

CHIEF EXECUTIVE
www.csiro.au



Australia's Innovation System

CSIRO Submission 14/498

Inquiry By: Senate Economics Reference Committee

July 2014

Contents

Introduction	3
1. Innovation: Driving Australia's productivity	4
2. Industry access to knowledge supporting productivity and competitiveness	5
3. Delivering benefits from research	15
4. The necessary role of Government in supporting innovation	17
Conclusion	21
Attachment 1: Industry Research and Development data	22
Attachment 2: CSIRO's Policies and Posture of transfer of Intellectual Property to Industry	25
Attachment 3: Extract from Manufacturing a better future: the role of science, technology and innovation ...	29
Attachment 4: CSIRO – Delivering Impact with Industry	31
References	40

COPYRIGHT

Images, including all photographs; the CSIRO logo and text in this Submission are protected by copyright.

Rights to reuse material are as follows.

Textual material: Unless otherwise indicated, copyright in textual material included in this Submission belongs to CSIRO and is provided under a Creative Commons Attribution 3.0 Australia licence.

The details of the relevant licence conditions are available on the [Creative Commons](http://creativecommons.org) website, ([www.creativecommons.org.au](http://creativecommons.org)) as is the full legal code for the CC BY 3.0 AU license. (<http://creativecommons.org/licenses/by/3.0/legalcode>).

Attribution for CSIRO textual material must be attributed to CSIRO as: © CSIRO 2014.

No rights to reuse images/photographs, third party material, the CSIRO logo or any material protected by a trade mark are granted.

Where either CSIRO or a third party holds copyright in images, photographs or other identified third party material included in this Submission, the copyright remains with that party. Permission of the copyright owner may be required to use the material. CSIRO has made reasonable attempts to clearly identify third party material and to ensure that the copyright owner has consented to this material being included in this Submission.

IMPORTANT DISCLAIMER

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Introduction

CSIRO welcomes the opportunity to provide a submission to the inquiry into Australia's innovation system. Whilst acknowledging the breadth of the inquiry, CSIRO has concentrated its submission on industry sectors with which CSIRO has significant engagement and focussed on three key issues:

1. The current effectiveness of the innovation system in delivering productivity and competitiveness to Australian industry;
2. Opportunities to improve access to R&D for knowledge intensive industries in areas of global growth; and
3. The role of Government in driving innovation and the impact this has on productivity and competitiveness.

CSIRO also acknowledges the importance of developing and maintaining the skilled Science, Technology, Engineering and Mathematics (STEM) workforce, but notes that this will not be a focus of the submission.

When performing well, a national innovation system can deliver productivity gains and positive social and environmental outcomes.¹ Innovation systems are characterised by the 'stocks' and 'flows' of knowledge between industry, research organisations, government and the broader society and they are fundamental to a productive economy and the wellbeing of a society. Effective innovation systems are highly connected as it is through these connections that organisations identify and trade knowledge, skilled employees and technologies. To leverage these flows it is important that an organisation – whether research, government or industry – has the capacity to absorb knowledge and translate it into improved products, processes, or services.

Within an innovation system, research is often framed as to whether it is investigator-led or mission-directed. Universities generally perform investigator-led research, often with the support of government funded granting bodies such as the Australian Research Council. Publically funded research agencies almost exclusively perform mission-directed research that is focused on addressing specific problems or opportunities as they have a mandate to focus on research that delivers economic, environmental, and social benefits. All high performing national innovation systems balance investment between, and have different mechanisms for managing, mission-directed and investigator-led research. A balance between mission-directed and investigator-led research improves the likelihood of pursuing and transitioning the best ideas into tangible outcomes.

1. Innovation: Driving Australia's productivity

Innovation, defined broadly as the process of translating an idea or invention into a good or service that creates value, and for which a customer will pay, is not an end in itself; it is a means to an end. The ends can be a broad range of economic, social and environmental benefits that drive national wellbeing, prosperity and development, including through the development of new products and services, better functioning societies or through improved public sector productivity. The impact of innovation upon the productivity and competitiveness of a national economy is a long term (multiyear and multiple decade) issue. In this paper we concentrate largely on the economic benefits derived through innovation. For examples of the economic, environmental and social benefits that mission-directed research can deliver please refer to <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies.aspx>.

As Australia grapples with the challenge of a decade of low and in some cases negative growth in productivity,² it is important to understand the levers available for influencing productivity. The Productivity Commission concludes that 'Productivity growth at the economy-wide level comes from innovation by enterprises, diffusion of these improvements to others and the reallocation of resources from less to more productive organisations and industries.'³ With over 60 per cent of Australia's productivity growth due to innovation,^{4,5} it is clear that Australia's future prosperity in large part relies on the ability of our innovation system to translate research and development outputs into innovative new products and services that enable Australia to remain internationally competitive.

2. Industry access to knowledge supporting productivity and competitiveness

As described above, two of the key features of highly functioning innovation systems are (1) high levels of connectivity between businesses, governments, and research organisations that facilitates the stocks and flows of knowledge, and (2) high levels of R&D talent within organisations to absorb new technologies and developments. However 'what usually distinguishes leading organisations is not so much their ability to create knowledge, as their ability to absorb and apply it to their own circumstances.'^{6,i}

Industry generally requires internal STEM capability to absorb and utilise knowledge. The challenge for internal firm capability is to know where to go in the innovation system to get the research needed to drive innovation such as the development of new products and services. The Australian innovation system produces world class research, but these outputs are distributed across more than 30 universities, several publically funded research agencies, and multiple medical institutes, that are geographically distributed, and their activities are – looked at from the outside – opaque. This represents a significant threshold problem for experienced industries and can thwart many small firms from accessing public sector research. For an example of how CSIRO supports industry identify a suitable research provider see the **Case Study: CSIRO's SME Engagement Centre**. The large number of research organisations involved also makes it challenging for both the research community and industry to develop scale and standing, even in fields for which Australia has specialised. CSIRO through its Precinct Strategy is working with industry, research organisations and governments to develop scale and standing based on existing national strengths.⁷ The **Case Study: National Resource Sciences Precinct** provides further information regarding this initiative.

CASE STUDY: CSIRO'S SME ENGAGEMENT CENTRE



©CSIRO

Working with Australian SME's is a key element in delivering on CSIRO's role. Each year CSIRO works with over 1000 SMEs developing and delivering innovation to existing industries and through testing and evaluation.

The CSIRO SME Engagement Centre has been operating for five years and was established to build long-term connections between SMEs and research organisations across Australia's Innovation System. It is differentiated by (1) its market pull approach where it helps SMEs understand what may be possible and providing tailored solutions to the needs of SMEs rather than marketing research capabilities, and (2) its ability to connect SMEs

to the most appropriate research capability, regardless of which research organisation it resides in. These two differentiating factors allow the Centre to consider the company and its need first, before thinking about the possible solutions. The Centre facilitates industry access to established program such as the Researcher in Business program. Examples of projects developed with the support of the SME Engagement Centre can be found here: <http://www.csiro.au/Portals/Partner/SME-Engagement.aspx>

The team was awarded the Australian Business Award for Innovation 2013 for its innovative approach to bridging the gap between SMEs and research organisations.

i An excellent example of the importance of being able to effectively 'absorb' technology is the comparative analysis of Lucent Technologies and Cisco Systems, and the subsequent success of Cisco on the back of an R&D absorption strategy in Michel Ferrary. (2011) Specialised organizations and ambidextrous clusters in the open innovation paradigm, European Management Journal. 29. 181–192.

CASE STUDY: NATIONAL RESOURCE SCIENCES PRECINCT



©CSIRO

The National Resource Sciences Precinct is a CSIRO, Curtin University and The University of Western Australia collaboration connecting the world's best researchers with industry and government to tackle some of the most complex challenges facing the resources industry.

Between its foundation partners, the Precinct hosts more than 400 FTE research staff all addressing the future needs of the global resources industries. It is supported by millions of dollars of advanced resources-oriented research infrastructure.

This pooling of resource science capabilities in Perth capitalises on the concentration of multinational resource companies, helping to turn Perth into a world recognised hub of mining expertise.

Larger businesses generally have the resources to develop their own R&D capabilities. These in-house R&D operations are not only useful for inventing and innovating products, services, and production processes, they also enable these firms to effectively collaborate with other organisations across the system to assist in the adoption and absorption of internally and externally generated knowledge and technologies. It is worth noting however that large businesses make up less than 1 per cent of Australian firms.⁸

The high cost of building and maintaining a high quality in-house R&D capability generally prohibits SMEs, defined herein as organisations comprising less than 200 employees, from undertaking their own R&D activities. This forces them to outsource their R&D requirements to external providers. While this approach can offer substantial cost savings, without having the relevant expertise in-house, the process of absorbing these technologies and knowledge back into their business is often a significant challenge and reduces the potential impact of the innovation. The difficulty in outsourcing R&D requirements is demonstrated by less than 10 per cent of innovation active SMEs collaborating with universities and non-commercial research organisations.⁹

Research and development intensity – or the ratio of research and development to industry value added – decreases with the size of the business, with small businesses spending approximately one quarter as much as large businesses.¹⁰ In combination with the small number of large firms this results in a relatively small number of large firms undertaking or collaborating on the majority of R&D in Australia.

Business investment in Australian R&D is moderate by OECD standards (1.24 per cent of GDP compared to an average of 1.58 per cent) and varies between industry sectors, with between one in three and three in five firms report that they are innovation active.¹¹ This means that for many sectors, less than half of firms consider themselves to be active in any form of innovation and are less likely to be able to generate productivity gains.¹² Of these innovation-active firms, only between one in five and one in three (by industry sector) have introduced new goods and services or any new operational process during the past year.¹³ For further information refer to Table 1 in **Attachment 1: Industry Research and Development data**.

The flow of knowledge, notably within the private sector, is critical for investment in R&D to be productive. This flow relies to a significant degree on the ability of the industry to absorb or generate new ideas. New knowledge through R&D can either be obtained through employing highly qualified research staff or through working closely with knowledge providers such as research organisations like CSIRO.¹⁴ Australia's research workforce is average in size for a similarly sized advanced economyⁱⁱ with four scientists and engineers per thousand people.¹⁵ But unlike almost all other advanced economies, only 30 per cent of Australia's R&D workforce is employed in industry, which is very low by OECD standards, and compares particularly poorly with innovation powerhouses US and Japan who have almost 80 per cent of their R&D workforce in industry.¹⁶ This low percentage not only limits the ability of Australian industry to undertake its own R&D activities but also limits business-to-business collaboration and business-to-research organisation collaboration.¹⁷

ii The Australian economy is different from many economies we compare ourselves to. We need to be careful translating lessons to Australia. Some of the attributes that differentiate the Australian economy are that it is heavily resource focussed and has a relatively small % of high/medium high technology manufacturing.

CASE STUDY: AUSTRALIAN R&D PERSONNEL IN INDUSTRY

©CSIRO

Australia has relatively low numbers of industry R&D personnel compared to other advanced economies. A comparison between Australia and similar advanced economies regarding this and other industry relevant R&D data is contained in Table 2 in **Attachment 1: Industry Research and Development data**.

Low numbers of industry R&D personnel alone would be an issue for industry research capability but is compounded by the low number of staff transitioning between research organisations and industry. The transfer of knowledge between research and industry and the start-up and growth

of new firms is hindered by this low transition rate. Some of the issues driving low transition rates between sectors include limited recognition of work in other sectors, difficulties in transferring employee benefits (notably superannuation), and that the performance of many research staff is assessed by their academic publications which generally do not continue if the academic takes on an industry role.

To stimulate the high technology industry sectors of the Australian economy, strategies to grow the levels of industry in-firm R&D capability, and the levels of business-to-business and business-to-researcher activity should be considered. In terms of measures available to develop a higher level of researcher engagement, these fall into two broad categories, those that support collaboration and changes to the incentives associated with research funding.ⁱⁱⁱ

To better support collaboration between the public sector research system and industry, and between firms, the following measures could be introduced:

1. Support more 'connector' mechanisms (networks) to facilitate and catalyse the forming of valuable human networks, culture and connections, particularly around science precincts and priority industry sectors (in particular, knowledge-intensive competitive industries in areas of global growth);
2. Promote transparency of system wide capabilities and needs, and
3. Promote standardisation and streamlining of commercial access arrangements by publicly funded research agencies (see **Attachment 2: CSIRO's Policies and Posture of transfer of Intellectual Property to Industry**).

Given the Australian industry R&D capability profile, public sector research organisations (including universities and CSIRO) could also be further encouraged to fill the gaps identified in industry research capability. Supplementing the research capability of industry to improve industry's competitiveness should be designed primarily from the application perspective. Ideally this is not an add-on requirement for existing science grant programs as they have a different (and necessary) focus. For example the Australian Research Council (ARC) and National Health and Medical Research Council (NHMRC) competitive grant processes are primarily designed to lead to the advancement of new knowledge and the subsequent production of academic papers, rather than for collaboration with industry in applied research or to deliver research outcomes with the greatest impact on national productivity and competitiveness. Currently only a small proportion of investigator-led R&D supported through competitive grant processes are co-managed by or transparent to industry.

To address the shortfall in industry R&D capability and encourage deeper connections between research and industry, Australia could direct a greater proportion of national innovation investment towards industry-led models that assist large, globally connected firms invest in systemically significant R&D activity. It is these larger Australian-domiciled firms and multi-national corporations that drive a disproportionate level of R&D activity and innovation; and that provide access to global supply chains for Australian SME's and researchers. Additional support mechanisms are also required to encourage engagement with the global innovation supply chain.

The following two examples illustrate programs that could be implemented in the Australian Innovation System to bridge the gap between research and industry. These programs combine measure to increase collaboration with incentives for industry focussed research.

ⁱⁱⁱ CSIRO acknowledges that there are multiple challenges for industry in deciding the level of STEM investment that can be supported and in undertaking or accessing R&D, including access to capital and the cost of labour. These are outside the areas of CSIRO expertise and discussion with industry would identify key issues and opportunities to resolve.

CASE STUDY: DANISH NATIONAL ADVANCED TECHNOLOGY FOUNDATION

The Danish National Advanced Technology Foundation (DNATF) helps bring innovative products to market through a 'mediated funding' scheme which combines project grants with active facilitation and conflict management. At any given time, the organisation is supporting more than 300 different projects in key sectors of the Danish economy: construction, energy/environmental, biomedical, manufacturing, IT and communications, and agriculture. Each year, DNATF provides over \$US100 million in funding for these private-public partnerships.¹⁸

A principal goal of DNATF is moving technical breakthroughs out of the laboratory and into the market. As universities and businesses collaborate, they must work through a range of cultural differences. The experience, expertise, and approaches found in a research university are far different from those found in a commercial enterprise.

This process also delivers another enduring outcome, the development of human resources able to conduct mediation between research and industry. The success of DNATF's projects depends on effectively bridging this gap through a cadre of project mediation officers, who receive significant training through a joint DNATF/Harvard Business School Executive training program and form a peer group of STEM experts who have sought a career in supporting knowledge transfer into industry.

The selection of a firm to participate in the program 'helps it to stay financially viable and significantly decreases the likelihood of bankruptcy by up to 2.7 times (270 per cent) four years after funding application. Selection also increases the average level of employment by 9.8 to 14.2 more employees for chosen firms, respectively two and three years after application. For innovative performance, selection of a firm for participation meant an increase in filed patents by up to 520 per cent, granted patents by up to 430 per cent and peer-reviewed publications 370 per cent, but the effect of selection was mainly felt in quality of the innovations.'¹⁹

CASE STUDY: INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY INNOVATION SCHOOL

The Japanese National Institute of Advanced Industrial Science and Technology (AIST) runs an Innovation School to address the lack of highly trained research staff entering industry and to address the lack of understanding of industry requirements by researchers.

Through the School, AIST hires postdoctoral fellows as 'AIST special researchers' for one year. The school combines lectures with on the job training in both AIST research laboratories and private companies.

Based on data from the first eight years of the School, program graduates are five times more likely to be employed in industry than other postdoctoral fellows.²⁰

The specific industry R&D capability gap varies between sectors. The current situation regarding the ability of public sector research organisations to fill the industry knowledge gap within a sector is outlined below. This analysis concentrates on those sectors with which CSIRO has the strongest collaborative links. (For further information on the work of CSIRO in each of these sectors please refer to **Attachment 4: CSIRO – Delivering Impact with Industry.**) Further data on the research capability and the current investment by Government in R&D of these and other industry sectors is contained in Table 3 in **Attachment 1.**

Pre-farm gate agriculture

Despite the small size of the vast majority of producers and firms in the pre-farm gate agriculture sector, translation of R&D into productivity gains is generally effective for three reasons:

1. The Rural Development Corporations provide a mechanism that consolidates industry requirements for R&D into an integrated portfolio, with this research directed towards the needs of producers.
2. The research has relatively stable funding through a well articulated mix of Government funding and industry levies.
3. Significant sector specific capability is maintained in organisations, including CSIRO, who have developed and maintained long term relationships with suppliers and key industry bodies.

This has allowed the sector to build a R&D system that can focus on opportunities based on their benefit to the industry, and indeed allows farmers and other producers to have a say in the direction of research. It is also efficient, as the approach minimises capability and activity duplication by enabling individual businesses to access world leading research from specialised research providers rather than needing to develop their own R&D capabilities. However, 50 years of growth in agricultural productivity may be at an end. Since the mid 2000s productivity growth has reduced to extremely low levels.²¹ Given that agricultural productivity has been heavily dependent on management of unfavourable weather conditions,²² it can be expected that a critical knowledge requirement for future agricultural research will be in relation to climate adaptation and management strategies and require a broad knowledge base.

CASE STUDY: INTERNATIONAL COMPETITIVENESS IN AGRICULTURE



©CSIRO

The Australian agricultural sector has remained internationally competitive despite significant global developments, including changing market demands and the threat of new market entrants. This enduring competitiveness has been underpinned by strong collaborative, long-lasting and sustainable R&D, which has seen the sector experience underlying long term productivity growth of 2 per cent,²³ well above the national average of 0.7 per cent.²⁴

Our international competitiveness in agriculture has been driven by ongoing research focussed on the needs of

Australia. CSIRO remains the largest contributor to research in agriculture related fields. By undertaking 20 per cent of agriculture R&D (by value in FY 11/12^{25,26}) and with authorship on over 20 per cent of Australia's research publications in agriculture, CSIRO is a strong driver of productivity growth in the sector. CSIRO has developed numerous long term partnerships with the sector that have generated significant value (see **Case Study: Cotton**).

CASE STUDY: COTTON



©CSIRO

In the cotton industry CSIRO has partnered with CSD, an Australian grower-based company since the 1980s to develop and deliver high quality cotton varieties for the industry. Currently 95 per cent of cotton grown in Australia is developed by CSIRO.

Australia's cotton growers produce yields two and a half times the global average and have produced the world's highest cotton yields for 20 years running.²⁷ This has enabled cotton production to become one of Australia's biggest agricultural industries; an average season is valued at more than \$1.3 billion a year. Economic assessments of

CSIRO's cotton breeding program show an estimated 80:1 return on investment and more than \$5 billion net present value from increased yield and regional adaptation in Australia.²⁸

Post-farm gate

The food industry is the largest manufacturing sector in Australia, making significant contributions to regional economies through employment, business and services. The food industry is Australia's largest manufacturer and is a significant contributor to the Australian economy. It currently employs around 300,000 people, half of them in rural and regional areas.²⁹ Current exports are predominantly of lower value agricultural commodities, for example bulk grains, meat and milk powder as most Australian exports are commodities processed to the minimum level necessary for stability and transport.

The Australian food industry is facing many headwinds, including cost competitiveness. Current conditions for researcher engagement with the food industry are suboptimal, especially for SMEs, and there is under utilisation of key pilot plant infrastructure and product development facilities. This has led to a market failure of research and development in the food processing sector with a loss of capability in food science, engineering and product development skills.

For these reasons a priority is innovation to underpin the renewal of Australia's food manufacturing sector that draws on consumer insights and leads to innovative products for export. This will require Australia to develop enhanced networks and capability in food science, engineering, pilot-plant scale-up and advanced logistics that can deepen linkages between the global scale food industry in Australia and the proximal Asian consumer markets. CSIRO is working with industry to achieve a more cohesive and effective innovation system that better supports Australia's food and beverage export industry and provides a more strategic approach to national food and nutrition R&D and technology transfer.

CASE STUDY: PRESHAFOOD LTD



Credit: Pidgeon by Design

CSIRO and Preshafood Ltd's work together has led to a new product, Preshafruit juices, which have seen ongoing and increasing market success. The company undertook all trials and the first commercial production of juices and fruit products in CSIRO's \$40m food processing pilot plant in Werribee, Victoria.

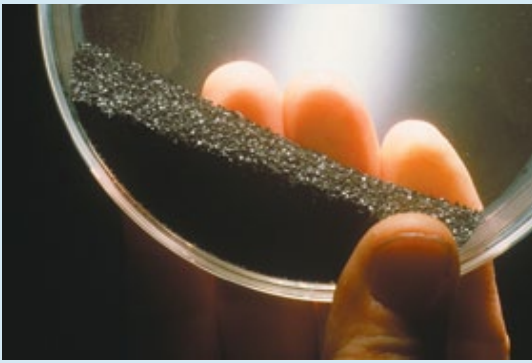
Preshafood's juices, Preshafruit, use high pressure processing means the juices have a shelf life of up to 210 days and can be classified as 'raw food' because they haven't been heat treated.

The juices were awarded the 2010 Australian Institute of Food Science and Technology Food Industry Innovation Award, and the World's Best New Juice Award plus the overall prize of Best New Concept at the 2009 Beverage Innovation Awards.

Extractive resource industries

Although the number of R&D staff employed in the sector is relatively low, the sector maintains a considerable financial investment in R&D.³⁰ Translation is generally effective as the major mining multi-national corporations have maintained some in-house capability and have developed strong links to Australian and international research expertise. In addition the generic nature of products ensures that research of relevance to a large number of businesses can be coordinated through industry bodies (e.g. Australian Coal Association Research Program) or Government research organisations (e.g. CSIRO and Geosciences Australia). Even with these organisations it is important to obtain critical mass of research capability which is why CSIRO with research and industry partners is developing the National Resource Sciences Precinct.

CASE STUDY: INNOVATIVE UNDERGROUND LONGWALL AUTOMATION TECHNOLOGY INCREASING EFFICIENCY & PROTECTING LIVES



©CSIRO

Coal mining comprises approximately 24 per cent of employment and 27 per cent of total revenue of the mining industry. Although it is an important industry for Australia's gross domestic product, it can also be a hazardous workplace. Despite significant OH&S progress many challenges remain, including the development of sensors and automation technologies to replace miners operating below ground in hazardous conditions. In partnership with the coal industry, CSIRO has developed an underground automation system that improves productivity while isolating people from mining hazards. To support the commercialisation of the technology CSIRO signed a

worldwide licensing agreement with Inbye, an Australian mining services business.

CSIRO's new automated process has resulted in: improved safety conditions for longwall mining equipment operators; uptake of CSIRO's automation technology into more than half of Australia's underground longwall coal operations; and increased productivity that is delivering an economic benefit upwards of up to 10 per cent.

Medical technology and biotechnology

Many of the companies in the medical technology and biotechnology sector had their genesis in research conducted in universities, CSIRO, hospitals and medical research institutes. The history of these companies has resulted in strong links to the research community often combined with significant in-house R&D capabilities. In addition through substantial Government support and funding, the medical research sector has increased substantially and this has allowed the sector to maintain a diverse range of organisations across the product development value chain. Regardless, like all sectors, due in part to the small Australian venture capital market,³¹ but particularly due to its global nature, the sector does face challenges further down the development pipeline as illustrated in the development of Equivac® where despite success in the laboratory (see **Case Study** over the page), attracting a commercial partner was challenging.³²

As for the extractive resources industry in the development of National Resource Sciences Precinct, CSIRO is working with the medical technology industry and research partners in the development of the Clayton Precinct. Within the Clayton Precinct, Monash University, CSIRO, the Australian Synchrotron and the Melbourne Centre for Nanofabrication contain capability used in collaboration with the medical technology industry. CSIRO is working with research partners to attract infrastructure investment that would further connect and enhance the ability of the precinct to support industry. This builds on the strong existing collaborations Monash and CSIRO have with Australian companies working in this sector including; GE, CSL, Mesoblast, Allied Healthcare, Universal Biosensors, Agilent Technologies, Lieca and CSL. The research is also well connected both nationally and internationally with partners such as the Walter & Eliza Hall Institute, Australian Regenerative Medicine Institute, The Alfred Hospital, Monash Medical Centre, Imperial College, Warwick and Newcastle University UK, IITB in Mumbai, SEU in China, and Rutgers University, New Jersey.

CASE STUDY: EQUIVAC® HeV – FIRST VACCINE TO PROTECT OWNERS AND EQUINE INDUSTRY AGAINST THE DEADLY HENDRA VIRUS



©CSIRO

One of the biggest threats to Australia's society today is major pandemics transferred, not from human to human, but from animals to humans. The Hendra virus that was first identified in horses in 1994 is a Bio-Safety Level-4 disease agent, which is the most dangerous level in the world. Equivac® HeV is a world-first commercial vaccine for a Bio-Safety Level-4 disease agent.

Impacts flowing from the development and commercialisation of the vaccine include increasing personal safety for horse owners, vets and others regularly interacting with horses. It also enhances security for the

Australian horse industry and reduces time spent in quarantine and reduced costs attributed to disease response and containment and minimised the chances of the virus mutating and spreading more readily between horses, or from human to human.

Manufacturing

'In recent years the rising cost of doing business, including the high Australian dollar, has placed pressure on our trade-exposed manufacturing and services industries. However, the rise of Asia, including the significant growth of middle class consumers, presents a range of opportunities for Australian firms.'³³

The translation and absorption of R&D in the manufacturing sector is limited due to a relatively low number of researchers in manufacturing, complex R&D needs and low uptake of new technology. According to OECD data 'the number of researchers in the manufacturing and service sectors in Australia (3.1 per 1000 employed in industry, 2009) was less than a third of the average figure for the four Scandinavian countries (10.0) and the United States (10.5)'.³⁴ These figures reveal a critical lack of investment in innovation in Australia's manufacturing sector and place the sector at a significant disadvantage when competing globally.

Based on available data Australia has the lowest percentage value add (Approximately 6–7 per cent of total manufacturing value add) in the OECD for high technology in the manufacturing sector.^{35,36} Limited high-tech value-add is often due to poor internal capability limiting innovation and resulting in the slow uptake of new technology. Programs such as the Federal Government's Research in Business program offer firms a low cost means to utilise specialist skills for a fixed period of time to address a critical challenge or opportunity. Although these programs tend to be small in size relative to the pool of potential applicants, they often have a low number of applicants from industry due to industry's low capacity to absorb R&D and a lack of awareness of these types of schemes. Unlike the pre-farm gate agriculture sector where the limited number of products emerging from the sector enables the RDC model to be successful, the manufacturing sector is more challenging due to the vast array of products developed and the consequential diversity of research needs. Manufacturing has been the subject of a significant amount of analysis over the past few years. An example of improving connections between innovation and industry is shown in **Case Study: Australian manufacturer secures key position in international supply chain through CSIRO's innovative textile and fibre technology.**

CASE STUDY: AUSTRALIAN MANUFACTURER SECURES KEY POSITION IN INTERNATIONAL SUPPLY CHAIN THROUGH CSIRO'S INNOVATIVE TEXTILE AND FIBRE TECHNOLOGY



Credit: North Sullivan Photography

The Australian manufacturing industry is facing pressure from increasing production costs and mounting global competition. To increase their market share and be competitive, Australian businesses need support to grow, gain a competitive advantage, and improve profitability.

CSIRO's involvement with Textor, a small-to-medium Australian enterprise, has helped to improve manufacturing processes by applying smart technology to improve efficiency, contributing to the: significant increase in annual gross turnover; provision of innovative solutions and extensive list of clients, such as Poise and Kimberly-Clark; and, expansion into the Asia-Pacific export market, distributing to Singapore, Vietnam, India and New Zealand.

Textor engaged senior researcher, Dr Niall Finn, through the CSIRO's Small and Medium Enterprise (SME) Engagement Centre, to work with the company to develop new and unique manufacturing technologies to improve the quality of its products. This project was supported by the Enterprise Connect Researchers in Business (RiB) program, an Australian Government initiative that provides funding to support the placement of researchers directly into businesses to develop and implement new commercial ideas.

The collaboration not only relied on the research expertise of CSIRO but the research infrastructure within CSIRO and other research partners including the National Synchrotron.

Rising international competition will make it difficult for Australia to maintain the high technology manufacturing sector without specific interventions. Significant effort will be required to improve industry-research linkages, enhance the support for industry focussed research, and address the low R&D capabilities of firms that limit their ability to develop and absorb research and technology. Further information on programs that can address some of these challenges is included in the **Case Study: Reducing Risk in product development and demonstration** and in **Attachment 2: CSIRO's Policies and Posture of transfer of Intellectual Property to Industry**.

CASE STUDY: REDUCING RISK IN PRODUCT DEVELOPMENT AND DEMONSTRATION

A strategy that is emerging internationally is that of incentives for proof of concept projects aimed at the development of new products to mitigate the cost and technical risks, whilst demonstrating market potential. A recent study 'The role of science, research and technology in lifting Australian productivity'³⁷ has identified a need to learn from international experience with regard to the types of programs that are effective.

The form that these programs take vary significantly with some providing specific purpose grants to industry, whereas other provide venture capital with the expectation of a return to the funder.

The US based Small Business Innovation Research (SBIR) program,³⁸ the Victorian Market Validation Program³⁹ and the Australian Growth Partnership program⁴⁰ are examples of these. A specific intention of all such programmes is to drive innovation uptake in SMEs.

CASE STUDY: BIOFIBA LTD



©CSIRO

from technology developers into product-centric, sales focused companies.

Through the CSIRO administered Australian Growth Partnership program, CSIRO has invested in Biofiba Ltd, a NSW-based SME with an innovative manufacturing process for the production of simulated timber export pallets.

The Australian Growth Partnership funding permits SMEs, having commercially risky projects requiring R&D at CSIRO and limited access to other forms of capital, to secure finance under flexible commercial terms.

These partnerships with CSIRO allow high potential technology SMEs to manage their cash flows as they evolve

Key issues and opportunities

A combination of low industry research capability, poor absorptive capacity and limited collaboration has resulted in difficulty for some sectors of industry to innovate.

There are variations between industry sectors that need to be considered separately when examining the Australian innovation system. In general the research needs of the extractive resources and pre-farm gate agriculture sectors appear to be being met whereas this is not the case for other sectors such as manufacturing, e.g. food processing.

There are opportunities to increase Australia's industry R&D workforce, increase rates of collaboration between research and industry, and increase the industry focus of publically funded research.

3. Delivering benefits from research

Australia is recognised as a key member of the global science community with authorship on 3.5 per cent of global research publications,⁴¹ indicative of a strong research capability. In contrast, Australia produces only 0.17 per cent of global patent applications and the nation makes IP payments 3.9-fold in excess of its IP receipts.⁴² (Refer to Table 2 in **Attachment 1** for further details.) This indicates a fundamental weakness in the innovation system, the difficulty in translating R&D into benefits for society. Notwithstanding this weakness, Australia has some outstanding success stories where small investments by Government have provided exponential returns. (See **Case Study: How Australian Federal Government funding enabled Cochlear to grow into a world leading medical devices company.**)

CASE STUDY: HOW AUSTRALIAN FEDERAL GOVERNMENT FUNDING ENABLED COCHLEAR TO GROW INTO A WORLD LEADING MEDICAL DEVICES COMPANY

Cochlear Limited was formed by Paul Trainor in 1981 with the assistance of a \$4 million grant from the Australian government to support the commercialisation of the hearing implants pioneered by Dr Graeme Clark.

The company was listed on the Australian Stock Exchange in 1995 and by 2001 had provided 30,000 implants to hearing impaired clients. By June 2013 Cochlear was a \$3.5 billion company, headquartered in Sydney, with a staff of over 2,700 across 25 countries that invests over \$120 million a year in R&D and provides over 25,000 implants a year.⁴³

CSIRO's vision is: *'Our science is used to make a profound and positive impact for the future of Australia and humanity'*. The Productivity Commission has acknowledged the effort of CSIRO in developing a framework and supporting tools to plan, monitor and evaluate the economic, social and environmental impacts of our science.⁴⁴ Through the framework, CSIRO has a portfolio view of the impact being pursued within and across Flagships and Themes to help make informed decisions. Planning future impact assists the alignment of research activity with Flagship goals and enables CSIRO staff to articulate and communicate the impact of their work. Articulating future impact and monitoring progress towards that impact provides greater confidence to our clients, the government and the general public. CSIRO makes the following observations about delivering impact to industry, the community and government based on these experiences.

Engagement of partners

The delivery of the social, economic and environmental benefits of a research program is best enabled through the engagement of all partners, including end users, in the development, evolution and delivery of the R&D. This broad engagement helps shape the direction of the research to include the necessary steps for effective utilisation of the research outcomes into new products, services or processes. The reason this ongoing engagement is important is that research is not a linear process but requires regular iteration to ensure that the research and its goals remain achievable and acceptable to key partners. An important demonstrator of the engagement of partners is the investment of resources including financial commitment, but a particularly crucial factor for success is the attention of business management at the decision-making level.

Active research portfolio management

CSIRO research is actively managed within nine portfolios, known as Flagships.^{iv} The Flagships, which account for 87% of CSIRO's total investment in the 2014/15 Budget, have goals developed around national challenges that are shaped and iterated with input from external experts from industry, government and scientific institutions that form its advisory committees and review panels. These active and participatory engagements provide incalculable value in terms of informing, challenging and refining CSIRO's research goals and pathways to maximise the likelihood of the uptake and adoption of Flagship research. It is CSIRO's experience that some form of active research portfolio performance management is essential to ensure that investment of public resources in research achieves its maximum environmental, economic or social impact. Regardless of whether a

iv CSIRO manages its research through three lines of business; Flagships, Services, and National Facilities and Collections. These distinct lines of business enable CSIRO to use appropriate management structures to suit the needs of our clients and research partners. Investment in national facilities and collections in FY14/15 is estimated to be \$163 million. Use of these national facilities and collections includes significant use by Flagships in addressing national challenges.

CSIRO activity services the public and/or private sector, national benefit in the context of national challenges and opportunities is the threshold criteria.

Active research portfolio management helps ensure the relevance of research by allowing for research to adapt to market, regulatory and other changes. It encourages the fast fail of projects through modifying or even cancelling projects that are unlikely to deliver on their intended impacts (see **Case Study: Performance Management in the Light Metals Flagship**). Active research portfolio management contrasts strongly with the processes applied to the vast majority of investigator-led research. Where research is conducted without active provisions to monitor progress towards impact outcomes, lack of evidence makes it difficult to understand the effectiveness of individual grants and the programs as a whole. It also makes it difficult to inform future research investment decision making and communication with policy makers and industry funders on the benefits of research.

CASE STUDY: PERFORMANCE MANAGEMENT IN THE LIGHT METALS FLAGSHIP



Credit: iStock/Grafissimo

An example of active portfolio management is that of CSIRO's Light Metals Flagship. At the time of starting the Flagship, there was a national dialogue that suggested that an important national challenge was extracting more value from our resources industry through moving up the value-adding chain by local processing. Following evidence and external validation that there was mixed and low levels of interest from industrial partners in magnesium and aluminium research, despite the substantial technical and scientific progress that was being achieved by CSIRO researchers, the decision was taken by CSIRO to remove Flagship funding for magnesium and aluminium research.

This funding was used to boost research in titanium as there was strong interest from large multi-national corporations and local small and medium enterprises for CSIRO innovations in titanium processing to be brought to market faster. This has subsequently seen licensing of CSIRO research breakthroughs in titanium to Australian and global industrial partners who are now making substantial investments in establishing a domestic titanium production industry with links to global supply chains. Eventually this decision led to the Light Metals Flagship being closed with the remaining investment in titanium continuing through the Manufacturing Flagship.⁴⁶

Key issues and opportunities

To ensure that research delivers social, environmental and economic impact it is important that research has design, implementation and delivery buy-in from government, research, community and industry partners.

The active involvement of research users in the design and execution of R&D programs is best practice for impact focussed R&D.

Active portfolio management is critical to ensure investments of scarce public resources in research achieve their maximum likelihood and intensity of economic, environmental and social impacts.

4. The necessary role of Government in supporting innovation

Government support of science and innovation has led to many radical and transformative innovations that have fuelled the dynamics of capitalism; from railroads to the internet, modern-day nanotechnology to pharmaceuticals, and GPS to touch screen displays; many innovations trace their most early, risky and capital-intensive investments back to a government. However, despite this formative role that government investment can play, a translation partner is required to deliver social, economic, and environmental benefits. In the case of the development of new products and services, receptive and resourced industry partners are critical to translate the research.

Substantial benefits flow in a well designed and supported innovation system. For example South Korea, through sector specific industry policies, a strong education sector and strong Government and industry support for research and development has led the country to become a major economic powerhouse in a relatively short period of time. Other countries like Germany (see **Case Study: The German Innovation System**) have built a strong innovation system on a range of government policies and programs designed to ensure that the transition of R&D into new products and services is realised. The mechanisms outlined in the Case Study are equally applicable to the Australian Innovation System.

CASE STUDY: THE GERMAN INNOVATION SYSTEM

The German Innovation System provides an example of how a country can realise substantial benefits through targeted Government support. Government support in Germany takes many forms including strategic direction and research investments against those strategic directions. There are also other reasons why Government support for the German Innovation System is considered successful:

1. The German Government releases regular long term innovation strategies.⁴⁷
2. The roles of the organisations in the system are well defined, reducing resource inefficiencies and unnecessary capability and activity duplication.
3. The balance of funding between the various sectors of the system is made based on national need, ensuring that resources are focused on resolving problems critical to Germany's global competitiveness. These needs are reviewed regularly to ensure the mix is appropriate.
4. Funding for research that delivers social, economic and environmental benefits is balanced against funding for supporting collaboration and funding that supports the development of new research capability and infrastructure.
5. The German Government recognises that its industry cannot compete on a volume cost basis but rather on the production of high value products and services. The importance of maintaining a high to medium-high technology economy, including an industry base that matches that and a long term industry focussed R&D sector (e.g. conducted by Fraunhofer) illustrates the Government's commitment to maintaining this competitive advantage.
6. Research funding for industry is transparent with policy rules understood by both industry and the public sector.

This approach has enabled Germany to maintain a strong manufacturing industry despite increasing international competition.

As well as being responsible for many of the most transformative inventions, government investment in R&D significantly boosts productivity. The OECD found that a one per cent increase in public R&D expenditure could be expected to generate a long run increase in productivity of 0.28 per cent.⁴⁸ This compares with a productivity increase of 0.11 per cent for a one per cent increase in business R&D expenditure.

Supporting the delivery of economic, social and environmental benefits

Australian industry has a long tradition of adapting research from other locations.⁴⁹ Despite our ability to adapt ideas from overseas to generate productivity gains – noting that approximately 90 per cent of Australian patent applications are filed based on overseas innovations⁵⁰ – it is the other 10 per cent of Australian generated patents that enable Australian industry to develop the world leading products and services that drives our international competitiveness. Without these Australian grown patents and noting other challenges to Australia's international competitiveness, there would be very few opportunities for Australian industry to compete internationally delivering products and services higher up the value chain. For example, Government investments in CSIRO have enabled research that has helped develop internationally competitive industries with substantial benefits for Australian industry and the broader community. An example is shown in the **Case Study: Delivering impact with the Australian prawn industry through development of new aquaculture feeds and improved prawn production**.

Government support also enables the research sector to develop and transfer intellectual property to industry. For further information on how CSIRO enables industry to utilise the intellectual property that it develops refer to **Attachment 2: CSIRO's Policies and Posture of transfer of Intellectual Property to Industry**.

CASE STUDY: DELIVERING IMPACT WITH THE AUSTRALIAN PRAWN INDUSTRY THROUGH DEVELOPMENT OF NEW AQUACULTURE FEEDS AND IMPROVED PRAWN PRODUCTION



©CSIRO

Around 50 per cent of all prawns eaten in Australia are imported from countries such as China and Vietnam. Tiger prawns, in particular, are threatened in many parts of the world, partly due to overfishing. CSIRO and partners saw an opportunity to further improve Australian seafood, boost the aquaculture industry and deliver improved, high-quality products to consumers.

Impacts from the collaboration include: an estimated increase in the Australian farmed prawn industry's production from 5,000 tonnes to 12,500 tonnes per annum, adding \$120 million per annum to the value of the industry

by 2020, assuming all farms achieve the same productivity increases as existing users; increased food security in Asia through better breeding stock and diets; and, a new international industry for bioactive aquafeed ingredients.

Enabling collaboration

As previously noted, the innovation system can be thought to consist of both 'stocks' and 'flows' of knowledge. Even with Australia's strong 'stocks' of R&D capability, a good 'flow' of knowledge is required as it is through relationships that knowledge is generated, absorbed, and translated to deliver social, environmental and economic benefits. A useful strategy, when designing the R&D and innovation processes to support industry requirements, is to design this from the perspective of the 'downstream' recipient of the knowledge. Research is not a linear process and requires ongoing long-term collaboration with substantial flows of knowledge between partners, funders and end-users including at the start of the R&D process, to maximise the likelihood of success. The flow of knowledge around the innovation system is generally in response to competent and informed demand.

A lack of understanding of other components of the innovation system and how to access or share knowledge are major impediments to translating research into new products and services. Research collaboration is not built through a transactional approach; rather it needs to be built around substantial and beneficial relationships. Specific effort is required to connect the innovation system to enable these types of relationships. The Government through its policy and program levers has the ability to facilitate productive long-term collaboration between research and industry for the targeted development and application of knowledge that can lead to improved productivity and competitiveness or improved environmental, economic and social outcomes. Below are two case studies that demonstrate how CSIRO collaborates with industry to deliver economic benefits, and with other research organisations to build research capability in areas of national need.

CASE STUDY: CSIRO COLLABORATION WITH BOEING



Credit: Bigstock/Paha_L

CSIRO and Boeing Research & Technology (Boeing's central R&D organisation) enjoy a healthy, 25 year relationship managed by an Alliance structure. In FY 11, Boeing named CSIRO its Global R&D 'Supplier of the Year'. Boeing Chairman and Chief Operating Officer, Jim McInerney, cited 'outstanding results and top-notch customer satisfaction' as the key to being judged the 'the best of the best'.

Over the length of the relationship, CSIRO and Boeing have jointly invested about \$110M across a wide array of R&D activities. CSIRO's relationship with Boeing has also played a key role in the development of Boeing's operations in

Australia. Boeing's decision to establish research and development laboratories in Brisbane and Melbourne has led to the employment of 34 scientists, many of whom collaborate with CSIRO on joint projects.

CASE STUDY: CSIRO'S NATIONAL RESEARCH FLAGSHIP COLLABORATION FUND

CSIRO's National Research Flagship Collaboration Fund is an example of how resources can be invested to encourage collaboration at relatively low cost without the need for separate entities, 'bespoke' governance, contracting structures and related time consuming establishment efforts. The fund has enabled extensive research and industry collaborations across the global innovation system, supporting over 500 different research collaborations. Based on a low cost and simple framework for management of IP these collaborations are aligned to achieving the economic and community impact goals of the National Research Flagships within existing governance mechanisms. Significant administrative savings and alignment benefits would flow from channelling other research program funding schemes through such a mechanism.

Building research capability

Through the conduct of R&D in the public and private sectors, the acquisition and incorporation of new skills, competencies and technologies, and the development of research infrastructure, Australia can build its capability to respond to new opportunities and challenges as they arise. World class research capability enables Australian businesses to develop the new and innovative products and services that will lift productivity and enable global competitiveness. Government support of R&D across universities, CSIRO and industry, through research and infrastructure funding, as well as supportive policies and programs is critical to developing the national research capability. See **Case Study: Building research capability and infrastructure – The Australian Animal Health Laboratory (AAHL)** for an example of how Government funding has enabled CSIRO to develop world leading research capability that enables Australia to address biosecurity challenges. Large scale national research infrastructures such as AAHL are of such scale and service such a wide range of requirements and clients, that it is often only Governments who are able to invest in these facilities. This funding model then permits efficient usage across the nation whilst ensuring Government's research needs are met.

CASE STUDY: BUILDING RESEARCH CAPABILITY AND INFRASTRUCTURE – THE AUSTRALIAN ANIMAL HEALTH LABORATORY (AAHL)



©CSIRO

AAHL is one of the world's leading High Security Physical Containment Level 4 facilities for work on animal exotic (foreign) diseases and the most advanced facility in terms of providing animal health diagnostic services. Despite Australia's strict quarantine procedures, there is still a risk that an exotic disease could be introduced into Australia. The potential impacts, dependent on the disease, include illness in humans, domestic animals and wildlife and cost to the economy of billions of dollars through loss of trade, tourism and other costs associated with recovery from a disease outbreak. The diagnostic skills and knowledge of scientists at AAHL form an important component of

Australia's preparedness to deal with an emergency disease outbreak. AAHL has been crucial in identifying and characterising new diseases including Hendra Virus, Australian Bat Lyssavirus, Pilchard Herpes Virus and Abalone Herpes Virus.

Allocating funding

Through its program and policy levers the Government has a critical role to play in ensuring a strong innovation system. By balancing R&D that is focussed on delivering economic, environmental and social benefits, with support for collaboration that increases the flow of knowledge and support for investigator-led research that builds national R&D capability, the Government can ensure a more productive and efficient innovation system.

Additional Government funding may be required to encourage transformation in those sectors that lack long term strategy and where critical mass has not emerged. In addition those industry sectors where it is the Government's intention to support 'science and innovation and promoting the growth of industries of the future'⁵¹ may be appropriate for additional Government funding.

An overarching national innovation strategy with corresponding institutional or funding scheme mechanisms to adjust research activity to align with the needs of industry, government and the community, could support a focus on those areas we wish to build or maintain and hence reduce the risk of investing scarce research resources in activities that will not be utilised. The B20 in its list of recommendations to the G20⁵² noted that to promote structural flexibility, all G20 Governments should, 'Establish a national innovation agenda and pipeline with supporting structural reforms.' It would also help to reduce duplication of R&D activities and infrastructures. This could enable R&D investment to be less bound by particular research topics, sectors or organisations, rather what is of greatest benefit to the nation.

Key issues and opportunities

Government investment and the conditions created by Government are central to driving innovation and hence national productivity and competitiveness.

A National Research Strategy could help focus effective and efficient investment in leading research and development to underpin Australia's competitiveness.

Research support schemes that have industry innovation as their explicit goal should include industry involvement throughout the duration of the R&D as translation to industry is generally through a collaborative model not through a linear model.

Conclusion

For Australia to remain globally competitive we must ensure that the R&D capabilities and activities conducted across the national innovation system support our key industries and those that we wish to grow. Some sectors, such as mining and agriculture which successfully utilise government and market mechanisms to translate the outputs of R&D into global competitiveness, illustrate the critical role of R&D in underpinning long-term economic growth and prosperity. A national innovation system that balances investigator-led research, mission-directed research, in-firm research, and that supports the translation of publically funded research outputs into the private sector, would help the Australian economy better shift to a focus on production of high value goods and services which is essential to managing the structural adjustment arising from the slowing of the mining sector and to also differentiate ourselves in the quickly developing Asia-Pacific region.

In this paper we have provided an overview of the national innovation system, highlighting the strengths and weaknesses through the use of quantitative analyses, case studies, and our experiences. In summary, these are:

- Government policies and investments play a key role in shaping the R&D capabilities, activities, and translation mechanisms in a national innovation system. A National Research Strategy would focus investment and R&D into critical sectors and would help balance the relative amounts of investigator-led, mission-directed, and in-firm R&D activities and capabilities.
- A combination of limited industry research capability, capacity to absorb technologies, and rates of collaboration between research and industry sectors has resulted in difficulty for some industry sectors to innovate and remain globally competitive. However, the R&D capacity of Australia's industries are varied and should be considered separately when designing new programs. The relative support provided for each sector should also align with the importance of that sector to the productivity and prosperity of Australia.
- To ensure that the R&D undertaken delivers the required social, environmental, or economic impact it is important that the activities are both designed and implemented by a consortia of research, government, and industry partners. Active involvement of all parties throughout the R&D ensures the research best leverages the available capabilities, minimises risks of activity and investment duplication, and is focused on solving the needs of the end user.

Attachment 1: Industry Research and Development data

TABLE 1: AUSTRALIAN INDUSTRY R&D AND INNOVATION BY INDUSTRY ANZSIC CODE, 2011–12^v

INDUSTRY SECTOR	BUSINESS R&D EXPENDITURE		FIRM R&D STAFF	FIRMS THAT INTRODUCED ANY NEW GOODS OR SERVICES	FIRMS THAT INTRODUCED ANY NEW OR SIGNIFICANTLY IMPROVED OPERATIONAL PROCESSES	INNOVATION-ACTIVE BUSINESSES		OUTPUT SHARES 2011-12
ANZSIC CODE	\$M	% TOTAL	PYE			% BUSINESSES WITH ANY INNOVATION ACTIVITY	% INNOVATION-ACTIVE BUSINESSES CONDUCTING JOINT R&D	% TOTAL INDUSTRY GROSS VALUE ADDED
Agriculture Forestry and Fishing	189.7	1.0	614	4.8	15.6	30.1	13.5	2.6
Mining	4,104.1	22.4	4,729	8.5	21.1	46.5	16.0	11.2
Manufacturing	4,473.9	24.4	18,196	27.8	29.5	55.8	8.4	8.3
Construction	819.5	4.5	2,475	11.8	13.4	35.9	4.1	8.4
Financial and Insurance services	2,985.2	16.3	12,404	18.3	17.0	45.4	7.2	11.5
Australian Total	18,321.3	100.0	64,906	20.4	19.1	46.6	6.5	100.0

^v Table 1 Data sources: ABS8104 2011-12; ABS8167 2011-12 Tables 1 and 3; ABS 8166 2011-12 Table 1; ABS8167 2011-12 Table 3; PC Productivity Update May 2013

TABLE 2: COMPARISON OF SOME INDICES OF R&D PERFORMANCE FOR AUSTRALIA AND SELECTED COUNTRIES^{vi}

COUNTRY	GROSS NATIONAL INCOME PPP	SCIENTIFIC ARTICLES	NATIONAL PATENT APPLICATIONS 2012		INTELLECTUAL PROPERTY PAYMENTS		HIGH TECHNOLOGY EXPORTS		INDUSTRY R&D PYE 2011 ^{vii}
	\$B\$		BY RESIDENTS	BY NON- RESIDENTS	RECEIPTS BOP, USD M	PAYMENTS BOP, USD M	\$M (USD)	AS % OF MANUFACTURING	PYE
USA	16,514.5	567,231	268,782	274,033	124,182	39,889	148,772	17.8	
UK	2,206.2	159,750	15,370	7,865	12,486	8,413	67,787	21.7	108,614
Canada	1,430.9	85,031	4,709	30,533	3,745	10,867	24,039	12.4	140,423
Australia	945.2	70,668 3.5% of WO total	2,627 10% by resident	23,731	861 0.355% of WO total	4,187 1.6% of WO total	4,761	12.7	64,906
Netherlands	718.6	49,714			5,561	3,627	63,963	20.1	50,494
Belgium	443.7	26,839			2,651	2,642	36,504	11.4	35,010
Austria	362.4	18,806			776	1,543	16,176	12.8	29,734
Norway	332.3	14,428			350	588	4,514	18.8	17,561
Denmark	241.6	20,174			8,827	14.2	27,861
Finland	208.8	14,235			3,316	1,637	4,448	8.5	27,960
New Zealand	136.3	11,047	1,425	5,674	293	969	706	9.7	8,800
World	96,580.9	2,118,689	1,513,100	834,300	242,387	254,326	1,933,747	(17.6)	

vi Table 2 Data sources: OECD.Stat accessed 8/7/14 10:30GMT; AU: ABS; CA: Statistics Canada see <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ151a-eng.htm>; Web of Science 2013 Publication data, <http://apps.who.int/infocentre/databases/whois/whois.asp> Accessed 22/7/14

vii OECD.Stat accessed 8/7/14 10:30GMT; AU: ABS; CA:

TABLE 3: ESTIMATED AUSTRALIAN R&D EXPENDITURE BY SEO^{viii}

2011/12 R&D INVESTMENT	INDUSTRY	COMMONWEALTH	STATE/ TERRITORY	UNIVERSITIES	PRIVATE NON-PROFIT	CSIRO ^{ix}	TOTAL
Socio-economic objective	\$'000	\$'000	\$'000	\$'000	\$'000	\$'000	\$'000
Defence	197,124	598,797	0	63,233	0	8,950	859,154
<i>Economic Development</i>							
Plant Production and Plant Primary Products	302,487	121,143	188,934	253,462	3,255	167,558	869,281
Animal Production and Animal Primary Products	165,619	98,046	154,848	170,419		134,626	588,932
Mineral Resources (Excluding Energy Resources)	2,742,403	121,062	17,415	128,023		93,401	3,008,903
Energy	2,361,179	181,872	8,030	341,427		137,776	2,892,508
Manufacturing	4,562,845	108,110	5,674	534,131	21,815	87,416	5,232,575
Construction	933,773	35,614	4,820	147,535	0	11,569	1,121,742
Transport	438,193	32,049	7,461	107,966		8,799	585,669
Information and Communication Services	1,835,591	105,360	1,200	349,976	3,716	20,119	2,295,843
Commercial Services and Tourism	3,809,373	4,188	1,736	174,662		4,854	3,989,959
Economic Framework	21,499	76,203	2,843	349,907	0	11,894	450,452
<i>Total Economic Development</i>	<i>17,172,962</i>	<i>883,647</i>	<i>392,962</i>	<i>2,620,741</i>		<i>678,015</i>	<i>21,070,312</i>
<i>Society</i>							
Health	563,605	264,706	429,323	3,270,960	827,510	88,124	5,356,104
Education and Training	57,031	12,626	21,952	404,237	58,822	3,314	554,668
Law, Politics and Community Services	56,377	31,375	16,413	473,836	3,544	3,602	581,545
Cultural Understanding	1,969	8,340	14,294	550,752	244	2,291	575,599
<i>Total Society</i>	<i>678,982</i>	<i>317,046</i>	<i>481,982</i>	<i>4,699,786</i>	<i>890,119</i>	<i>97,332</i>	<i>7,067,915</i>
<i>Environment</i>	<i>228,504</i>	<i>438,573</i>	<i>230,486</i>	<i>919,687</i>	<i>11,810</i>	<i>298,456</i>	<i>1,829,060</i>
<i>Expanding Knowledge</i>	<i>43,750</i>	<i>166,901</i>	<i>22,568</i>	<i>1,369,522</i>		<i>121,292</i>	<i>1,602,741</i>
Total	18,321,322	2,404,965	1,127,998	9,609,736	944,425	1,204,046	32,408,446

viii Data sourced from ABS 8104.0, 8111.0, 8109.0, and CSIRO input to 8109.0

ix Note CSIRO data may exceed total Commonwealth R&D expenditure due to the revision of CSIRO data, particularly in Plant Production and Animal Production

Attachment 2: CSIRO's Policies and Posture of transfer of Intellectual Property to Industry

Context

CSIRO's function is:

'to carry out scientific research for ... assisting Australian industry; furthering the interests of the Australian community; contributing to the achievement of Australian national objectives ... to encourage or facilitate the application or utilization of ... research ... or any other scientific research ...'

In order to achieve these objectives, CSIRO manages its intellectual property in a strategic manner and makes accessible research results in an appropriate manner for the intended use. CSIRO has a bias towards public disclosure of new knowledge, for much of its research portfolio and publishes approximately 2700 scientific articles each year.

The pathways to distribution and transfer of knowledge and technology are various – conference papers and articles in the scientific literature; reports to government, in parliamentary forums and to industry; forums; people exchanges and collaborations; media communications; as well as through contractual means such as licensing, formation of spin-out companies, and the sale or exchange of rights. All of these paths can be valid mechanisms for generating impact, although on a case-by-case basis one or more of these will be more appropriate transfer mechanisms than others.

Intellectual property management – and where appropriate, registration of the intellectual property rights – are tools to achieve these desired outcomes. CSIRO protects its intellectual property where it considers that is appropriate to support subsequent commercial development of the rights by commercial collaborators or to facilitate follow-on capital investment by the market in technology development and its adoption. CSIRO also seeks protection for intellectual property that may be used as a platform to encourage collaboration or to obtain access to other people's important intellectual property. Such protection (which mechanisms are also a form of public disclosure, albeit delayed) preserves greater choice later on as the research knowledge is further developed, including the options for making that intellectual property available, freely or widely.

When developing intellectual property in collaboration with other parties (and much of CSIRO's research is collaborative with other parties), CSIRO works with those partners to identify the party that is best placed to manage intellectual property in the national interest.

CSIRO's Policy

CSIRO has obligations to comply with government policies and international protocols, including respecting the intellectual property (IP) rights of others. The CSIRO Board has approved a set of IP Principles, aimed at being transparent with collaborators and clients and to facilitate early clarity of IP access rights. These Principles (see below) have been published on the csiro.au website.

TEN PRINCIPLES FOR GENERATING IMPACT FROM INTELLECTUAL CAPITAL

1. Our primary purpose in generating and transferring knowledge is to achieve impact.
2. We will strive to choose the best transfer path to maximise impact. These pathways include public dissemination, exclusive or non-exclusive licensing, assignment or reciprocal agreements to increase collaboration and access to third party Intellectual Property Rights.
3. We seek to ensure that dealings and agreements with third parties appropriately preserve and protect IP, and provide a sound governance framework for IP decision making.
4. Ownership and control of IP should generally vest with the party best placed to manage the intellectual property across the full scope of the technology and its potential utilisation.
5. If we agree to enter into IP co-ownership arrangements, the contract will include a governance framework regulating the exercise of all relevant components of the IP and addressing the allocation of IP costs.

6.	Where the IP is expected to generate commercial returns, we generally expect a reasonable and proportionate return in exchange for access rights.
7.	We will retain sufficient intellectual property access rights to enable the conduct of further research in accordance with our charter.
8.	We respect the IP of others but support the principle of exemptions for research use.
9.	We will enforce our IPR and contractual rights in a manner consistent with our statutory charter and roles within the innovation system.
10.	In the context of maximising the impact of our research efforts we will endeavour to ensure that intellectual property and knowledge is made available for humanitarian uses and the public good. In further developing these principles and related protocols we will seek to work with our national and global peers within the research community to promote a common approach to the management of intellectual capital.

PRINCIPLE 6

The preferred pathway for commercial use of CSIRO's intellectual property will depend on the nature of the intellectual property, beneficial interests, the relevant sector, the availability of potential licensees and of capital. In those situations where the intellectual property and technology of CSIRO being transferred to the market is expected to generate significant commercial returns, CSIRO's posture is that it is appropriate that an equitable return arising from that exploitation should be shared with CSIRO to be reinvested into further research and development in the national interest. The level of this commercial return may, as appropriate, take into account the research investment made by the parties, the intrinsic value of the intellectual property and technology, the additional investment required to realise market returns and the risks in commercialisation. However, CSIRO seeks to generate benefits for Australia ahead of returns to itself and strives to choose the best transfer path to maximise impact.

Licensing decisions may include the following trade-offs which are considered in the context of maximising impact:

- Making the intellectual property available to the market on an exclusive basis, or via multiple non-exclusive licenses
- Licensing to a large company with an established market position, scale or capability to take the technology to market readiness
- Seeking capital partners for the development of a new enterprise to develop the technology, or
- Providing IP rights to an existing SME enterprise, to promote the growth of the company.

CSIRO Patent Portfolio and Licensing

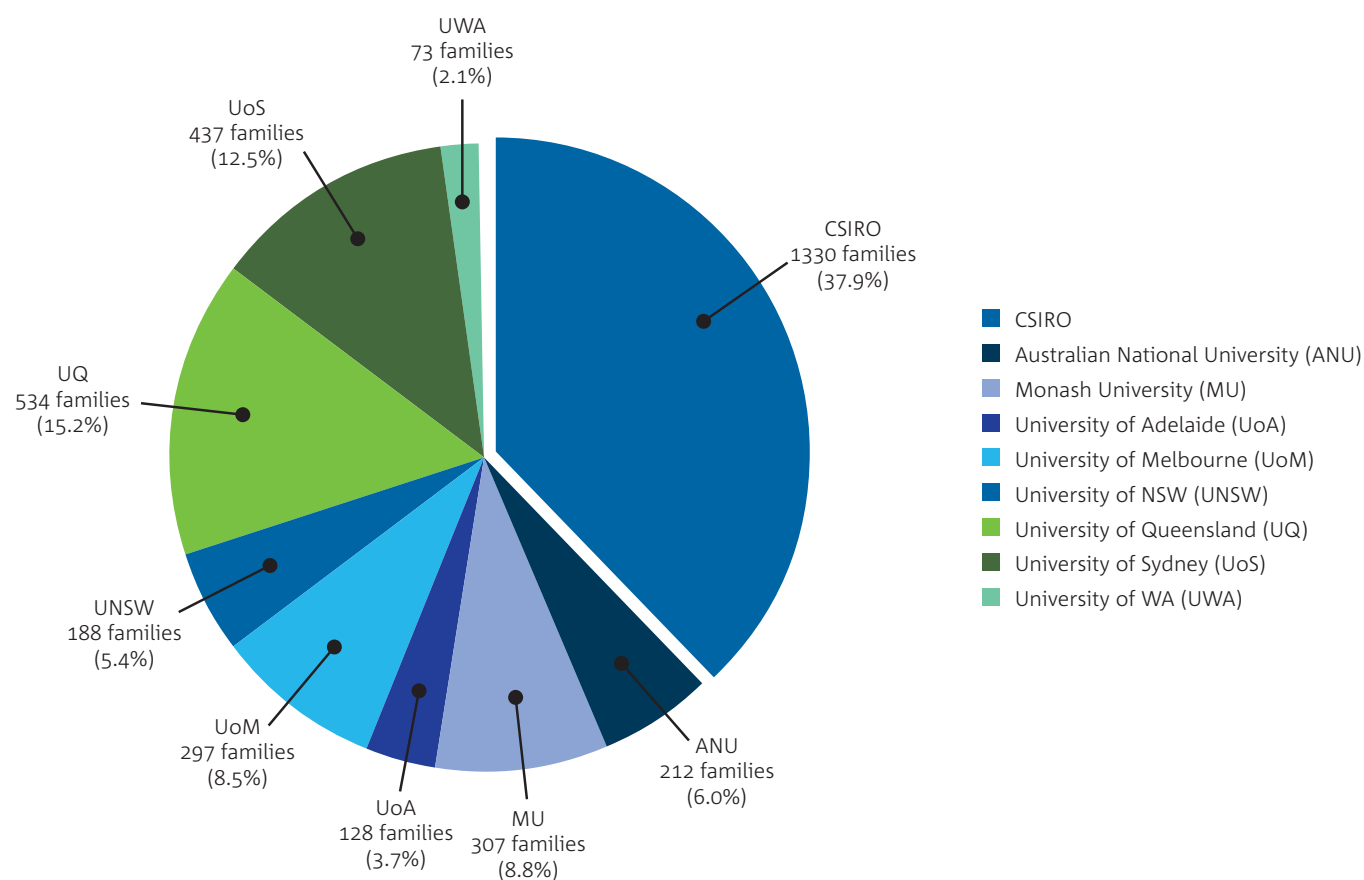
CSIRO currently maintains 756 items of registered intellectual property, including 660 families of patents or patent applications, 90 Plant breeders Rights and 6 designs. CSIRO is one of Australia's largest filers of Australian provisional patent applications – CSIRO is responsible for over 3 per cent of the patent applications under the PCT patent system, filed between 2006 and 2012 by first-named Australian applicants.

To put these figures into a context:

- The origin of the inventions is a key factor in the subsequent management of the intellectual property. Approximately 30 per cent of these assets have arisen during research collaborations with other parties, be they industrial partners, government research institutes or university collaborators. Where a commercial collaborator is involved during the conduct of the research, that collaborator will generally have either a licence, or first rights to take a licence, to use the intellectual property for commercial purposes;
- Considering the 660 families of patents or patent applications, 380 of these (58 per cent) have arisen from science conducted by CSIRO where that science has not been funded by third party funds;
- In a competitive global field, it is often appropriate to make an application for patent coverage early after the initial discovery and demonstration of the invention. However it commonly takes many years to take an invention from its proof of concept stage to a commercially attractive technology. For these reasons, a patent portfolio is expected to include intellectual property for which licenses have not been entered;

- 280 patents (42 per cent of all CSIRO's patents or patent applications) are the subject of a research use licence and 172 (or 26 per cent) are the subject of commercial license rights. {There is some overlap in these license numbers because some of patents are licensed (non-exclusively) to a commercial partner, but are also subject to separate research license rights to develop up other applications, for example. This overlap is often the case where the patent covers 'platform' intellectual property and so is non-exclusively licensed – for example, for different gene silencing applications};
- The CSIRO patent portfolio includes 380 patent/patent application families which are not as yet licensed, 70 per cent of this 380 being not as yet published through the patent system due to being inventions made in recent time periods (i.e. not available to the public as yet, but will be disclosed by the Patent Office as the patent application progress);
- Most of CSIRO's plant varieties are licensed (76 are licensed);
- CSIRO also maintains 230 trademarks, 20 of which are licensed;
- 58 per cent of CSIRO's licensees (both from our registered IP assets and non registered rights) are Australian.

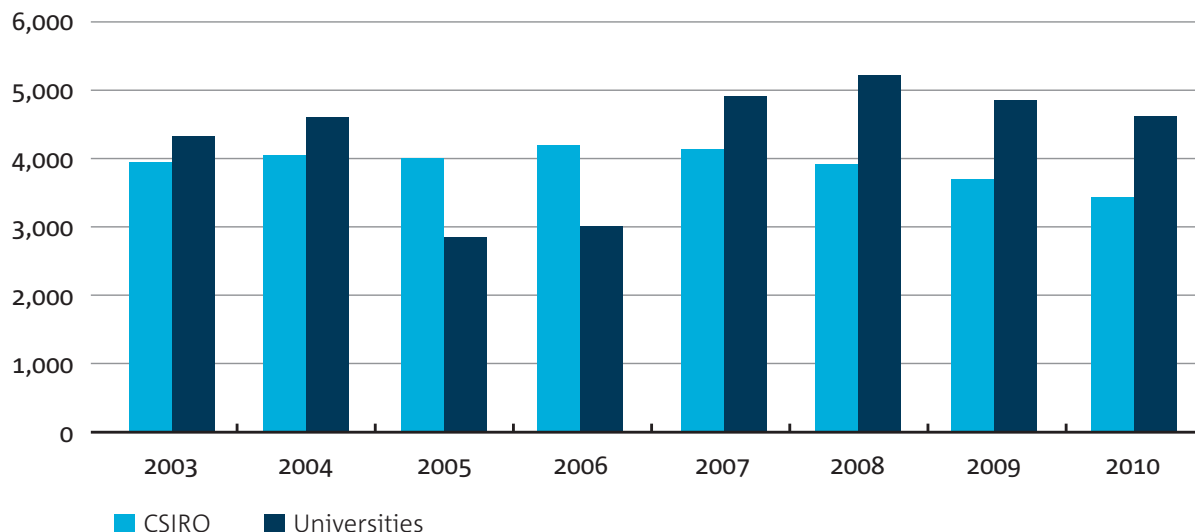
Recently, CSIRO has reviewed and streamlined its patent portfolio to include only significant or platform technologies. Following this, CSIRO still holds more than twice as many patent families in its portfolio as the most patent-intensive Australian university.



Note: statistics refer to patent families which have an EP, US or WO publication between 2000–01–01 and 2011–12–31.

Source: CSIRO IP & Licensing Inteum database & Thompson Reuters (includes variety of IP databases including Derwent)

CSIRO maintains patent portfolio numbers that are comparable with the aggregated university patent portfolio (as reflected in the 2010 KCA Commercialisation Metrics Report). As described above, the recent decline in patent numbers held by CSIRO reflects a recent streamlining of CSIRO's patent portfolio:



Source: KCA Commercialisation Metrics Report 2010

Issues that arise

Anecdotal evidence indicates that businesses, particularly small and medium sized firms, find the 'national innovation system' complex to deal with for commercial arrangements. The reasons for this include that different organisations in the system currently adopt different policies and standards, ranging across commercial issues of the financial aspects of transactions, the respective responsibilities of the partners in managing risks and their control aspects during the commercial engagement, and the ownership of intellectual property, its management and use. To further confound these issues, there are varying degrees of capacity (time availability, specialist knowledge, and legal capability) in institutions and businesses to efficiently come to agreement on these issues.

On the issue of intellectual property, whilst it may be appropriate in some cases for approaches to the management of intellectual capital to vary from public sector research institution to institution, there are a number of common elements that are shared across the spectrum of institutions. It is CSIRO's proposal that the Ten Principles reflected in the box would be an appropriate input to the development of a set of national principles for intellectual property management by public sector research institutions (to be implemented in association with the Statement of IP Principles for Australian Government Agencies).

Attachment 3: Extract from Manufacturing a better future: the role of science, technology and innovation⁵²

3.3 Improving connections between innovation and industry

3.3.1 REDUCING RISK IN PRODUCT DEVELOPMENT AND DEMONSTRATION

A strategy that is emerging internationally is that of incentivisation of proof of concept projects aimed at the development of new products to mitigate the cost and technical risks, whilst demonstrating market potential. The US based Small Business Innovation Research (SBIR) program and the Victorian Market Validation Program are examples of these. A specific intention of such programmes, which often use Government requirements as a market, is to drive innovation uptake in SMEs. For example, there are a large number of Defence related projects in the UK Small Business Research Initiative (SBIR).

Additionally, Open Innovation programs operated by multinational companies, such as P&G and EADS are emerging to identify solutions and prospective ideas to supply the knowledge for their future products. Companies such as Nine Sigma also operate Open Innovation knowledge markets, where Nine Sigma seeks solution providers on behalf of others.

3.3.2 CREATING AN INNOVATIVE AND FLEXIBLE WORKFORCE

Many of the barriers discussed can be addressed when there is a good understanding between the researcher as an individual and the output goals of the company. However, current pathways for enabling researchers to understand the needs of industry are few. Career progression, remuneration, superannuation and work practices are highly separated and not conducive to the movement of people between the research and innovation cultures. Developing mechanisms to enable individuals to straddle those cultural barriers offers significant potential for connecting innovation to industry.

Australia has a number of successful programs that seek to move people across the innovation system into industry. However, more needs to be done. A specific program that seeks to increase connectivity and dialogue between researchers and business is the Enterprise Connect Researcher In Business (RIB) program. The program aims to break down the barriers between research and industry and has resulted in over 100 Australian SMEs bringing a researcher into their company. When these projects are successful they go a long way to building the trust and understanding that results in continued engagement and translation of knowledge to Australian manufacturing. Other mechanisms for creating a flexible workforce that can develop innovation, which respond both to market pull and technology push include:

- Formalising science-based staff secondments into industry during the first five years of employment within a research institution/university;
- Generating opportunities for industry research and development staff to be seconded into research institutions/universities with a specific focus on their unique company-based challenges; and
- Ensuring science staff at research institutions/universities are not penalised through their remuneration and superannuation for moving between research organisations and industry.

3.3.3 INDUSTRY RESEARCH CLUSTERS

Another mechanism for promoting the connections between innovation and industry is the establishment of 'cluster' groupings of companies along and across supply chains, which focus on developing and exploiting platform technology that has been invented within research organisations and universities.

A specific example of an existing industry research cluster is around the transfer of Additive Manufacturing technology into industry, through the Victorian Direct Manufacturing Centre. This cluster is composed of Australian SMEs working on immediate applications of additive manufacturing in printing, machine tools, defence and sports equipment.

Clustering can also be applied to develop coordinated R&D within academia and promote technology transfer, which is a rate-limiting step for innovation in Australia. National Innovation Networks are one concept to draw multiple institutions and sites together to collaborate, prioritise and address training and development, market

awareness and technology awareness. The Victorian Organic Solar Cell Consortium is an example of this form of concerted collaboration to bring a new technology to market.

This network concept could be used as a model across all sectors of manufacturing.

3.3.4 REWARDING INDUSTRIAL RESEARCH

Rewarding both individuals and organisations for successful industrial research is another basic strategy for building connections. This requires the identification and incentivisation of the right people with the right capabilities and interests to achieve alignment between the desired science outcome for the researcher and the desired outcome for the company. As well as reward strategies within larger organisations, potential nationwide strategies to achieve this include:

- ♦ The ARC grant system could apply an increased weighting to industrial collaboration in the success of the ARC application; and
- ♦ A prestigious new five year Fellowship could be established and administered by the ARC to encourage and reward industry focused research.

3.3.5 TAKING ADVANTAGE OF GLOBAL CONNECTIONS

Australian manufacturers can take advantage of Australian research institutions and University connections to extend into the global innovation system. Currently, there are significant connections between Australian researchers and researchers in other parts of the world. These connections should be leveraged to access the best capabilities from the global innovation system and create strategic linkages overseas from Australian corporations.

Attachment 4: CSIRO – Delivering Impact with Industry

CSIRO delivers benefit to industry in a number of ways, including conducting research and services (working with over 2200 companies each year); providing near-to-market, technical support services in areas of CSIRO expertise (over 1600 companies per year); participating in collaborations with industry collaboration vehicles including 36 CRCs (CSIRO is the largest single participant in the CRC program), 15 RDCs and 28 industry associations. In 2012–13, CSIRO conducted more than \$430m of research and development activities under these arrangements with firms, industry associations and collaborative arrangements (including resources and capability co-invested by CSIRO from own resources), and these arrangements represented approximately 35 per cent of CSIRO's research and services activities for that financial year. CSIRO also conducted research under grants from Australian governments to the value of more than \$200M, a significant proportion of which would be relevant to industry support. In FY2012–13 CSIRO received \$37.5M revenue from industry partners who have actively licensed CSIRO intellectual property.

The following sections give a description of CSIRO's activities in sectors that have been identified^x as being knowledge-intensive competitive industries in areas of global growth:

- Food and Agribusiness
- Mining Equipment, Technology and Services
- Medical technologies and Pharmaceuticals
- Oil and Gas
- Advanced Manufacturing

with emphasis on industry connections and also providing a perspective on the research capability in an Australian and global perspective.

Food and Agribusiness

CSIRO'S R&D ACTIVITIES IN THE SECTOR

CSIRO's goal is to deliver sustainable productivity growth and value to food and fibre production in support of the economy, the environment and the health of Australians.

RESOURCES

In 2012/13 CSIRO's expenditure in Food and Agribusiness was \$230.6M including \$109.9M from non-appropriation sources.

EXAMPLES OF INDUSTRY CONNECTIONS

New high value dairy products from waste streams

CSIRO's expertise in developing separations technologies has enabled Murray Goulburn to capture valuable proteins from whey, which had previously been considered a waste product of cheese production.

BARLEYmax™ Grain

CSIRO-developed BARLEYmax™ grain offers food manufacturers an ingredient that improves the nutritional profile of their products and provides digestive health benefits to consumers. BARLEYmax™ is now licensed to four Australian food producers, and 11 consumer food products are available, including cereals, wraps, muesli bars, rice blends and a loaf bread. See: <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/Barley.aspx>

Omega-3 canola

CSIRO, Nuseed and Grain Research & Development Corporation have come together to undertake the research and trials to develop the highest quality of long chain DHA omega-3 in oilseed plants at levels equal to or better than fish oil. Plant-based omega-3 oil production is a sustainable, long-term solution to the growing demand for

^x In the Industry Portfolio Budget Statement 2014–15, Minister Macfarlane indicated a focus on manufacturing areas identified as knowledge-intensive, competitive and undergoing global growth. The five primary areas identified are food and agribusiness; mining equipment, technology and services; medical technologies and pharmaceuticals; oil and gas; and advanced manufacturing. The Portfolio Budget Statement noted that, to this end, science and research were key requirements and should be more focused to deliver commercial outcomes.

omega-3 oils, which is driven by demand for supplements and fortified foods for human consumption and feed additives in industries like aquaculture.

Cotton Seed Distributors

CSIRO developed cotton varieties with improved disease resistance and increased water efficiency are licensed to this company in Australia and internationally. More than 95 per cent of Australian cotton, as well as half the dryland cotton grown in the US and about one-third of the cotton in Brazil, Turkey and Greece can be linked to CSIRO-bred varieties. Cotton production on an average Australian season is valued at more than \$1.3 billion. See: <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/Cotton.aspx>

FOOD AND AGRIBUSINESS SECTOR CLIENT FEEDBACK	WILLINGNESS TO RECOMMEND
<p><i>'CSIRO provides a service to conduct clinical trials in animals that is not available elsewhere in Australia. The team at the Werribee research facility are extremely helpful and accommodating... I would like to compliment and thank both the Werribee team and Dr ... for their extremely high standards as a service provider for our industry.'</i> – Industry client #1 (F&A)</p> <p><i>'Our experience with CSIRO has been very positive. We have found CSIRO staff knowledgeable, easily contactable and well prepared. CSIRO staff are also well networked and have a good understanding of other projects within CSIRO, which helps when searching for information. Overall a positive experience.'</i> – Industry client #2 (F&A)</p> <p><i>'I have experienced a positive collaboration experience with CSIRO and look forward to continuing this in the future. The interaction has resulted in my own team presenting results that have had a higher degree of data and scientific integrity.'</i> – Industry client #3 (F&A)</p>	<p>Average score 8.8/10</p> <p>83% of clients rated 8 or higher</p> <p>0% of clients rated 5 or lower</p> <p>From 36 responses,</p> <p>58 projects surveyed,</p> <p>62% response rate</p>

RESEARCH PRECINCT DIRECTLY SUPPORTING THIS SECTOR

The **Natural Sciences Precinct (Canberra)** will have a focus on foundation research addressing continental scale problems and opportunities by integrating knowledge across a range of scales from gene to landscape and bringing together the natural sciences and the social sciences and economics. The issues tackled include food security, profitable agri-business, new bio-based manufacturing, landscape management under competing demands, water security, carbon emissions and agricultural resource assessment of northern Australia.

SCIENTIFIC PUBLICATIONS AND CONNECTIVITY

CSIRO is Australia's largest publisher of scientific publications in the relevant fields^{xi} and CSIRO publications represent more than 20 per cent of Australia's output in the scientific fields of Agricultural Sciences (21 per cent) and Plant & Animal Science (14 per cent). The University of Queensland is Australia's next largest producer with output 60 per cent of that from CSIRO. CSIRO's research is of highest quality in Australia (on a citation basis) and is 58 per cent more cited than the world average. CSIRO's agricultural and land usage research is underpinned by environmental and ecology research. CSIRO contributes 17 per cent of Australia's output in the scientific fields of Environment and Ecology. Network analysis of scientific publications shows that CSIRO is the most central Australian institutional 'node' in Agricultural Sciences, Environment/Ecology and Plant & Animal Sciences.

Over the last five years, Australia's research publication output in Food & Agribusiness was the tenth largest in the world (the top nine countries being USA (18.7 per cent), China (10.5 per cent), Brazil (7.9 per cent), Spain, Japan and India (6–5 per cent), Germany, Italy and Canada (4.6–4.2 per cent)). Australia's share of global output in this sector has been gradually but steadily rising over the last few years, going from 3.9 per cent in 2009 to 4.2 per cent in 2013. China's rate of increase in publications has been, as in many other fields, meteoric, but perhaps more surprising is Brazil's position in third place.

LICENCES AND PATENTS:

CSIRO has 129 licence arrangements and has a portfolio of 179 patent families and 110 Plant Breeders Rights.

xi WoS subjects FOOD SCIENCE & TECHNOLOGY, NUTRITION & DIETETICS, AGRICULTURE MULTIDISCIPLINARY, AGRONOMY, FISHERIES, AGRICULTURE DAIRY & ANIMAL SCIENCE, AGRICULTURAL ECONOMICS POLICY, AGRICULTURAL ENGINEERING, HORTICULTURE and SOIL SCIENCE, along with all publications where the abstract, title, keywords or cited document titles contained one of the keywords 'livestock', 'agribusiness' or 'pasture'

Mining Equipment Technology and Services

CSIRO'S R&D ACTIVITIES IN THE SECTOR

CSIRO works across the minerals value chain including in the areas of discovering mineral resources; the future mine; advanced processing technologies; transforming productivity through on-line analysis; sustainability through systems innovation; securing the future of Australia's carbon steel materials industry; and, growing Australia's light metal industry.

RESOURCES

In 2012/13 CSIRO expenditure was \$71.4M including \$19.5M from non-appropriation sources.

EXAMPLES OF INDUSTRY CONNECTIONS

AuScope

CSIRO partnered with Geoscience Australia, 11 universities and state government agencies to improve the availability and accessibility of comprehensive geoscientific data through the AuScope portal. The portal provides seamless access to Australian geosciences data at atomic to continental scale within and between geological surveys and their clients. AuScope will enable mineral deposits to be discovered earlier and will reduce the cost of mineral exploration. See: <https://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/AuScope.aspx>

Direct Nickel Limited

Direct Nickel Limited has been working with CSIRO to scale up their hydrometallurgical process for nickel laterite deposits.

METS SECTOR CLIENT FEEDBACK	WILLINGNESS TO RECOMMEND
'World-class expertise.' – Industry client #1 (Mining)	Average score 8.2/10 74% of clients rated 8 or higher 5% of clients rated us 5 or lower From 39 responses, 73 projects surveyed, 53% response rate
'CSIRO are equipped with suitable equipment and have the highest quality personnel.' – Industry client #2 (Mining)	
'Pragmatic research backed by sound evidence, good practice and transparent methodology.' – Industry client #3 (Mining)	
'Very useful/practical outcomes and findings. Very focused on client's specific questions, queries, etc. Very good reporting.' – Industry client #4 (Mining)	
'Depending on the field, highly competent and responsive staff.' – Industry client #5 (Mining)	

RESEARCH PRECINCT DIRECTLY SUPPORTING THIS SECTOR

The **National Resource Sciences Precinct** is a focus for Australian resource science research involving researchers and students from CSIRO, the University of Western Australia, Curtin University, the Western Australian Government, industry and others. The precinct will be internationally recognised, as a leading minerals and energy research and development centre and a key influencer in Asia and South America. The National Resource Sciences Precinct currently hosts over 900 research staff addressing the future needs of the global resources industries, supported by over A\$700 million of research infrastructure, and the precinct's 'spokes' extend both nationally and internationally. The establishment of the National Resource Sciences Precinct offers the opportunity to embrace a more holistic view of the future research and development needs of the resources sector, expanding the traditional science and engineering disciplines to include areas such as social and environmental sciences and resource economics.

The **Advanced Resource Characterisation Facility** has been established by CSIRO, University of Western Australia and Curtin University, with funding support from the Science and Industry Endowment Fund (originally from a gift from CSIRO of funds received from licences to CSIRO's WLAN technology), as part of the National Resource Sciences Precinct. The Advanced Resource Characterisation Facility will provide a global hub for performing metre to atomic scale analyses which, when combined with the four dimensional data integration capability provided by the Pawsey Centre, will create a ground-breaking research facility having a resource focus unmatched anywhere in the world. The Facility is acquiring three pieces of sophisticated measuring equipment

to be used for research, analysing and interpreting – on multi-scales – the constituent materials in samples from the geoscience research community and geoscience industries.

SCIENTIFIC PUBLICATIONS AND CONNECTIVITY

In Mining Equipment, Technology & Services,^{xii} CSIRO is Australia's largest producer of research publications and represents 14 per cent of the country's total output. The ANU is the next largest contributor producing 20 per cent less publications than CSIRO. The sector represents 9 per cent of the CSIRO's total output of scientific publications. CSIRO research in this sector is strong and is 48 per cent more cited than the global average. Network analysis of scientific publications shows that CSIRO is the most central Australian institutional 'node' in these fields.

Over the last five years, Australia's research publication output in Mining Equipment, Technology & Services was the ninth largest in the world. Country output in this field follows similar patterns to the view of world research as a whole, with the US ranked first (24.9 per cent), China second (15.6 per cent), followed by traditional sources of research output, including the UK, France, Germany, Canada, Italy and Japan. Australia's share of global output in this sector has been gradually but steadily rising over the last few years, going from 4.8 per cent in 2009 to 5.3 per cent in 2013.

LICENCES AND PATENTS

CSIRO has 54 licence arrangements and has a portfolio of 65 patent families.

Energy Oil and Gas

CSIRO'S R&D ACTIVITIES IN THE SECTOR

CSIRO's energy research aims to ensure energy supply; to maximise Australia's wealth from its energy resources; and to reduce greenhouse gas emissions. CSIRO's oil and gas exploration and production research aims to apply new technologies and knowledge to offshore basins to ensure that the country has secure supplies of power and transport fuels for the coming decades.

RESOURCES

In 2012/13 CSIRO expenditure was \$238.2M including \$96.9M from non-appropriation sources.

EXAMPLES OF INDUSTRY CONNECTIONS

BuildingIQ – Reducing energy consumption in landmark buildings around the world

CSIRO is helping commercial building owners in Australia and the US to reduce their energy consumption by up to 30 per cent, through our BuildingIQ technology. Even though it is only early days for the roll-out of the technology, in 2013 alone, BuildingIQ has already saved customers \$1.5 million in energy costs. It has received multiple industry awards including the Bloomberg New Energy Pioneers Award and Global Cleantech 100 award in 2012. Cities across the United States are already using the Building IQ system to manage their HVAC needs. One of New York's iconic buildings, the Rockefeller Centre, is for example using the system and has saved 13 per cent of its energy consumption in 12 months.

Solar air-conditioning – cool technology to warm your home

CSIRO has invented a new solar air-conditioning system using innovative three-in-one technology that provides hot water, cooling and heating for Australian homes. This solar system uses only a fraction of the electricity of current systems and halves greenhouse gas emissions. By using less electricity especially at peak demand times, it helps to avoid building costly electricity network expansions. It is currently being trialled in close collaboration with a major Australian manufacturer of solar hot water systems in residential homes on Magnetic Island.

xii WoS subjects MINING & MINERAL PROCESSING, GEOSCIENCES MULTIDISCIPLINARY, GEOCHEMISTRY & GEOPHYSICS, MINERALOGY and ENGINEERING GEOLOGICAL

CSIRO's activities in the Energy sector have resulted in formation of new companies and working with those companies:

- **Habidapt** is a new company formed in 2014 to commercialise CSIRO's energy systems management technology
- **eCoult** is a Company formed to commercialise CSIRO's Ultrabattery technology for stationary purposes. Company recently acquired by East Penn Manufacturing
- **Hyssil** – CSIRO is working with this Victorian building materials company to develop a super-light weight GHG friendly alternative to cement
- **Dyesol** – CSIRO is working with DYESOL on research into the development of a higher efficiency dye-sensitizer for application in the building-integrated photo-voltaic (BIPV) materials program.

ENERGY OIL & GAS SECTOR CLIENT FEEDBACK	WILLINGNESS TO RECOMMEND
<i>'Excellent people to work with who are committed to making a positive impact.'</i> – Industry client #1 (EO&G)	Average score 8.5/10 82% of clients rated 8 or higher 6% of clients rated 5 or lower From 34 responses, 66 projects surveyed, 52% response rate
<i>'This is a mature project and I have found the CSIRO Project Team has an excellent understanding of the project and systems and are committed to producing results & reports in agreed timeframes.'</i> – Industry client #2 (EO&G)	
<i>'For Physics based water quality monitoring applications CSIRO is outstanding nationally and internationally...'</i> – Industry client #3 (EO&G)	
<i>'CSIRO has an excellent depth and breadth of expertise to bring to a project. It also has a high recognition and reputation that brings with it a level of authority to science output. The problem in this case to be examined is politically and publicly sensitive and CSIRO provided a very high quality output.'</i> – Industry client #4 (EO&G)	

RESEARCH PRECINCT DIRECTLY SUPPORTING THIS SECTOR

See the National Resource Sciences Precinct.

SCIENTIFIC PUBLICATIONS AND CONNECTIVITY

CSIRO publications represent 17 per cent of Australia's output in the scientific fields of Geosciences and of Environment and Ecology and the network analysis of scientific publications shows that CSIRO is the most central Australian institutional 'node' in these fields.

CSIRO's contribution to Australian output in Energy Oil & Gas^{xiii} is 16 per cent and so CSIRO's contribution to this sector is critical. Curtin University is Australia's next largest producer. CSIRO's research in this sector is of good quality and is 38 per cent more cited than the world average. The organisation's output in Oil and Gas has been increasing in recent years, though a planned reduction in liquid fuel research may reduce this growth.

Over the last five years, Australia's research publication output in Energy Oil & Gas was the ninth largest in the world. China's rate of increase in publications has been, as in many other fields, meteoric; unlike most other fields, it has overtaken the US in terms of output volume. Australia's share of global output in this sector jumped in 2010 from around 3.2 per cent to around 3.8 per cent, at which level it has remained.

LICENCES AND PATENTS

CSIRO has 99 licence arrangements and has a portfolio of 106 patent families.

^{xiii} Research in this sector was identified by analysing publications where the abstract, title, keywords or cited document titles contained one of the keywords 'oil', 'gas' or 'petro*' in the subject areas MINING & MINERAL PROCESSING, GEOSCIENCES MULTIDISCIPLINARY, ENGINEERING GEOLOGICAL, ENERGY & FUELS and ENGINEERING OCEAN, along with publications where the abstract, title, keywords or cited document titles contained the keyword 'petro*' in the subject areas ENGINEERING CHEMICAL, CHEMISTRY MULTIDISCIPLINARY, CHEMISTRY APPLIED, GEOCHEMISTRY & GEOPHYSICS and GEOLOGY.

Advanced Manufacturing

CSIRO'S R&D ACTIVITIES IN THE SECTOR

CSIRO is looking to build the agility and resilience of Australian manufacturing companies, to increasing their productivity and competitiveness.

RESOURCES

In 2012/13 CSIRO expenditure was \$223M including \$65.4M from non-appropriation sources (inclusive of Medical Technologies and Pharmaceuticals). In 2012/13, CSIRO expenditure in Medical Technologies and Pharmaceuticals was \$89M including \$26.7M from non-appropriation sources.

EXAMPLES OF INDUSTRY CONNECTIONS

Textor Technologies

CSIRO partnered with Textor Technologies a leading Australian supplier of medical and healthcare textiles. Textor, with CSIRO's expertise and world-class textile research facilities has produced new materials with tailored properties that are significantly more absorbent and comfortable for consumers. See: <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/Manufacturing.aspx>

Protecting Australia's Defence Force with innovative body armour

CSIRO partnered with Australian Defence Apparel (ADA), the Defence Materials Technology Centre and the Victorian Centre for Advanced Materials Manufacturing to develop significantly lighter armour to better protect Australian soldiers in combat. Research is also being carried out with local textile companies to develop new soft body armour and materials for other protective kit. Key industrial partners are Bruck Textiles, ADA, Tectonica and Textor Technologies. See: <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/BodyArmour.aspx>

Aerospace linkages: Boeing, Marand and Ferra

CSIRO conducts research relevant to the aerospace sector with leading organisations like Boeing, Lockheed Martin, Airbus, NASA, GKN and GE. Central to CSIRO's engagement in aerospace is its 25 year partnership with Boeing, who employs in the order of 3500 staff locally. CSIRO's research goes across bio-fuels to advanced materials, modelling of complex systems and environmental interactions as well as new digital manufacturing technologies like additive manufacturing, assistive automation, sensor technologies and applied informatics. CSIRO partners with the local aerospace supply chain with organisations like Marand and Ferra Engineering as well as organisations looking to diversify into the aerospace supply chain.

MANUFACTURING SECTOR CLIENT FEEDBACK	WILLINGNESS TO RECOMMEND
<p><i>'We would recommend CSIRO to others as the work was conducted to an international standard. The team at CSIRO provided a high-quality scientific approach to the conduct of the experiments. The team we dealt with has a high level of technical expertise and provided high quality experimental results in a difficult research area...' – Industry client #1 (Manufacturing)</i></p> <p><i>'CSIRO reputation of scientific competency with impartiality or independency to industry players involved. Additionally the brand equity of a CSIRO endorsed process and outcome is respected.' – Industry client #2 (Manufacturing)</i></p> <p><i>'I have had a most productive and rewarding collaboration with a team from Materials Science Engineering at CSIRO. Publications and grants have resulted from this collaboration and further developments are planned for our ongoing project. There is a real chance we may translate our research into the clinic which could only have happened as a result of our multidisciplinary research project with CSIRO partners.' – Industry client #3 (Manufacturing)</i></p>	<p>Average score 8.7/10</p> <p>83% of clients rated 8 out of 10, or higher</p> <p>7% of clients rated 5 or lower</p> <p>From 43 responses,</p> <p>61 projects surveyed,</p> <p>70% response rate</p>

RESEARCH PRECINCT DIRECTLY SUPPORTING THIS SECTOR

The Australian Manufacturing and Materials Precinct in Clayton will be a hub for a wider network of industry and research-based organisations to connect, collaborate and focus on translating research outcomes to industry. CSIRO and Monash are the founding partners are working together to drive the Precinct. The South East metropolitan region of Melbourne is home to 40 per cent of Victoria's manufacturing companies, as well as CSIRO, Monash University, the Australian Synchrotron, and the Melbourne Centre for Nanofabrication. The Australian Manufacturing and Materials Precinct will help drive the innovation necessary for Australia's manufacturing industry to remain competitive, locally and globally connected, and form an attractive target for talent and inbound investment.

SCIENTIFIC PUBLICATIONS AND CONNECTIVITY

CSIRO is the third largest producer of Advanced Manufacturing^{xiv} research publications in Australia and represents 11 per cent of the country's output. The University of Queensland and UNSW both produce slightly more publications. CSIRO's research quality is at a reasonable level, being 32 per cent more cited than the world average. There has been a decline in CSIRO's output of scientific articles in this sector in recent years.

Over the last five years, Australia's research publication output in Advanced Manufacturing was the thirteenth largest in the world. China's rate of increase in publications has been, as in many other fields, meteoric; unlike most other fields, it has overtaken the US in terms of output volume. Also noteworthy in the rankings as deviations from the overall global picture are South Korea, India and Taiwan, all of which produce more research in this area than Australia. Australia's share of global output in this sector has been fluctuating over the last few years, with no strong pattern of increase or decrease.

LICENCES AND PATENTS

CSIRO has 60 licence arrangements and has a portfolio of 165 patent families.

Medical Technologies

CSIRO'S R&D ACTIVITIES IN THE SECTOR

CSIRO's medical devices and materials research aims to develop and evaluate new biomedical devices and platform materials technologies capable for application in tissue and regeneration. This will support the Australian biomedical manufacturing industry by creating new products and technology for local and global markets.

RESOURCES

In 2012/13, CSIRO expenditure in Medical Technologies and Pharmaceuticals was \$89M including \$26.7M from non-appropriation sources.

EXAMPLES OF INDUSTRY CONNECTIONS

Medical Developments International

CSIRO is working with Medical Developments International (a Victorian SME) to develop a new production process for methoxyflurane – the pain-relieving ingredient used in *Penthrox™* (commonly known as the 'green whistle'). This will strengthen Medical Developments International's position as the only global manufacturer of this drug. The project will help Medical Developments International to significantly reduce the cost of producing *Penthrox™* and facilitate large-scale production to support their plan to sell *Penthrox™* in the UK and Europe. Medical Developments International is seeking regulatory approval to sell the drug in the United Kingdom and Europe, which if granted, will see Medical Developments International increase production of the drug using CSIRO's manufacturing process.

^{xiv} WoS subjects MATERIALS SCIENCE COMPOSITES, MATERIALS SCIENCE PAPER & WOOD, MATERIALS SCIENCE BIOMATERIALS, METALLURGY & METALLURGICAL ENGINEERING, MATERIALS SCIENCE MULTIDISCIPLINARY, ENGINEERING MANUFACTURING, MATERIALS SCIENCE TEXTILES, MATERIALS SCIENCE CHARACTERIZATION & TESTING, MATERIALS SCIENCE COATINGS & FILMS, MATERIALS SCIENCE CERAMICS, ENGINEERING INDUSTRIAL, NANOSCIENCE & NANOTECHNOLOGY and BIOTECHNOLOGY & APPLIED MICROBIOLOGY.

Mesoblast

CSIRO is working with Mesoblast, a listed SME company, to optimise future bio-manufacturing needs through the development of manufacturing processes that can be scaled sufficiently to produce stem cells to meet clinical needs, at an acceptable cost of goods.

Much of CSIRO's activities in the Medical Technologies sector has resulted in formation of new companies, a number of which are now listed on the ASX, and working with those companies:

- ♦ PolyNovo tissue repair (now called **Calzada**) is commercialising technology for burns and wound repair
- ♦ **Polyactiva** (drug delivery) – is commercialising polymeric drug delivery technology – a privately held, venture-backed company
- ♦ **AviPep** – is licensed to this Victorian biotechnology company that is commercialising antibody technology with potential in the imaging and treatment of cancer
- ♦ **Adalta** – a privately held, venture-backed company that is commercialising antibody libraries for therapeutic use
- ♦ **Evogenix**, which merged with Peptech to form Arana
- ♦ **StarPharma** is commercialising a dendrimer nanotechnology platform, with biomedical and agricultural applications
- ♦ **Benitec Ltd** is commercialising CSIRO's gene silencing technology in human therapeutics
- ♦ **Elk Orthobiologics** – commercialising Gene Directed Enzyme Prodrug Therapy
- ♦ **VacTx Pty Ltd** – commercialising vaccine technology

MEDICAL TECHNOLOGIES SECTOR CLIENT FEEDBACK	WILLINGNESS TO RECOMMEND
<i>'Specialised knowledge and experience in bacterial, mammalian cell culture and regulatory requirements for recombinant organisms. This is not widespread in Australia.'</i> – Industry client #1 (Biotechnology)	See Manufacturing section (above)
<i>'We were able to achieve our goals in the licensing agreement struck with CSIRO; equally importantly a relationship has been established between our internal innovation group and the applied research resources of CSIRO, enhancing future opportunities to collaborate.'</i> – Industry client #2 (Medical Devices)	
<i>'Work was done on time, on budget, technically all correct. Happy customer!'</i> – Industry client #3 (Medical informatics client)	
<i>'All reporting requirements are met in full and reports are submitted on time. Invoices are always accurate and on time. Any queries are dealt with professionally and quickly.'</i> – Industry client #4 (Community Health organisation)	

RESEARCH PRECINCT DIRECTLY SUPPORTING THIS SECTOR

The Australian Manufacturing and Materials Precinct (see above).

SCIENTIFIC PUBLICATIONS AND CONNECTIVITY

Technical note: Identifying research in this sector is challenging, primarily for the technical reason that there is no easy way to distinguish medical technology research from other medical research. The results are dependent upon the analytical method and so only general comments, based on two different analytical approaches, will be provided.

Over the last five years, Australia's research publication output in Medical Technologies & Pharmaceuticals was the ninth largest in the world (as indicated by both analytical approaches). Country output in this field follows similar patterns to the view of world research as a whole, with the US ranked first, China second, followed by traditional sources of research output, including the UK, France, Germany, Canada, Italy and Japan. Australia's share of global output in this sector has been rising reasonably rapidly over the last few years, going from 2.9 per cent in 2009 to 3.8 per cent in 2013 or 3.4 per cent to 4.1 per cent (depending upon which technical approach is used).

Medical research per se is not a focus for CSIRO, although the organisation has a strong track-record in particular in the application of materials technology to medical devices, and in clinical research related to nutrition. It is thus unsurprising that the bibliometric analysis shows that CSIRO's research represents only between 1.0–1.4 per cent of Australia's output in this area.

LICENCES AND PATENTS

CSIRO has a portfolio of 90 patent families and 33 licences.

References

- 1 Department of Industry (2013) Australia Innovation Systems Report, pg 9
- 2 Eslake (2011) Productivity: The Lost Decade, Reserve Bank of Australia 2011 Conference: The Australian Economy in the 2000s
- 3 Productivity Commission (2008), Annual Report 2007-08
- 4 Commonwealth of Australia (2011) Australian Innovation Systems Report 2011
- 5 Barnes P & McClure A (2009) Investments in Intangible Assets and Australia's Productivity Growth, Productivity Commission Staff Working Paper
- 6 Productivity Commission (2008) Annual Report 2007-08
- 7 CSIRO (2014) Australia's Global Precincts, <http://www.csiro.au/Portals/Partner/Global-Precincts.aspx>
- 8 Department of Industry (2012) Australian Small Business: Key Statistics and Analysis
- 9 Department of Industry (2013) Australia Innovation Systems Report, pg 56
- 10 Department of Industry (2012) Australian Small Business: Key Statistics and Analysis
- 11 Australian Bureau of Statistics (2013) 8104.0 – Research and Experimental Development, Businesses, Australia, 2011-12
- 12 Department of Industry (2013) Australia Innovation Systems Report
- 13 Department of Industry (2013) Australia Innovation Systems Report
- 14 Schmidt (2005) Absorptive Capacity – One Size Fits All? A Firm-level Analysis of Absorptive Capacity for Different Kinds of Knowledge
- 15 Batelle (2013) 2014 R&D Global Funding Forecast
- 16 OECD (2011), OECD Science, Technology and Industry Scoreboard 2011, OECD Publishing
- 17 Department of Industry (2013) Australia Innovation Systems Report, see Table 2.1 Indicators of Australia's collaboration activity by innovation active businesses, pg 56
- 18 Harvard Business School (2014) Client Success Story: Danish National Advanced Technology Foundation
- 19 Chai and Shih (2013) Fostering Translational Research: Using Academic-Industry Partnerships to Improve Firm Survival, and Innovative Performance, Harvard Business School Working Paper 13-058
- 20 National Institute of Advanced Industrial Science and Technology (2014) The AIST Innovation School, presentation to CSIRO International, 22nd January 2014
- 21 Sheng, Mullen and Zhao (2011) A turning point in agricultural productivity: consideration of the causes, ABARES research report 11.4
- 22 Productivity Commission (2014) PC Productivity Update, pg 19
- 23 Sheng, Mullen and Zhao (2011) A turning point in agricultural productivity: consideration of the causes, ABARES research report 11.4
- 24 Productivity Commission (2014) PC Productivity Update, pg 2
- 25 ABS R&D data 8109.0, 8104.0, 8111.0 for FY11/12
- 26 CSIRO submission to the Survey of Research and Experimental Development Government and Private Non-Profit Organisations 2011-12, Revised data
- 27 Cotton Australia (2014) The Australian Cotton Industry, <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry>
- 28 CSIRO (2013) Transforming the cotton industry for competitive results <http://www.csiro.au/Portals/About-CSIRO/What-we-do/Impact-case-studies/Cotton.aspx>
- 29 Select Committee on Australia's Food Processing Sector (2012) Inquiry into Australia's food processing sector

- 30 Australian Bureau of Statistics (2013) 8104.0 – Research and Experimental Development, Businesses, Australia, 2011-12
- 31 Australian Bureau of Statistics (2014) 5678.0 – Venture Capital and Later Stage Private Equity, Australia, 2012-13
- 32 Middleton (2012) How we developed the Hendra virus vaccine for horses, The Conversation, <http://theconversation.com/how-we-developed-the-hendra-virus-vaccine-for-horses-10429>
- 33 Department of Industry (2014) Department of Industry Portfolio Budget Statement, pg 23
- 34 Pettigrew, A. G. (2012) Australia's Position in the World of Science, Technology and Innovation, Occasional Paper Series, Issue 2. Office of the Chief Scientist, Canberra.
- 35 OECD Structural Analysis Database (STAN)
- 36 ABS (2009) Experimental Estimates for the Manufacturing Industry, cat. no 8159.0.
- 37 Bell, J. Frater, B. Butterfield, L. Cunningham, S. Dodgson, M. Fox, K. Spurling, T. and Webster, E. (2014) The role of science, research and technology in lifting Australian productivity, Report for the Australian Council of learned Academies, www.acola.org.au
- 38 United States Government, SBIR/STTR, <http://www.sbir.gov/>
- 39 Victorian Government, Market Validation Program, <http://www.business.vic.gov.au/grants-and-assistance/programs/driving-business-innovation/market-validation-program>
- 40 CSIRO (2012) Australian Growth Partnerships, <http://www.csiro.au/Portals/Partner/Collaborate/AGP.aspx>
- 41 Thomson Reuters (2014) Web of Science
- 42 OECD MSTI, Main Science and Technology Indicators database, 2013/1.
- 43 Cochlear (2014) Cochlear website, www.cochlear.com
- 44 Productivity Commission (2007) Public Support for Science and Innovation, pg 487
- 45 CSIRO (2011) CSIRO Strategy 2011-2015
- 46 Shih, Pierson and Lau (2012) CSIRO: The Light Metals Flagship Decision, Harvard Business Review: Case Study
- 47 German Federal Ministry of Education and Research (2012) High-Tech Strategy 2020 for Germany
- 48 Khan and Luintel (2006) OECD Science, Technology and Industry Working Papers 2006/06: Sources of Knowledge and Productivity – How robust is the relationship?
- 49 M. Dodgson, A. Hughes, J. Foster, and J.S.Metcalf (2011) Systems thinking, market failure and the development of innovation policy: The case of Australia, Centre for Business Research, University of Cambridge, Working Paper No. 397, December 2009.
- 50 IP Australia (2014) Australian Intellectual Property Report 2014, pg 9
- 51 Department of Industry (2014) Department of Industry Portfolio Budget Statement, pg 23
- 52 B20 (2014) Driving growth and jobs to increase global living standards: Key messages from the B20 to the G20
- 53 CSIRO (2012) Manufacturing a better future: the role of science, technology and innovation: Report prepared by CSIRO for the Prime Ministers Manufacturing Taskforce (Paper 8) pgs 15,16 and 18

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

AT CSIRO WE SHAPE THE FUTURE.

We do this by using science to solve real issues. Our research makes a difference to industry, people and the planet.

As Australia's national science agency we've been pushing the edge of what's possible for over 85 years. Today we have close to 6,500 talented people working out of 58 centres in Australia and internationally. Our people work closely with industry and communities to leave a lasting legacy. Collectively, our innovation and excellence places us in the top ten applied research agencies in the world.

We ask, we seek, we solve. We are CSIRO.

FOR FURTHER INFORMATION

Enquiries should be addressed to

Craig Roy
Deputy Chief Executive
a PO Box 93, North Ryde, NSW 1670
e craig.roy@csiro.au

Main submission author

Duncan Byrne
Advisor – National and Global
Innovation Systems
Strategy, Performance and International
a PO Box 225, Dickson, ACT 2602
t +61 2 6276 6593
e duncan.byrne@csiro.au