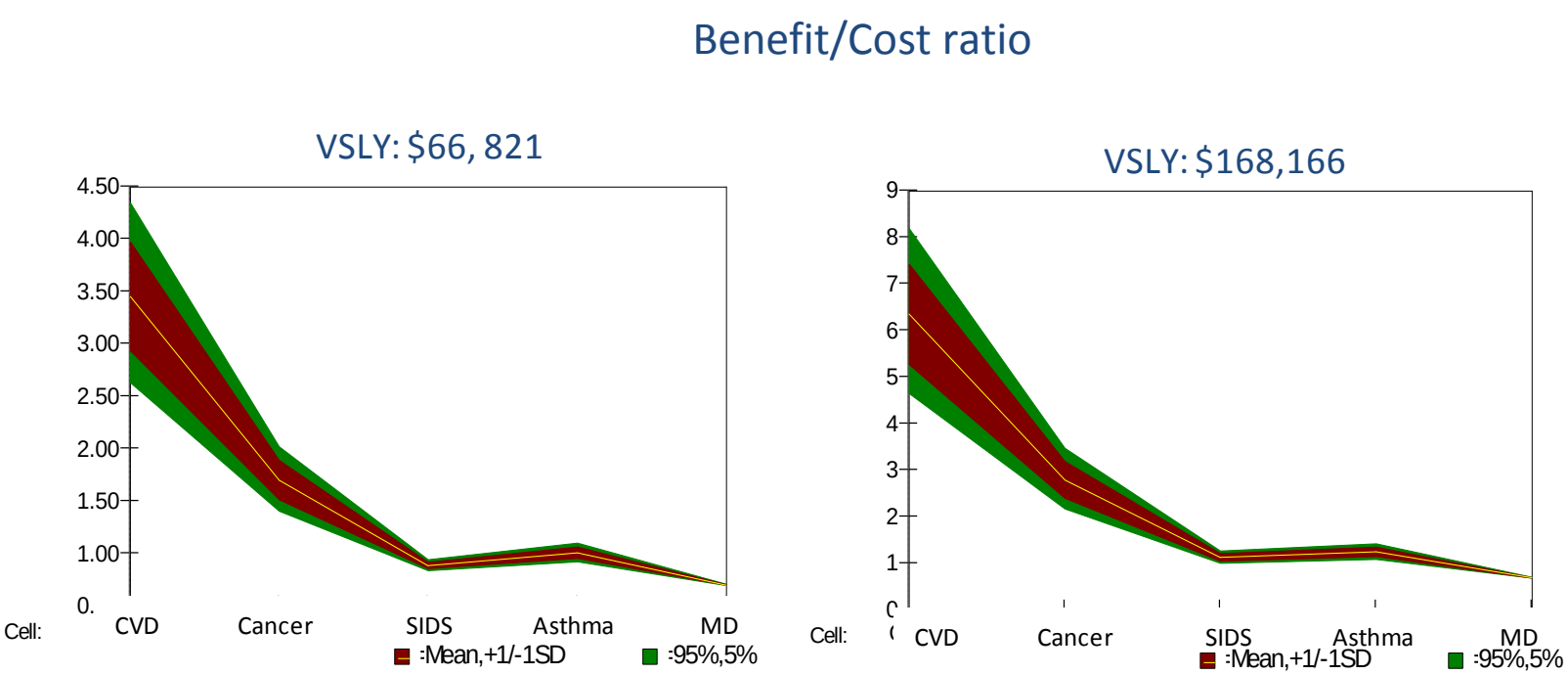
Source: Deloitte Access Economics

Figure 4.5: Distribution of net benefit ($m) from the sensitivity analysis



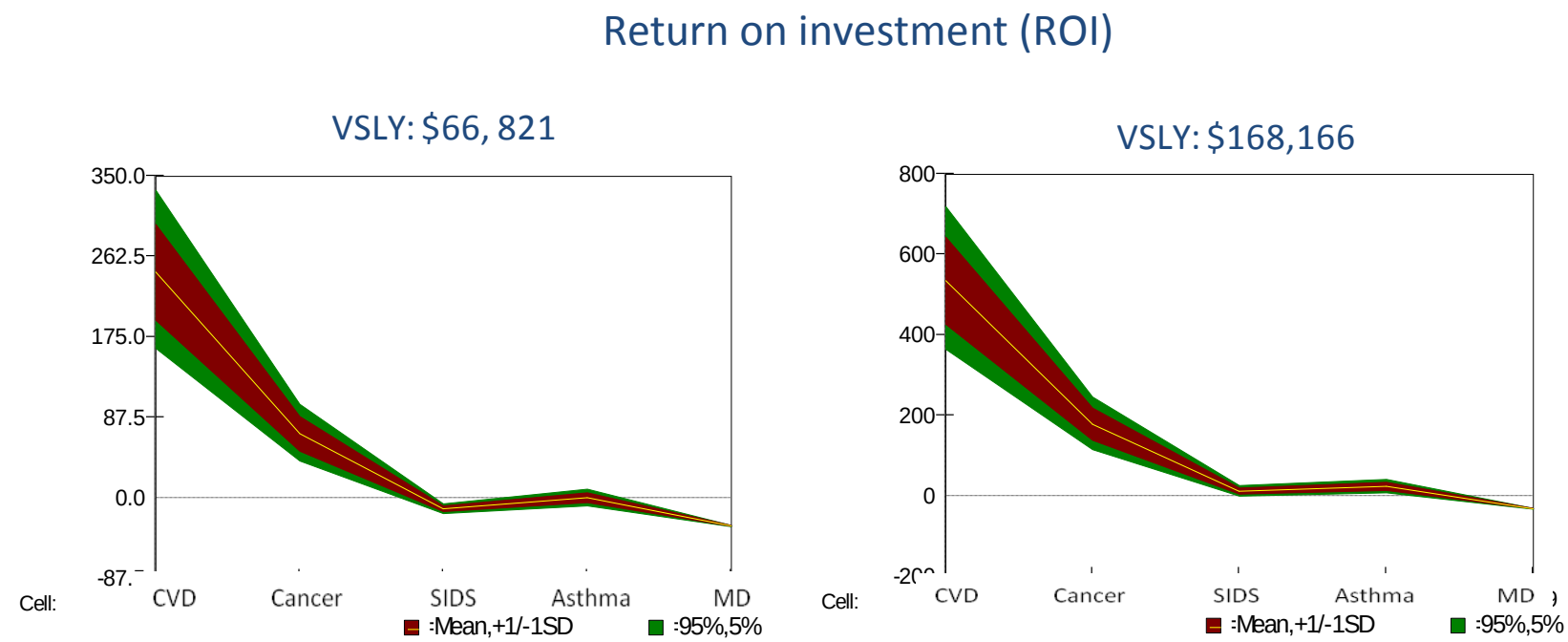
Source: Deloitte Access Economics

Figure 4.6: Distribution of benefit/cost ratio (B/C ratio) from the sensitivity analysis



Source: Deloitte Access Economics

Figure 4.7: Distribution of return on investment (ROI) from the sensitivity analysis

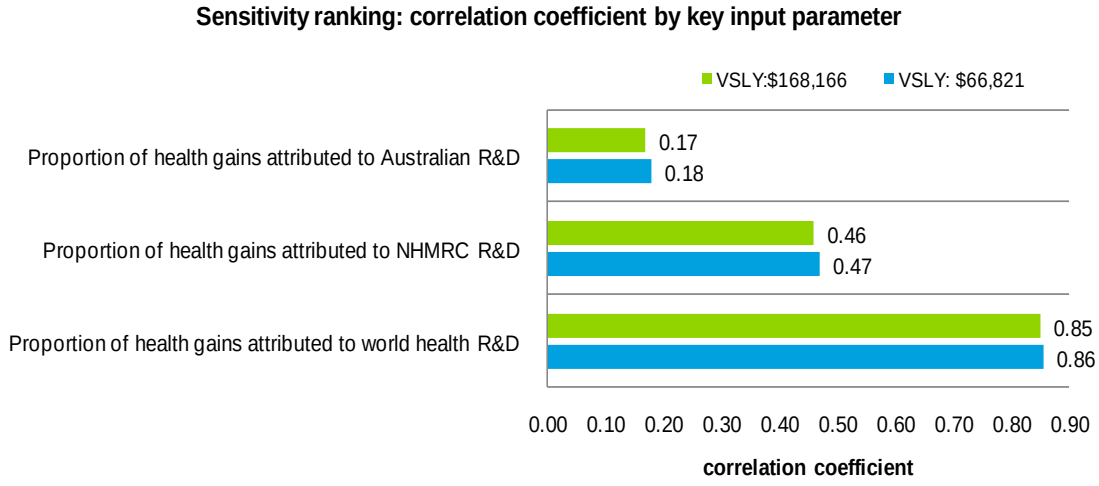


Source: Deloitte Access Economics

The results presented in Table 4.14 and Table 4.15 are the product of each input changing simultaneously within the simulation. However, changes in inputs do not have the same effect on the results due to the alternative distributions placed around the inputs. For example, changing the proportion of health gains attributed to world health R&D by 10% will have a different impact on the results compared to changing the proportion of health gains attributable to Australian R&D by 10%.

To determine which inputs are driving the simulation results, the sensitivity of the results to each input was determined using a rank order correlation. This measures the strength of the relationship between the benefits from NHMRC funded R&D and the inputs under investigation to provide an indication of the change in the benefits from a change in an input parameter while holding all other parameters constant. Chart 4.22 shows the correlation coefficients of the simulation results for each parameter used to determine the proportion of health gains attributable to NHMRC R&D, given the ranges adopted in the sensitivity analysis. A higher correlation was associated with a greater impact of the parameter on the output values (i.e. the health benefits) from the sensitivity analysis. The chart shows that net benefits, ROI, and the B/C ratio are most sensitive to the proportion of health gains attributed to global R&D. The proportion of health gains attributed to NHMRC R&D had the second highest impact, while the proportion of health gains attributed to Australian R&D had the lowest impact.

Chart 4.22: Sensitivity of results to key model input parameters



Source: Deloitte Access Economics.

4.5.9 Limitations

There are a number of limitations of the methodology used in the current study which should be noted. The projection of health gains to 2050 was unable to account for the impact of recent health trends such as rising obesity, or improvements in detection and diagnosis of disease, on future burden of disease estimates. Additionally, the analysis assumed an average 40 year lag period between investment in health R&D and the achievement of health gains, and while this is supported anecdotally, there may be instances where R&D is able to be converted into health gains within a more rapid

timeframe, and so these findings may underestimate the full magnitude of gains attributable to R&D. Finally, while NHMRC funded R&D has produced substantial commercial gains, the application of a similar ratio of investment to commercial gains for individual diseases may not consistently reflect the actual commercial potential of that investment. The future may not be the same as the past, and commercial gains may vary substantially from the average for different projects within a therapeutic area.

5 Conclusions

5.1 Summary of findings

Gains in wellbeing

- A total of 98,426 DALYs are estimated to be averted in Australia between 2040 and 2050 relative to 2000 burden of disease levels for CVD, cancer, SIDS, asthma and MD combined, as a result of R&D investment between 2000 and 2010.
- The total value of the wellbeing gains for these diseases attributed to NHMRC R&D is estimated to be approximately $6 billion in 2011 dollars, with nearly $4billion of health gains attributed to CVD R&D.
- The majority of the wellbeing gains are estimated to be DALYs averted by males which reflects the higher expected benefits to males in the future in relation to CVD, cancer, SIDS and asthma.
- Wellbeing losses are projected for MD. This can be interpreted as an increase in the burden of disease due to an increase in incidence within the "at risk" population.

NHMRC expenditure on health R&D

- In 2009, NHMRC spent $711 million on health R&D, which was a 320% growth on 2000 expenditure ($169.5m), and the equivalent of 0.23% of Australian GDP. By contrast, Commonwealth R&D and total Australian R&D expenditure levels increased 63.2% and 90% respectively during a similar timeframe (ending 2008).
- As a percentage of GDP, NHMRC R&D expenditure showed an internal annual growth rate of 9.76% across the decade. As a proportion of total Australian R&D expenditure, NHMRC R&D funding grew from around 4% in 2000, to 9% by 2009.
- NHMRC funding for the key diseases all showed growth across the decade 2000 to 2010, collectively growing by over 350%, with strong real funding increases for cancer (416%), asthma (343%), CVD (259%) and MD (306%), with the lowest growth for SIDS (47%).
- Between the years 2000 and 2010 the NHMRC invested approximately $862 million in CVD R&D, $1.2 billion in cancer R&D, $5.7 million in SIDS R&D, $156 million in asthma R&D and $28 million in MD R&D, leading to a total of $2.2 billion across the five diseases.

Net benefits from NHMRC R&D

- Gains from health R&D include costs avoided due to less expenditure within the health care system.
  - Avoided direct health system costs resulting from NHMRC health R&D are estimated at $530 million for CVD, $161.7 million for cancer, $872 for SIDS, $6.1 million for asthma and -$0.02million for MD.
  - Indirect costs also make up a large component of disease cost born by society, including productivity losses, deadweight loss and other financial costs. Indirect costs avoided as a result of NHMRC funded R&D included $402 million

for CVD, followed by cancer with $236 million, asthma with $42 million, and SIDS with $0.07m. On the other hand, MD showed a net increase in indirect costs, indicating increased prevalence of the disease.

- A large amount of NHMRC R&D research has yielded valuable commercialisation benefits. In response to NHMRC health R&D funding between 2000 and 2010, commercial benefits are estimated to be around $621.7 million for CVD, $831.2 million for cancer, $4.1 million for SIDS, $112.8 million for asthma, and $20.1 million for MD.
- The projected net benefits from NHMRC health R&D performed between 2000 and 2010 is estimated to be around $4.39 billion for CVD, $1.96 billion for cancer, $0.7 million for SIDS, $35.5 million for asthma, and -$8.4 million for MD.
- The ROI is around 509% for CVD, 170% for cancer, 12% for SIDS, 23% for asthma and -30% for MD. As an example, this means that a dollar invested in Australian health R&D for CVD is estimated to return an average net health benefit valued at $5.02. Put another way, the Benefit/Cost ratio for CVD is 6.1, which means that a dollar invested in Australian health R&D for CVD returns $6.00 in health benefits on average. B/C ratios for the remaining diseases were estimated at 2.7 for cancer, 1.1 for SIDS, 1.2 for asthma and 0.7 for MD.
- Even though there is large uncertainty surrounding the inputs, there is a 90% chance that the total net benefits from Australian R&D across the five diseases lie in the range $4.5 billion to $9.2 billion with a VSLY of $168,166, and in the range $1.8 billion to $4.1 billion with a VSLY of $66,821.
- Results from sensitivity analysis suggest that net benefits, ROI, and the B/C ratio are most sensitive to the proportion of health gains attributable to world R&D. The proportion of health gains attributed to NHMRC R&D had the second highest impact, while Australia's contribution to world health R&D showed the lowest correlation to these disease research outputs.

5.2 Implications and recommendations

Findings from this report affirm the continued benefits to society from NHMRC funded health R&D, in terms of value of life and wellness gained.

The diseases examined in this study (CVD, cancer, SIDS, asthma and MD) collectively form about 40% of the burden of disease in Australia, representing a significant burden on society and the health system. NHMRC funded R&D has the potential to avert a significant proportion of this burden, which is borne primarily by individuals through morbidity and mortality but also by society through increased demands on health services.

The magnitude of benefits attributed to NHMRC R&D for nearly all diseases examined in this study exceeds the original cost of NHMRC R&D funding. MD, however, shows a net loss, with future burden of disease and health costs associated with this illness exceeding the investment which has been channelled into MD R&D. The implication of this is not that the existent R&D has been ineffective, but rather that the R&D to date has not been of sufficient magnitude to reduce the projected future increases in disability associated with this disease for the Australian population.

With health care expenditure expected to grow considerably over the next 30 to 40 years, finding more efficient ways of delivering health gains from the existing health budget becomes critical. Investment in health R&D has the potential to deliver long term and enduring gains in the prevention of growth in disease and in more effective and efficient treatment of acute illness, both of which should result not only in improved population health, but in reductions to health expenditure and other costs to government. While the diseases examined in the current study vary in terms of the magnitude of the return on investment that they offer, all apart from MD demonstrate a benefit/cost ratio above parity, indicating that any investment costs would be recouped through health related gains.

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Appendix A: NHMRC funding datasets

Table A.1: NHRMC-defined funding datasets

Therapeutic area	Identifier	Description
Cancer	Keywords	cancer, tumor, tumour, neoplasm,malignant, sarcoma, carcinoma , metastatic, metastasis, metastases, epidemiology (review each),smooth muscle tumor/tumour, soft tissue tumor, osteosarcoma, Paget*, bone cancer, osteolytic bone disease, rhabdomyosarcoma, cancer cell-mediated osteolysis, cervical, HPV, papillomavirus, cervix, Papilloma, chemo*, chemotherapy, anticancer, neoadjuvant (chemotherapy), cytotoxic (chemotherapy), immunotherapy, radiotherapy, radiation therapy, radiation, childhood cancer, Atrocytoma, brain stem glioma, ependymoma, neuroblastoma, retinoblastoma, medulloblastoma, colon, bowel, colorectal, digestive system cancer, gastric cancer, digestive system neoplasm, stomach cancer, stomach neoplasm, pituitary, thyroid, parathyroid, pancreas/atic, adrenal gland, adrenocortical carcinoma, Pheochromocytoma, ovarian, testicular, Renal cell carcinoma, Kidney cancer, eponym Grawitz tumor, gurnistical tumor, extra-renal primary neoplasm, renal lymphoma,transitional cell carcinoma,oncocytoma,angiomyolipoma, Wilm, prostate and bladder), Ovarian cancer, Granulosa cell, Sex cord-stromal tumours, farrhenoblastoma, stromal cell, Germ cell neoplasms,ovary, ovarian neoplasm, Surface epithelial-stromal, cystadenocarcinoma , Primary peritoneal, head and neck, Leukemia, acute lymphoblastic, Lymphocytic leukemia, acute myeloid leukaemia, ALL , Erythroleukemia ,acute myelogenous leukemia, liver cancer, hepatocellual carcinoma, hepatocarcinogenisis, cholangiocarcinoma, adenocarcinoma, liver metastases, hepatoma, lung cancer, adenocarcinoma, alveolar cell carcinoma , large cell carcinoma, small cell carcinoma, bronchogenic carcinoma, mesoth*, asbest*, lymphosarcoma, lymphoma, Hodgkin*, Non-Hodgkin* , burkitt, lymphatic system, melanoma, myeloma, plasma cell myeloma, multiple myeloma, Kahler, Esophageal cancer, Oesophageal cancer, Esophageal tumor, Oesophageal tumor, adenocarcinoma (review each grant), epidermal (review each grant) basal-cell carcinoma, skin cancer, squamous cell
		carcinoma (review each grant), nonmelanoma skin cancer, non-melanocyte, epithelial (review each grant), seminoma, testicular tumor, malignant tumor of the testis, tumor of the testes, Cancer of the testis, testicular carcinoma
	Grant type	all grant types except IRIISS and equipment grants
	Fields of research	Oncology and Carcinogenesis - Review other FOR as necessary
Asthma	Keywords	asthma, chronic inflammatory disorder of the airways, inflammatory disorder of the airways, wheezing, laboured breathing, narrowed air passage
	Grant type	all grant types except IRIISS and equipment grants
	Fields of research	Allergy, Respiratory conditions

Cardiovascular (inc. stroke)	Keywords	heart, cardiovascular, cardio, vascular, Angina, chest pain, aneurysm, atherosclerosis, artherosclerosis, arteriosclerosis, atheromatous plaques, Atheroma, atherosclerotic, occlusion, atrial fibrillation, fibrillation, atrium (review), atrial (review) blood pressure, hypertension, hypotension, pulmonary hypertension, elevated blood pressure, systolic, cardiac arrest, Irregular beating, Cardiac arrhythmia, arrhythmia, dysrhythmia,Tachycardia, Bradycardia, cardiomyopathy, hypertophic, hypertophy, enlarged heart, venticular hypertrophy, rheumatic heart, heart muscle, dilated cardiomyopathy, Ischemic cardiomyopathy, Ischaemic cardiomyopathy, left ventricle hypertrophy, myocardium, vasculitis, inflamed blood vessels, inflammation of the blood vessels, cardiac fibrosis, pericarditis, cardiac surgery, heart surgery, coronary surgery, Congenital Heart Disease, Congenital Heart Defects, congestive heart failure, CHF, congestive heart disease, congestive cardiac failure, Coronary artery, CAD, Coronary heart, CHD, ischemic heart disease, ischaemic heart disease, IHD, cardiac ischemia, cardiac ischemia, cardiac ischaemia, cardiac ischaemia, myocardial ischemia, myocardial ischaemia, metabolic syndrome, Insulin resistance syndrome, microcirculation, heart attack, myocardial infarction, MI, peripheral vascular disease, PVD, Disease of the blood vessels, Peripheral artery disease, PAD, Raynaud's, peripheral arterial, atherosclerotic peripheral arterial disease, pulmonary embolism, risk factors, stroke, cerebrovascular accident, cerebrovascular cerebral infarction, hemorrhagic, ischemic, ischaemic, cerebral infarction, hemorrhagic, carotid (review-all), thrombus, thrombosis, deep vein, DVT, blood clot, occlusion, thromboembolism, heart valves, tricuspid, mitral, aortic, pulmonic, stenosis, restenosis
	Grant type	All sub types except Equipment and IRIISS Grants
	Fields of research	Cardiology (incl. Cardiovascular Diseases)
SIDS	Keywords	SIDS, sudden infant, infant death, cot death, crib death
	Grant type	all grant types except IRIISS and equipment grants
	Fields of research	Review all but in particular Respiratory Diseases FOR
MD	Keywords	muscular dystrophy, Duchenne, myotonic dystrophy, Becker, Distal muscular dystrophy, Emery-Dreifuss muscular dystrophy, Facioscapulohumeral, Limb-girdle, Oculopharyngeal, MD
	Grant type	all grant types except block funded institutes, IRIISS and equipment grants
	Fields of research	Neuroscience nec, Neurology and Neuromuscular Diseases Autonomic Nervous System, Cellular Nervous System, Cell Neurochemistry, Central Nervous System, Motor Control, Neurogenetics, Peripheral

Source: Source: NHMRC, 2010

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