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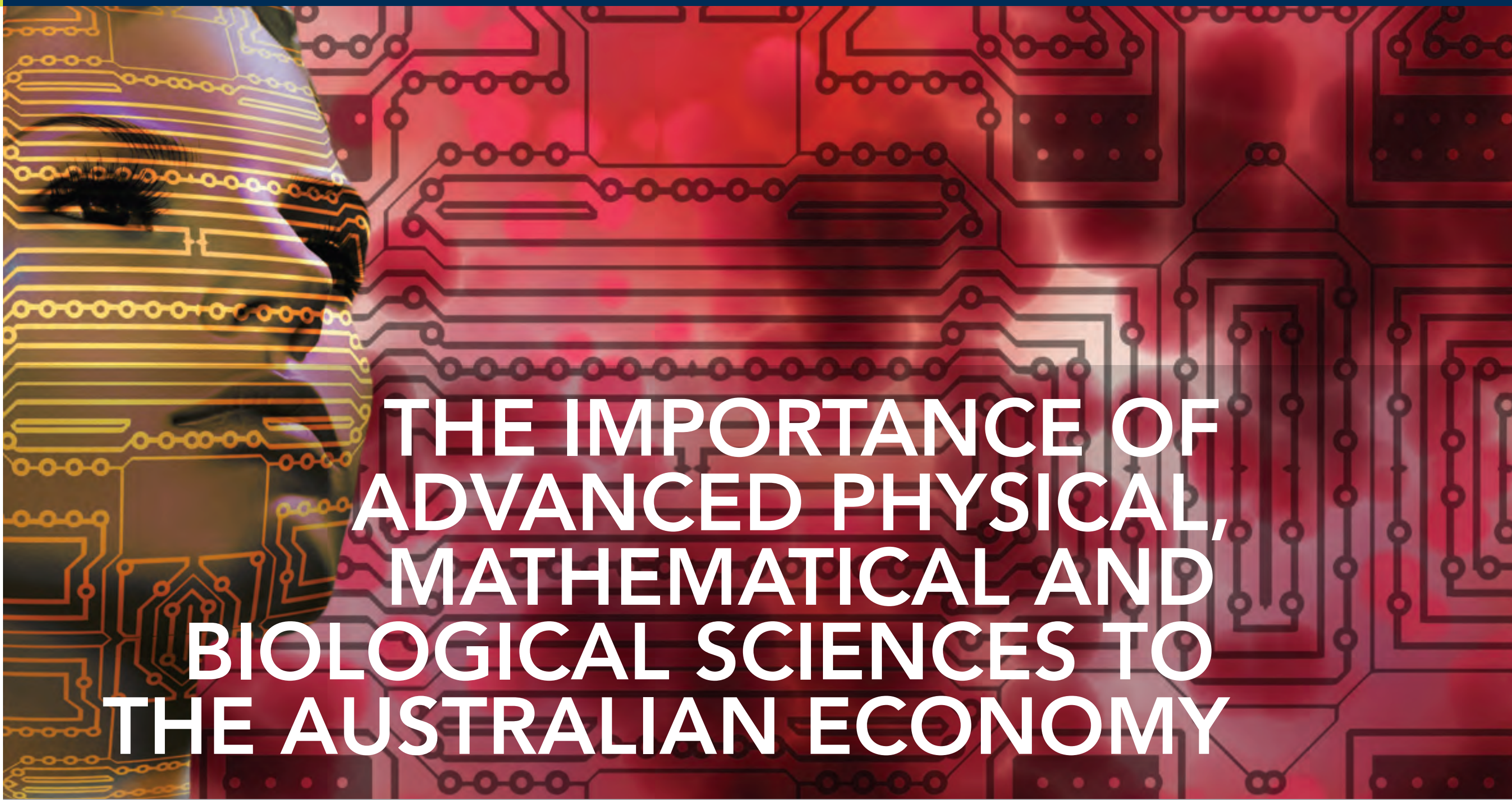

THE IMPORTANCE OF ADVANCED PHYSICAL, MATHEMATICAL AND BIOLOGICAL SCIENCES TO THE AUSTRALIAN ECONOMY

JANUARY 2016

Prepared for the Office of the Chief Scientist and the
Australian Academy of Science by the
Centre for International Economics

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Suggested citation

"The importance of advanced physical, mathematical and biological sciences to the Australian economy", Australian Academy of Science, 2016

This document is available online at www.chiefscientist.gov.au and www.science.org.au

Scientific editing by James Dixon and Ed Highley
Design and Layout by GrathX graphics
Printed and bound by Canprint

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FOREWORD

The Office of the Australian Chief Scientist commissioned the Australian Academy of Science to develop two complementary reports on the importance of recent advances in a selection of the sciences in the knowledge that the economy is not an end in itself but a means by which we realise our many goals. The Academy contracted the Centre for International Economics to do this work.

We now have, for the first time, two reports that estimate the extent to which our economy, our health and our environment are based on global advances in specific fields of knowledge over the past 20 to 30 years.

While further analysis and projections may follow, the reports aid policy making and public discussion based on rigorous estimates of the current contribution of the core sciences.

The contribution is substantial—and consistent with estimates for the same sciences made using different methods in other countries.

It is estimated that if advances in the physical, mathematical and biological sciences over the past 20 to 30 years had not occurred, and those advances had not been incorporated into a range of products and services, our economy would be between 20% and 30% smaller than it is today.

Further, it is estimated that if advances in the biological sciences over the past 30 years had not occurred, and the new medical products and practices underpinned by those advances had not been created, the burden of disease in Australia would be 18% to 34% higher than it is today.

These reports do not attempt to make a case for more science funding by speculating on future returns on investment; nor do they seek to quantify how much of our economic value can be attributed to scientific knowledge first acquired in Australia compared to knowledge uncovered in other parts of the world.

Much of the impact of new knowledge on the economy is incremental, but the cumulative effect of these changes is undoubtedly substantial. Science is now, and will continue to be, important to the economy and therefore important to all Australians.

ABOVE LEFT:
Australia's Chief Scientist,
Professor Ian Chubb AC

ABOVE RIGHT:
Professor Andrew Holmes AM PresAA FRS FTSE
President
Australian Academy of Science

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ADVANCED PHYSICAL, MATHEMATICAL AND BIOLOGICAL SCIENCES*—

underpinning Australian economic activity and worth $330 billion each year

Physical, mathematical and biological sciences help to support our national wealth.

We need to continue our national commitment to the advanced physical, mathematical and biological sciences if we are to recognise opportunities and capture the rewards. It is of substantial economic benefit.

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*Advanced means science undertaken and applied in the past 30 years for the biological sciences and 20 years for the physical sciences.

14%

14% of Australian economic activity relies directly on advances in the physical, mathematical and biological sciences

26%

The total direct and flow-on impact of advances in the physical, mathematical and biological sciences amounts to 26% of Australian economic activity or about **$330 billion per year.**

$84b

Exports associated with advances in the physical, mathematical and biological sciences are worth around $84 billion a year. This is 32% of Australia's goods exports and equivalent to 25% of total Australian exports of goods and services.

$185b

The direct contribution of advances in the physical, mathematical and biological sciences to the economy is around $185 billion per year

1.172m

10% of total Australian employment (about 1.172 million jobs) is directly related to advances in the physical, mathematical and biological sciences

Advances in the physical, mathematical and biological sciences are sources of new and useful knowledge, which creates net benefits for the Australian economy. The application of this new knowledge has, among other benefits:

- expanded the economy by making it more productive
- improved health through better medical products and practices
- provided a knowledge base for improved environmental and natural resource management.

The Australian Academy of Science and the Office of the Australian Chief Scientist commissioned the Centre for International Economics (CIE) to research and develop estimates of the economic—and, to a limited extent, the health and environmental—benefits of recent advances in physical, mathematical and biological sciences.

The research to produce these estimates took place in two parts, published as two related reports.

- The importance of advanced physical and mathematical sciences to the Australian economy (Report 1), published in March 2015, looked at the impact in Australia of worldwide advances over the past 20 years in basic physics, mathematics, chemistry and the earth sciences (the 'physical and mathematical sciences')
- The importance of advanced biological sciences to the Australian economy (Report 2), published in January 2016, looked at the impact of worldwide advances over the past 30 years in the basic disciplines of biology, including cell biology, genetics, microbiology, anatomy, physiology and ecology.

Both reports are available at www.chiefscientist.gov.au and www.science.org.au.

The time frames chosen for these reports—20 years for the physical and mathematical sciences and 30 years for the biological sciences—reflect the time it takes to develop and apply new knowledge in each of the fields.

HOW THE ESTIMATES WERE DERIVED

We derived the estimates of direct economic impacts in these reports through a two-stage 'bottom-up' process. First, groups of eminent scientific experts established by consensus the extent to which the productive output of each of Australia's 506 industry classes was dependent on recent advances in scientific knowledge generally and in broad disciplines within the physical, mathematical and biological sciences. Those estimates were then validated or moderated by an iterative review in consultation with industry representatives and other experts.

We estimated flow-on impacts by applying the final 'direct impact' estimates to a general equilibrium model of the Australian economy.[1] Total economic impacts were established by combining direct and flow-on impacts.

Because of the uncertainty associated with estimates, the analysis also determined a range of scenarios for each estimate. We selected a 'middle' scenario as the figure most likely to be the truest reflection of the impact.

Case studies in both reports also illustrated the importance of science. We established health impacts using a similar methodology, but one in which experts estimated the extent to which underpinning biological sciences were related to improvements in treatment for the 23 most prevalent types of diseases affecting Australians. The resulting estimates were then validated or moderated by consulting with leading clinicians. To reflect uncertainty, we estimated upper and lower impacts.

We attempted to use a similar approach to estimate environmental impacts. However, it became clear during the consultation that there was not enough information to derive comprehensive national estimates. Therefore, the analysis of environmental impacts was limited to case studies.

The two reports give further information on the method, a literature review of other relevant research and references to sources of material in this synthesis report.

Our estimate for the total economic impact of recent advances in the mathematical, physical and biological sciences over the past 20–30 years broadly aligns with estimates that can be derived from a Productivity Commission study published in 2007 (PC 2007).

1 This model was developed by the CIE based on publicly available economic data and a widely accepted economic model developed by the Centre for Policy Studies and the Productivity Commission in 2006.

Both reports compare our results with other results in the literature.

Report 1 identifies a number of ways in which our methods improved on those used in similar recent studies. Unlike earlier researchers, we considered sciences as broad groups and then added our results together. This approach was necessary to avoid double-counting the impact of the sciences in individual areas.

Our estimates of the impact of science on measured economic activity may understate the value of science, as economic statistics are unlikely to capture the full extent of that value. For example, new consumer technology products that embody advanced scientific knowledge can provide more value to consumers in enjoyment and quality of life than their prices imply. We dealt partially with this problem for biological sciences by considering non-market impacts, but did not consider it for the physical and mathematical sciences.

THE IMPACT ON THE ECONOMY

Over time, knowledge discovered in the mathematical, physical and biological sciences becomes embodied in the inputs (the labour, capital, material and systems) that businesses and governments use to produce goods and services.

The application of new knowledge makes labour, capital, materials or systems more productive, allowing the economy to expand in two broad ways.

First, there is a direct gain in production because more output is produced for every unit of input.

By summing across industry classes, we estimate that around 14.2% of production in the economy—or $185 billion in gross value added (GVA) in 2012–13—uses inputs that embody knowledge discovered in recent advances in the mathematical, physical and biological sciences (the 'middle' case). If those advances had not occurred, that production would have been lost. While it is not possible to calculate this quantity precisely, using all information available to us we estimate that it is between 12.7% and 16.4% of the economy (or from $164 billion to $213 billion GVA in 2012–13).[2]

Second, this direct gain in production causes the prices of goods and services in the economy to fall. The flow-on impact of those price falls is a reallocation of resources across the economy, allowing it to expand further. We estimate the flow-on impact to be a further 11.2% of economic expansion in the middle case (or a further $146 billion GVA). The range of the flow-on effect is 7.4% to 15.3% of the economy (or $96 billion to $199 billion GVA).

Overall, in the middle case, we estimate that recent advances in the mathematical, physical and biological sciences have resulted in the Australian economy being bigger by 25.5% (or by $330 billion GVA in 2012–13) than it would have been without this knowledge. This estimate lies in a range of 20.5% to 30.6%. Figure 1 summarises these results.

HEALTH BENEFITS OF RECENT ADVANCES IN THE BIOLOGICAL SCIENCES

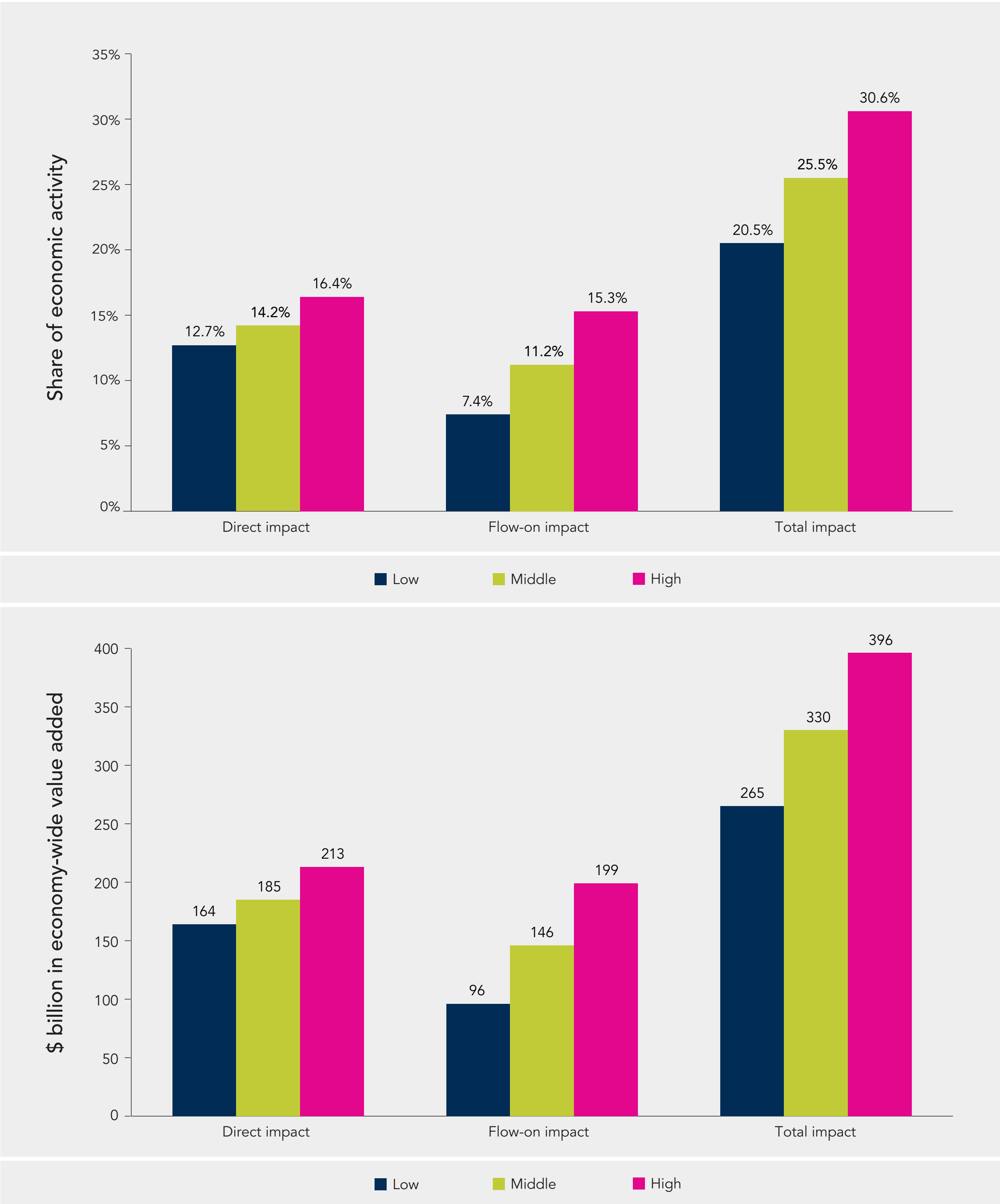
Our analysis of biological sciences also looked at the non-market impacts of advanced knowledge on Australians' health and environment.

One way of assessing population health is 'burden of disease' analysis, which compares the observed state of health with a hypothetical state of health in which everybody lives to an advanced age free of disability and disease. The difference between these two states is measured in *disability adjusted life years* (DALYs) lost to disease and disability. The most recent study in Australia by the Australian Institute of Health and Welfare, based on data from 2003, estimated that disease and disability in Australia accounted for 2.633 million DALYs across the population (Begg et al. 2007).

Report 2 on the biological sciences considered the impact of recent advances in biological sciences for 23 disease groups. It estimated the reduction in DALYs resulting from improvements in medicines and healthcare approaches based on new biological knowledge. The estimates suggest that if recent advances in the biological sciences had not occurred, and the new medical products and procedures that have resulted from those advances had been lost, the DALYs lost to disease and disability would have been 18% to 34% higher than they are.

2 The impact is calculated as a share of total economic output, measured as economy-wide value added. The measure of total value added used here ($1 297 billion) excludes the Ownership of dwellings industry (which makes up 9% of the total reported by the Australian Bureau of Statistics).

Figure 1 The importance of advances in the physical, mathematical and biological sciences



Data source: CIE estimates.

ENVIRONMENTAL BENEFITS OF RECENT ADVANCES IN THE BIOLOGICAL SCIENCES

The biological sciences are central to the management of natural resource systems. They play an important role in our understanding of the ways in which natural ecosystems deliver services that support humans and in our management of those systems.

Importantly, many of the impacts of natural systems on human outcomes are not directly priced in economic transactions, so the value of improved natural resource management (and therefore the value of biology) cannot be measured directly but must be inferred through a range of indirect methods.

Available estimates suggest that there is a lot at stake. For example:

- a 1% improvement in the ecosystem health of the Great Barrier Reef is valued at between $434 million and $811 million
- a 1% improvement in the health of the Coorong is valued at around $5.8 billion.

THE IMPORTANCE OF AUSTRALIAN SCIENCE

Together, the two reports provide estimates of the importance of recent global advances in science to Australia's health, environment and economy. While Australia's contribution to those advances is relatively small in absolute terms (Australian-based researchers produce around 3% of the world's scientific publications), this does not mean that 97% of the economic, health and environmental benefits described in the reports could be obtained purely by relying on international scientific efforts. Australian science is crucial to Australia, just as it is crucial to Australia's access to the science conducted in other parts of the world.

Scientific research is an international endeavour; no nation has the people or the resources on its own to do all that could be done. If every country relied on the efforts of others, no research would be conducted and every global citizen would feel the effects.

Because Australian science is integrated within a much larger global scientific enterprise, our scientists are one of the primary channels through which the nation gains access to the vast global pool of advanced scientific knowledge. While overseas scientific knowledge flows into Australia via other channels (including through imports that embody that knowledge), the channel that Australian scientists provide is essential because not all problems can be solved with 'off the shelf' science. In practice, solving many problems in Australia requires Australian scientists and other professionals to evaluate, select, adapt and complement advanced scientific knowledge from elsewhere before it can be applied here.

Further, Australian science underpins our ability to provide high-quality domestic education and training in science at university level. That education and training is essential to ensure a necessary supply of workers who are highly educated in science, technology, engineering and mathematics.

REFERENCES

Australian Academy of Science (AAS) 2015. *The importance of advanced physical and mathematical sciences to the Australian economy*, AAS, Canberra.

—— 2016. *The importance of advanced biological sciences to the Australian economy*, AAS, Canberra.

Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD 2007. *The burden of disease and injury in Australia 2003*, cat. no. PHE 82, Australian Institute of Health and Welfare, Canberra.

PC (Productivity Commission) 2007. *Public support for science and innovation*, research report, PC, Canberra.

ABBREVIATIONS AND ACRONYMS

CIE	Centre for International Economics
DALYs	disability adjusted life years
GVA	gross value added