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Promoting Australian industry: CSIRO 1949–79

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This paper addresses the manner in which the Commonwealth Scientific and Industrial Research Organisation (CSIRO) transferred its technology to Australian industry during the period 1949 to 1979. The analysis is framed within the changing economic and political scene in Australia and the changing expectations for public research organisations such as CSIRO. During the 1950s and 1960s CSIRO gave little direct attention to the processes of technology transfer but instead, following the prevailing wisdom, focused on high quality science and relied on existing extension services and patenting to capture the benefits from its research. This 'science-push' approach proved successful for Australia's rural industries but, with a few exceptions, less so for the country's secondary industries. By the early 1970s CSIRO faced pressures for change, induced by a tougher economic climate and changing views on the role of public research institutions. A shift toward greater customer relevance in its research would also need to be matched by new thinking about technology transfer.

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Introduction

The history of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the twentieth century has been canvassed in several publications,[1] including numerous divisional reports,[2] and is an important part of Australia's science and technology history.[3] It is the subject of the ongoing CSIRO History Project at Swinburne University of Technology.

This paper addresses a slice of this history, 1949–79, and examines the way the organisation sought to promote Australia's primary and secondary industries. It takes a corporate-level perspective and analyses the role of external economic and political factors in shaping the evolution of CSIRO's approach.

The CSIRO was established in 1949 as a direct successor to CSIR (the Council for Scientific and Industrial Research) that began in 1926. CSIRO retained the structure and research range of its forebear, except for aeronautical and defence-related research, but operated under new legislation. It became a statutory authority accountable to the Federal Minister and the Australian parliament, with a mandate that allowed it considerable discretion in charting directions, in allocating resources, and in targeting research outcomes.

The first-listed function in the legislation establishing CSIRO—'promoting Australian industry'—was the same as for its predecessor CSIR, namely:

> the initiation and carrying out of scientific researches and investigations in connexion with, or for the promotion of primary or secondary industries in the Commonwealth or in any territory of the Commonwealth or in connexion with any other matter referred to the Organisation by the Minister.[4]

CSIRO inherited from CSIR a strong track record of support for Australia's primary industries. Its pre-war research had delivered major productivity improvements in the plant and animal industries, in particular on problems specific to the Australian continent such as the control of pests and the remediation of trace element deficiencies. And during World War 2, CSIR had also contributed in areas such as lubricants, industrial chemistry, mineral processing, tropic proofing, food processing, as well as the pioneering development of radar.

The new organisation occupied a privileged position on the Australian scientific stage. In 1950 it employed just over 3000 staff, making it a large research institution even by international standards, and it dominated Australian science, accounting for about half of the total national spending on research. This dominant position was to diminish over time, but it was not until the 1960s that the total university research spend exceeded that of CSIRO. Even by 1970 CSIRO still accounted for ~25% of total Research and Development (R&D) expenditure by private and public sectors. The organisation continued to be the main channel of scientific advice for the Australian government until 1966 when the Federal Department of Education and Science was established.

This paper considers CSIRO's technology transfer experience during two periods that are largely defined by the economic climate. The next two sections look at the way that CSIRO promoted Australia's primary and secondary industries, first during the 1950s and 1960s, and then during the 1970s. The final section discusses the analysis.

The 1950s and 1960s

The economic setting

CSIRO benefited from the strong support of the Australian government during the leadership of Ian Clunies Ross (1949–59) and Frederick White (1959–70) (Table 1). There was a sympathetic environment in the post-war period for public research funding, attributable to the achievements of CSIR before and during the war, as well as public awareness of technology breakthroughs in areas such as aerospace, materials and health. Moreover, the post-war

[1] Schedvin (1987). Currie and Graham (1966). Collis (2002).
[2] CSIROpedia https://csiropedia.csiro.au/published-histories/, viewed 31 May 2018.
[3] Australian Academy of Technological Sciences and Engineering (1988).
[4] Commonwealth of Australia (1949) *Science and Industry Research Act 1949, Acts of Parliament 1901–1950*, Canberra, para. 9(a).

Table 1. Heads of CSIRO and responsible Federal Ministers in the 1950s, 1960s and 1970s

	Head of CSIRO	Federal Minister[B]
1950s		Labor Government
	1949–1959 Ian Clunies Ross, Chair[A]	1949 John Dedman
		Coalition Government
	1946–1949 Victor Richardson CEO	1950–1960 Richard Casey
	1949–1956 Frederick White CEO	
	1957–59 Stewart Bastow CEO	
1960s	1959–1970 Frederick White Chair	1960–1961 Donald Cameron
		1962–1968 John Gorton
		1968–1969 Malcolm Fraser
		1969–1971 Nigel Bowen
1970s	1970–1977 James Price, Chair	1971 David Fairbairn
	1977–1978 Victor D Burgmann, Chair	1971–1972 Malcolm Fraser
	1978–1985 J. Paul Wild Chair	Labor Government
		1972–1975 Bill Morrison
		1975 Clyde Cameron
		Coalition Government
		1975–1979 James Webster
		1979–1983 David Thomson

[A]During the period 1949–59, the administrative structure provided for a Chair, who had a large public engagement role, as well as a supporting Chief Executive. The organisational arrangements are analysed in Harrison (Harrison 1957).
[B]Excludes Ministers with tenure less than three months.

decades were an era of unprecedented economic growth for Australia and other industrialised countries.[5] Australia experienced an average Gross Domestic product (GDP) increase of 4.2% per annum during the 1950s and 5.3% per annum during the 1960s.[6]

The upshot was that these decades were propitious for CSIRO. As Frederick White later observed, this was a time when 'money was easy to obtain and the increase in our annual appropriation from the Commonwealth government was quite large so growth, therefore, followed suit'.[7]

CSIRO also received funding from the rural sector, primarily through a national levy on wool growers that had been introduced for industry research and extension (with matching funding from the federal government), and through a wool industry fund established from the profits on the sale of surplus wool bought by the government during World War 2. These two sources of external funding contributed 15–20% of CSIRO's total budget during the 1950s and 1960s. Fig. 1 shows CSIRO's expenditure for the period 1949–79 from Treasury and non-Treasury funds, with Fig. 2 revealing the dominant contribution to the latter from the wool industry, at least till the mid-1970s.

The importance of primary industries in the Australian economy in the post-war years is evident in Fig. 3. These industries were responsible for some 80% of total exports in 1950 and in 1970 still over 50% of the total. A widely held view was that scientific research was the way to reduce rural production costs and to improve product quality, and so maintain competitiveness. In addition, the structure of rural industries—many small businesses producing undifferentiated commodities—provided a strong case for publicly funded research and extension. The wool industry was the leading candidate for support and an integrated national program, centred on CSIRO, was established. CSIRO's wool research drew on disciplines from across the organisation and spanned the industry's value-chain: they included pasture improvement, pest control, animal breeding and physiology, genetics, wool chemistry and physics, yarn preparation and textile manufacturing. Other rural industries—notably beef, dairy, and wheat—also turned to CSIRO to improve their productivity and export potential.

By contrast, Australia's secondary industry had a domestic, rather than international, focus in the post-war decades. Although the manufacturing sector comprised a sizeable proportion of national production, its contribution to Australian exports was not large (Fig. 3) and was mainly rural-based products. Australia maintained high tariff walls that were conducive to building local manufacturing capabilities but a disincentive to seeking new export markets. In effect the high barriers permitted local manufacturers an easy life, protected from international competition. Overseas subsidiaries operating in areas such as the automotive and processing industries also had a local focus; manufacturing was preponderantly for Australian consumers. Technology could be purchased off-the-shelf or improved machinery acquired from abroad.

One measure of commitment to technological change is the amount that companies spend on their own R&D to generate new products and processes and assimilate innovative technology from abroad. By this metric Australia's secondary industry lagged

[5] Keating (2014). Boardman (2001).
[6] Australian Treasury (2001). Gillitzer and Kearns (2005).
[7] White (1976).

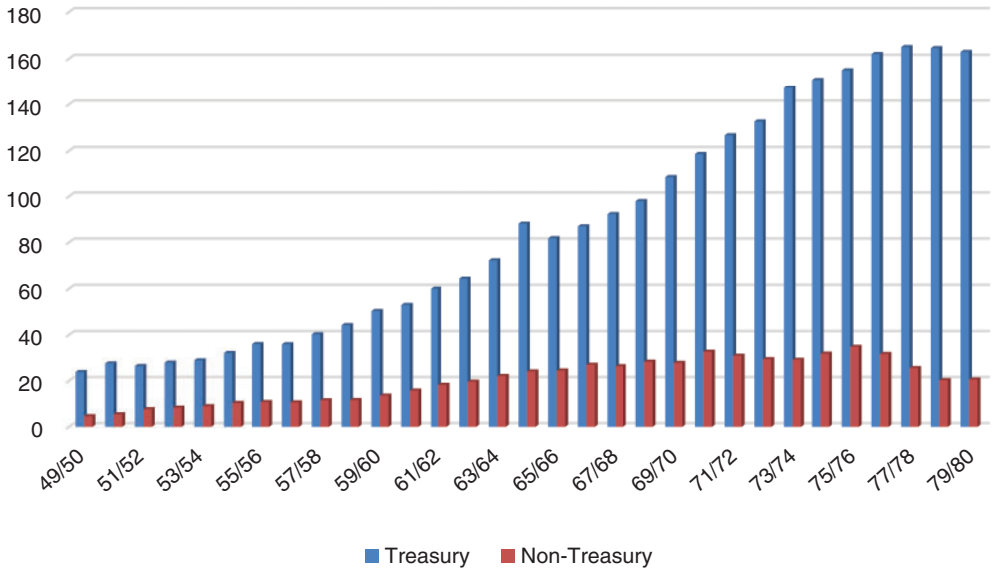

Figure 1. CSIRO expenditure 1949–79, by source of funds—$million (1979/80 dollars). Source: Funding data 1 drawn from CSIRO Annual Reports (1949/50–1979/80) and converted to constant dollars (1979/80 dollars) using the Reserve Bank of Australia inflation calculator https://www.rba.gov.au/calculator/.

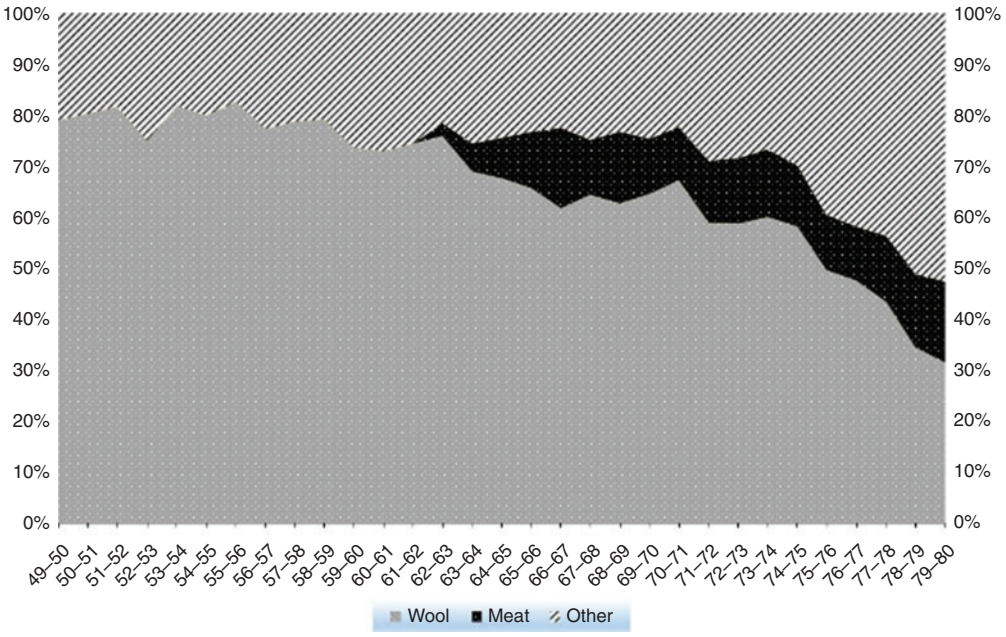

Figure 2. Proportion of CSIRO external funding contributed by the wool, meat and other industries, 1949–79.

internationally in the post-war period. Just a few local companies and foreign subsidiaries had their own research laboratories and, overall, industrial R&D was given low priority. The underlying situation was acknowledged by CSIRO Executive member Stewart Bastow:

> So long as the local manufacturing industry can be protected by tariffs in the local market from competition by the industries of more technically adventurous countries, so long as local industry has no ambition for wider horizons, there is no inherent reason for firms to undertake research and development.[8]

This sluggish attitude toward innovation and international competition by Australia's secondary industries inhibited the commercial opportunities for scientific research.

[8] Bastow (1964).

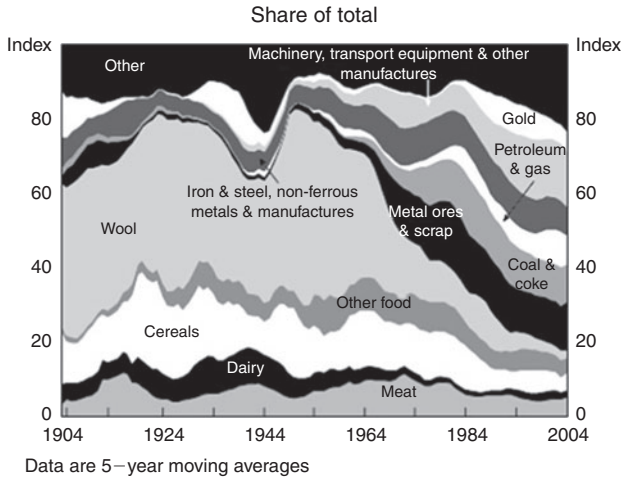

Figure 3. Share of Australian exports 1904–2004 (From Gillitzer and Kearns).[10]

Post-war thinking about research and technology transfer

A key factor shaping attitudes toward technology transfer was the prevailing thinking about science in the post-war industrialised world, namely the belief that excellence in scientific research would lead inexorably to commercial returns. This optimistic perspective followed a plethora of scientific achievements before and during World War 2, such as synthetic materials, aircraft, antibiotics, and nuclear fission. An early codification was the highly influential 1945 report the *Endless Frontier* by US presidential adviser Vannevar Bush.[9]

This view was widely shared and was a major factor in the growth of public research institutions across the world during the 1950s and 1960s and also (though not in Australia) of corporate research funding.[10] High-quality basic research was seen as the key to innovation and economic growth. Popularly expressed, it was held that scientific advancement alone would deliver technological change and social benefits and that scientists should work within disciplinary confines, make their results known by publication, and leave implementation in the hands of others.[11]

Similar thinking may be found in the Report of the 1957 Commission of Inquiry into Australian universities:

> It is obvious that most of the basic secrets of nature have been unravelled by men who were moved simply by intellectual curiosity, who wanted to discover new knowledge for its own sake. The application of the new knowledge usually comes later; it is also achieved by other men with different gifts and different interests.[12]

This notion of excellence in research as the engine of technology development and economic growth can also be seen in the leadership of Clunies Ross and White during the 1950s and 1960s. In particular they sought to build a strong, independent, scientifically eminent program of national research and break from the makeshift, responsive program that had driven CSIR during the war years. Moreover, this approach was supported the Australian government, with a notable role played by Richard (later Lord) Casey as Minister (1950–60) and as a member of the CSIRO Executive (1960–65).

Technology transfer in the 1950s and 1960s

This thinking gave priority to research rather than technology transfer. CSIRO should give primary attention to research, make the results known, and leave the implementation to others. Its role was not to do the research that firms should be doing by themselves, but to do the industry-relevant research that would not otherwise not be done. There was perceived to be a limited need for CSIRO researchers to interact directly with research users or to be involved in the follow-through to commercial outcomes.

The recruitment programs that were instituted to strengthen CSIRO's basic research capabilities had benefit for Australia and for CSIRO's scientific prestige. Several disciplines achieved world recognition during the 1950s and 1960s, such radioastronomy, plant physiology, animal physiology, micrometeorology and animal/wildlife research.[13] And new discipline-based divisions such as Protein Chemistry and Animal Physiology were established. From an industry perspective though this approach had its costs, as it meant less emphasis on linkages between CSIRO and Australian firms. As Schedvin has noted 'because there was assumed there was no knowledge-technology transfer problem the discipline-based divisions were often located physically and industrially at arms-length from consumers' and their research programmes were inclined to take on a life of their own.[14] In the pursuit of scientific excellence increased emphasis was being placed on 'pure basic research' at the expense of 'user-inspired basic research' (to use the terminology of Stokes).[15]

Not everyone agreed with this manner of thinking. One doughty defender of user-inspired basic research was CSIRO's Alan Walsh. Writing about Australian science in the post-war period he observed:

> scientific snobbery has its drawbacks and…results in many scientists believing that any type of scientific activity which has some real bearing on industry or commerce is intellectually and socially inferior to the so-called pure research. One of the tragedies of this attitude, which has been imported from Britain is that many people who have the ability to do first class applied research persist in some abstruse academic field to which they are not contributing anything worthwhile.[16]

Primary industries

The concept that CSIRO should conduct excellent research, make its results known, and leave the implementation to others, was by

[9] Bush (1945).
[10] Hounsell (1996).
[11] Roussel, Saad and Erickson (1991).
[12] Murray (1957).
[13] McKay (1976).
[14] Schedvin (1989).
[15] Stokes (1997).
[16] Walsh (1973).

and large well suited to its rural research. During this period CSIRO had six state committees, heavily weighted towards representation of rural industries with a brief to identify R&D priorities. CSIRO's research addressed industry level problems, and outcomes benefited communities of rural producers rather than individual commercial concerns.

The dissemination of research results was an important part of this. CSIRO's quarterly publication *Rural Research* was an accessible, technically sound and widely read publication. It comprised short topical articles that yielded technical advice or alerted farmers to the technology developments affecting productivity.

The transfer of technology to the rural industry relied heavily on State-based extension services with the support of rural industry associations. The extension services had a well-established role encouraging the uptake of new ideas and technologies by the farming community. CSIRO did not get directly involved in extension, but it did operate an Agricultural Liaison Research Office (1951–62) that helped train government extension officers.

This approach led to the successful transfer of numerous technologies to rural industries during the 1950s and 1960s. Some of the more prominent, successful, examples include:

- myxomatosis and the rabbit plague.[17] The release of the mosquito borne myxomatosis virus, in 1950/51 was an effective response to the post-war rabbit plague that was debilitating large part of Australia's agricultural land, and boosted national wool and meat production;
- cobalt treatment for sheep in mineral deficient coastal areas in the mid-1950s;[18]
- development of genetic techniques to promote multiple birthing in sheep enhancing sheep industry productivity, from the late 1950s;[19]
- control of cattle pleuropneumonia.[20] The protocols and testing established by CSIRO in the early 1960s managed to contain this endemic disease, By 1973 it had been eradicated and for the first time in one hundred years Australia could export live cattle freely;
- cattle for the tropics.[21] A cross breeding program through the 1950s and 1960s led to the breeding of cattle well suited for hitherto intolerant tropical regions; and
- introduction of dung-burying beetles.[22] This multidisciplinary project led to the successful testing, selection and release of dung-burying beetles onto cattle properties from the late 1960s.

Secondary industries

On the other hand this approach—that relied on excellent research, making the results known, and leaving the implementation to others—was less suited to secondary industries. First, the challenges were different: just a few sectors faced shared problems that could be addressed by research and from which multiple firms would benefit. For example, CSIRO was successful in setting up industry research associations in just a few areas -coal processing, welding, bread and sugar. Moreover, efforts to emulate the rural industry model—the dissemination of research information coupled with an industry extension service—proved unsuccessful. Both the Industrial Liaison Service, established by CSIRO in 1955, and the publication *Industrial Research News* that started a year later, struggled to achieve industry impact.

One method—making results freely available—was successful in a few cases. Designs for urban solar hot water systems were published and disseminated to local manufacturers during the late 1950s. A patented insect repellent spray was further developed and successfully marketed in Australia as Aerogard. Other examples included improved weather forecasting techniques, adopted by Commonwealth Meteorological Research Centre in the late 1960s, as well as a national coal resources survey. There were also longer term industry benefits from CSIRO's program on national and international measurement, including its pioneering work on the absolute ohm.[23]

In addition, a few CSIRO divisions, such as Building Research, Forest Products, Food Preservation & Transport, and Wool Textile Research maintained good working relations with their respective industries and provided continuing technical advice and support.

Patenting

The direct approach to transferring technology to commercial users via patenting and licensing was slow to develop in CSIRO. The organisation had inherited just a small portfolio of patents from CSIR, totalling 20 in 1945,[24] and the view of CSIRO's leadership had been that patents were not important for primary industries. Moreover, they could have a counter-productive effect of slowing down rather than accelerating the dissemination and diffusion of research outcomes. Indeed, it was not until 1955 that CSIRO had a formal policy on patenting. Two events contributed to this change of heart—the threatened loss of control of a CSIRO invention—shrink-proof wool, that had been patented by a British company, and second the invention of Atomic Absorption Spectrophotometry (AAS), a technology with substantial commercial prospects.

CSIRO's policy on patenting stated that the organisation would take out patents only in circumstances where it was in the public interest;[25] when there was a danger of others taking out patents on CSIRO's work; where it was unlikely that the invention would be developed and exploited commercially unless there was a patent; where inventions were likely to be exploited by overseas companies and substantial royalties could be collected; and where there was a need to ensure the quality and efficiency of CSIRO-generated

[17] McKay (1976).
[18] McKay (1976) p. 18.
[19] CSIROpedia https://csiropedia.csiro.au/Genetic-selection-for-multiple-births-in-sheep/, viewed 31 May 2018.
[20] McKay (1976) p. 29. CSIROpedia https://csiropedia.csiro.au/contagious-bovine-pleuropneumonia-eradication/, viewed 31 May 2018.
[21] McKay (1976) p. 34. CSIROpedia https://csiropedia.csiro.au/Cattle-for-the-tropics/, viewed 31 May 2018.
[22] McKay (1976) p. 8. CSIROpedia https://csiropedia.csiro.au/Dung-beetle-program/, viewed 31 May 2018.
[23] McKay (1976) p. 15.
[24] Discussion Paper, Executive Minutes of the CSIRO, May 1951, National Archives of Australia: A8819.
[25] CSIRO Patent Policy, Executive Minutes of the CSIRO, November 1955, National Archives of Australia: A8819.

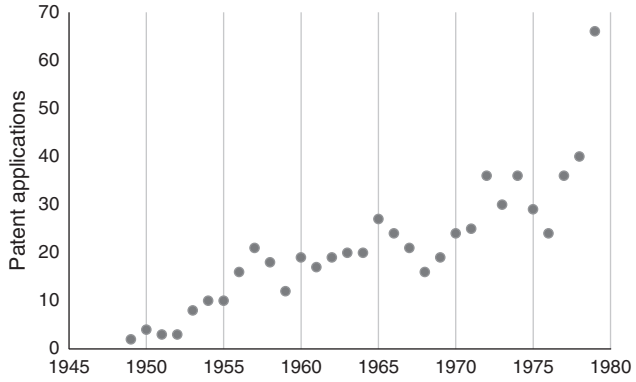

Figure 4. CSIRO patent applications 1949–79, by year of filing date. Source: IP Australia http://pericles.ipaustralia.gov.au/ols/auspat/.

technology. CSIRO would have the responsibility for negotiating the exploitation of patents and would issue exclusive or non-exclusive licences as appropriate.

The number of patent applications grew appreciably from the mid-1950s (Fig. 4). The Wool Textile Laboratory stands out for its industry orientation and the successful transfer (through patenting and international licensing) of CSIRO shrink-proofing technologies for fibres and woven fabrics and SIROSET pleating technology of woollen garments. It was, however, AAS, an invention from the Division of Industrial Chemistry, that had most impact on manufacturing sector and over time led to a thriving local instrument industry.

Curiously, the success of the AAS is mainly attributable not to the patenting approach but to the continuing involvement in its development by its inventor, Alan Walsh. The technology was first licensed to a British firm; this arrangement was subsequently revoked in favour of a non-exclusive licence that was taken up by the instrument maker Perkin Elmer and by companies in Australia and around the world. Walsh continued to be involved and worked with Australian companies including the local licensee, Techtron, to refine and build the instrument locally. Other local manufacturers followed and secured and achieved substantial export earnings in the years that followed. By 1970 there were fifteen licensed manufacturers worldwide and thousands of AAS units had been produced. The AAS technology also contributed to the expansion of the Australian mineral industry during this period by enabling rapid analysis of mineral exploration samples.

In retrospect, it appears clear that the real lessons from AAS for technology transfer were not taken on by CSIRO leadership. The successful outcome for Australian industry was not the result of excellent research alone, but one that relied heavily on the close and continuing relationships that Walsh maintained with several Australia companies. Rather than being a spur for CSIRO to move to a more 'hands-on' involvement in technology though, the AAS story came to be seen as reinforcing the view that, over the long-term, it was investment in excellent research and 'long-shot' projects would pay off for industry and government.[26] The responsibility for technology transfer rested with divisions, with the support of a small corporate legal and administrative group.

The 1970s

The setting

The decade of the 1970s was a period of new pressures and new challenges for CSIRO. Three key factors can be identified—a changing economic climate, changing views on the role of public research, and a changing national scientific scene.

The first was the extended period of economic growth in the post war period that had begun to fade by the late 1960s. With the beginning of the 1970s came a long era of international stagflation (high inflation and high unemployment) that was to run through to 1991:[27] during the 1970s annual real GDP growth averaged 3.4% and inflation 10.7%.[28] The situation for CSIRO was aggravated by the collapse in wool exports (Fig. 3) and the declining relative importance of agriculture in Australia's trade. CSIRO experienced budget pressures from tighter government funding accompanied by a decline in wool-levy funding. As a consequence there would be greater scrutiny of its activities and pressures for greater accountability.

The second factor was the change in the international economy that was accompanied by a shift in thinking about spending on R&D in the private and the public sector. By the late 1960s the belief that untrammelled scientific research was the key to corporate and national growth was under question.

In very simple terms, what happened was that the obvious effectiveness of R&D during the second world war, the economic growth during the 1950s and 1960s and the arguments of economists demonstrating the importance of the residual factor in growth had prompted governments to invest increasing sums in R&D without over worrying about the process whereby this investment was translated into economic growth.[29]

This meant that public research agencies faced pressures to become more accountable to governments in their spending, as well as calls to build closer relationships with industry. In the USA the 1970 Mansfield Amendment required defence R&D spending to be linked to specific outcomes. In the UK the 1971 Rothschild Report set out a new customer-contractor model for public R&D. Moving from a 'supply push' to a 'demand pull' perspective on government research, the model was essentially 'the customer says what he wants, the contractor does it, the customer pays'.[30]

The third factor was structural changes that affected the demand for CSIRO services. The heavy investment the organisation had made in wool research seemed less justified as exports fell. As Schedvin observed, 'After a quarter century of riding the sheep's back, changing CSIRO priorities and culture would be difficult'.[31]

[26] Grant (1977).
[27] Keating (2014).
[28] Stevens (2008).
[29] OECD (1989).
[30] Rothschild (1971).
[31] Schedvin (1989).

Another structural change was the rapid growth in minerals exports (Fig. 3). The minerals industry was well suited for research that delivered benefit to industries rather than individual firms, and operated effective research associations such as the Australian Minerals Industry Research Association (AMIRA).

In addition, CSIRO was adjusting to a lesser role on the national scientific stage: the universities, that had hitherto played a minor role in national research, had grown considerably. Also under new departmental arrangements, CSIRO was no longer the primary source of scientific advice to government.

Technology transfer in the 1970s

A consequence of these pressures was change in CSIRO. Chairman James Price drove administrative reforms that delivered greater corporate involvement in divisional activities and in setting priorities and allocating resources, with attention to relevance as well as quality as criteria in research activities.[32] In addition there was a strengthening of CSIRO's research into the environment and into minerals and energy. The need for a change in the organisation's culture was noted by Price in 1976:

> a criticism of CSIRO which I think has some validity is that during the period of expansion (the 1950s and 1960s) the Executive was unduly inward looking, perhaps understandably under the circumstance. The changes which have taken place in the 1970s have forced on us the acceptance of the need for more effective relations with various bodies and community groups – in particular with industry, with departments of State, with universities and with other bodies either involved in research or having research requirements.[33]

But change would not be an easy or painless matter. Australia's primary industries remained important but CSIRO needed to expand into other sectors of the economy and deliver valuable outcomes. The manufacturing sector had continuing underlying problems, despite its advocacy for greater CSIRO assistance. Australia had played little part in the General Agreement on Tariffs and Trade (GATT) negotiations of the 1960s that were aimed at reducing tariffs and freeing up international trade. The bulk of the manufacturing sector remained domestically focused and exhibited a low appetite for technological innovation. Indeed private sector funding for R&D shrank during the 1970s. As a proportion of GDP it fell from 0.47% in 1968/69 to just 0.21% in 1978/79. The distance still to be to be travelled was evident in the 1972 report of the CSIRO Secondary Industry Committee, that included senior industry representatives.[34] Its inquiry into the manufacturing sector found the main problem to be shortcomings in communication, and not as might now be seen, a culture that did not require, nor encourage, interaction with research users and a shared focus on commercial outcomes. While a few entrepreneurial Australian companies were able to work with CSIRO during the 1970s, any substantial change awaited the microeconomic reforms and trade liberalisation that began in the early 1980s.

Turning to technology transfer during the 1970s, three principal modes can be identified: continuation of the traditional non-commercial approach, strengthening of patent and licensing activity, and a new form of transfer, commercial collaboration. Each of these is addressed below and linked to prominent, successful examples.

(i)Non-commercial transfer to primary industries

Two notable examples of successful transfer via dissemination of research and rural extension services during the 1970s were:

- Skeleton weed control. The biological control for skeleton weed, a plant responsible for heavy damage to Australia's wheat production, was the target of extended ecology studies and development of a beneficial biological control program that reduced its impact.[35]
- Cotton breeding. Research leading to higher yield cotton varieties suitable for Australian environments was underway in the 1970s and would lead over time to an expanded productive industry in NSW and Queensland with major reductions in pesticide use.[36]

Another non-commercial approach that involved dissemination of research to numerous members of an industry rather than a single company concerned nickel exploration. Regional geochemical studies helped build an understanding of how ore bodies were localised and improve the success rate of mining companies exploring for nickel in Western Australia.[37]

(ii)Patenting and licensing

The patent and licensing route to technology transfer grew in importance in CSIRO during the 1970s with the number each year rising to about thirty, compared with about twenty a year in the 1960s (Fig. 4). This activity was supported by a specialist support group in CSIRO Headquarters.

Royalties from licensing peaked at less than $0.5 million per year in the late 1970s (Fig. 5). The licensing strategy was not aimed at earning income but at promoting long-term investment and marketing by the commercial licensee, as well as defensive patents (to prevent the exploitation of Australian intellectual property by overseas firms). The income that did occur was characteristically skewed in favour of just a few licences, as exemplified in the royalties for 1958 (Fig. 5), attributable to atomic absorption spectrophotometry. Inspection of CSIRO patents for the 1950s, 1960s and 1970s on the IP Australia database shows them to be overwhelmingly directed at novel manufactured products and services.[38] An estimated 40% of these were destined for use in rural and rural-based industries, 10% for use in the minerals and metal processing industries and 50% for use in other manufacturing industries.

[32] Collins and others (2004).
[33] Price (1976).
[34] Secondary Industry Committee, in-house report to Executive Committee, CSIRO 1972.
[35] CSIROpedia https://csiropedia.csiro.au/Skeleton-weed-biocontrol/, viewed 31 May 2018.
[36] CSIROpedia https://csiropedia.csiro.au/Cotton-breeding-and-new-cotton-varieties/, viewed 31 May 2018.
[37] CSIROpedia https://csiropedia.csiro.au/nickel-deposits/, viewed 31 May 2018.
[38] CSIROpedia https://csiropedia.csiro.au/nickel-deposits/, viewed 31 May 2018.

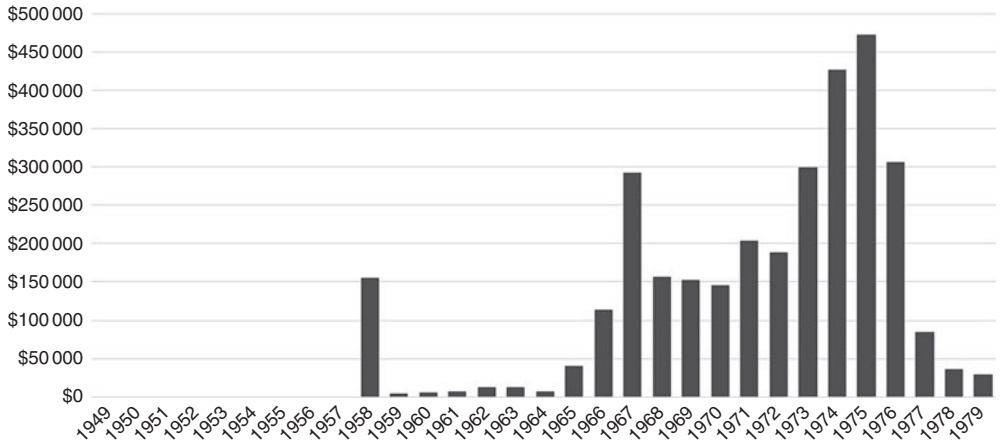

Figure 5. CSIRO licensing fees and royalties from the sale of products or technologies during the period 1949–79 (current dollars). Source: CSIRO Annual Reports.

The increased interaction between CSIRO and Australian manufacturing companies is evident in the patent data. Co-application had been extremely rare before 1970, but during the 1970s some 38 CSIRO patents had co-applicants, showing the relationships CSIRO had established, among others, with several minerals companies, the Reserve Bank of Australia (the banknote project) and ICI Australia, the local subsidiary of a large British chemicals company (ICI Australia was listed 27 times as co-patentee).

Some prominent examples of CSIRO technology that were successful in the 1970s were:

- Sirospun. A technology that reduced the cost of spinning by combining spinning and doubling in the one process and produced yarns with a smoother handle suitable for light-weight, 'Cool Wool' fabrics. The technology was patented in the 1970s and adopted by textile mills across the globe.[39]
- Sirosmelt. A novel high-intensity smelting process for the commercial production of non-ferrous metals and waste-treatment. The technology was licensed to Ausmelt and Mount Isa Mines and adopted in smelters around the world.[40]
- Cycloprothrin. A low toxicity insecticide and suitable for use in flooded rice paddies and active against major rice pests that was licensed to, and marketed by, the Japanese company Nippon Kayaku.[41]
- SIRO2 Oxygen Sensor. A rugged oxygen sensor capable of *in-situ* use in a range of extreme environments. This was licensed to two Australian companies, Ceramic Oxide Fabricators and Novatech with exports to more than 70 countries.[42]
- SIROFLOC. A water treatment developed by CSIRO that removes colour and turbidity from the use of recyclable magnetic powders (magnetite), subsequently commercialised with Davy McKee Pacific Pty Ltd and the Water Corporation of Western Australia.[43]
- Optical fibre nephelometer. A novel portable instrument to measure turbidity of liquids licensed to and commercialised by H. B. Selby Australia Ltd.[44]

(iii)Commercial collaboration

A new approach to technology transfer, commercial collaboration, emerged in CSIRO in the late 1960s. This involved a 'hands-on' continuing relationship between researchers and industry counterparts in the development and exploitation of the technologies. An early example was the commercial development of self-twist yarn technology.[45] This invention by David Henshaw of CSIRO's Wool Textile Laboratory enabled a radical increase in the rate of spinning woollen yarn. It was a technology with huge commercial potential but going from prototype to full scale operations was a task beyond the resources and capacities of CSIRO alone. Instead the Wool Textile Laboratory entered into a collaborative arrangement with an Australian company, Repco, to streamline the process and design and manufacture the spinning equipment. The technology was licensed to Repco and released in 1970 to be successfully taken up by mills around the world. Another example from this industry is the development of standardised objective measurement of the fibre diameters of wool in greasy bales that involved a collaborative arrangement bringing together the Division of Textile Physics, the Australian Wool Testing Authority and the Australian Wool Corporation.[46] This met a critical need for quality assurance in wool marketing

[39] CSIROpedia https://csiropedia.csiro.au/Sirospun/, viewed 31 May 2018.
[40] CSIROpedia https://csiropedia.csiro.au/SiroSmelt/, viewed 31 May 2018.
[41] CSIROpedia https://csiropedia.csiro.au/Cycloprothrin—the-first-designer-insecticide/, viewed 31 May 2018.
[42] CSIROpedia 2018 https://csiropedia.csiro.au/Oxygen-sensor-SIRO2/, viewed 31 May 2018.
[43] CSIROpedia 2018 https://csiropedia.csiro.au/SIROFLOC/, viewed 31 May 2018.
[44] CSIROpedia https://csiropedia.csiro.au/Optical-fibre-nephelometer/, viewed 31 May 2018.
[45] McKay (1976) pp. 13–14; CSIROpedia https://csiropedia.csiro.au/Self-twist-yarn/, viewed 31 May 2018.
[46] CSIROpedia https://csiropedia.csiro.au/objective-measurement-of-wool/, viewed 31 May 2018.

and comprised techniques to extract and test representative wool samples. It was launched in 1972.

CSIRO's mineral research had grown rapidly since 1960s and had a strong tradition of collaboration with Australian companies under the umbrella of AMIRA, the industry research association: this included shared definition of research problems and joint research projects. Collaborative examples included anode development for alumina processing and collaboration with the iron ore industry in areas such as pelletising, flotation, beneficiation and direct reduction.[47]

Further examples can be drawn from the manufacturing sector. The Interscan aircraft landing system was devised in the early 1970s by the Division of Radiophysics together with the Australian Department of Transport and industry partners, AWA and HDH.[48] This time-reference scanning beam technique had its origins in Australia's wartime radar research and was adopted as the world standard by the International Civil Aviation Organisation in 1978 and launched commercially.

A final prominent illustration of this approach is CSIRO's banknote technology. This was the outcome of a long-term collaborative project between CSIRO and the Reserve Bank of Australia that began in the late 1960s and culminated in the release of the world's first polymer banknotes in Australia 1988. The technology has been taken up in Australia and by several other countries.[49]

Government and the role of CSIRO

The changing social and economic environment dating from the late 1960s was the background to increased scrutiny of government agencies. CSIRO was part of a Review of Australian Science and Technology by the OECD in 1974,[50] and the1974–6 Royal Commission on Australian Government Administration. Its role was put under direct challenge in mid-1975 by a precipitate move by the Minister for Minerals and Energy, Rex Connor to transfer mineral research out of CSIRO and into the federal department. This was successfully opposed by CSIRO with support from the public, the opposition and government backbenchers.

In 1975 the Federal Government commissioned an Independent Inquiry into CSIRO, chaired by Professor Arthur Birch. The Committee Report reviewed the span of the Organisation's operations.[51] It recommended CSIRO remain a single organisation and that it continue its existing role in performing longer-term research to support Australian industry. It saw the principal role of CSIRO as strategic *mission-oriented* research and indicatively, proposed a research mix of 10% fundamental, 60% strategic-mission, and 30% tactical-problem oriented research). The Report called for CSIRO to expand its role in disseminating research information and stated that 'emphasis should be given to securing implementation of research results through close association with users, and development based on research results by users should be actively promoted'.[52]

The principal recommendations of the Birch review were accepted by government and led to changes in CSIRO. The organisation's long-standing flat divisional structure was replaced in 1977 by a two-level structure with divisions grouped together by industry sector into a new set of institutes. Impetus was also given to the rebalancing of CSIRO's research effort: by 1979 the percentage of total research expenditure dedicated to rural industries was 34.3%; to minerals, energy and water resources 15.2%; to manufacturing 26.6%; and to community interests (natural environment, health, tertiary industries) 23.9%.[53]

Following the Birch Report the Federal Government amended CSIRO's legislation.[54] The amended Science and Industry Research Act nominated as CSIRO's first-listed functions:

Para 9(a): to carry out research for any of the following purposes

- assisting Australian industry;
- furthering the interests of the Australian community;
- contributing to the achievement of Australian national objectives or the performance of the national and international responsibilities of the Commonwealth;
- any other purpose determined by the Minister.

Para 9(b): to encourage or facilitate the application or utilisation of the results of such research.

This extended the scope of CSIRO's activities, and reinterpreted its central role as one of assisting, rather than promoting Australian industry, and explicitly included technology transfer as a mandated function. What was less clear was the relative weights to be given to 9(a) and 9(b). It was not until a subsequent amendment of the Act in 1986 that it was specified that both 9(a) and 9(b) were primary functions and all other functions were secondary. The shift to a more outward-looking CSIRO that sought closer relationships with research users and customers, would take time.

Discussion

This paper examines the way CSIRO transferred its technology in the post-war decades and analyses the factors that shaped its evolving approach. The focus has been on the process rather than the outcomes of technology transfer although the case examples point to significant economic returns.

Technology transfer was not a major concern for CSIRO in much of the period addressed in this paper. Instead, the approach adopted by CSIRO, similar to that of comparable public research

[47] Bear, Biegler and Scott (2001).
[48] CSIROpedia https://csiropedia.csiro.au/Interscan-aircraft-landing-system/, viewed 31 May 2018.
[49] Solomon and Spurling (2014).
[50] OECD (1974).
[51] Birch (1977).
[52] Birch (1977), p. 26.
[53] *CSIRO Annual Report, 1979–1980*, p. 18.
[54] Commonwealth of Australia (1978).

organisations overseas, was to focus on the quality of its scientific research and not on the processes of transfer to industry. To a large extent this 'hands-off' approach worked quite well in promoting Australia's primary industries, notably wool, inasmuch as it drew on solid base of expertise provided by state-based extension services. It was an approach endorsed by the federal government during these years and rewarded with steadily increasing funding.

This 'hands-off' approach was less successful for Australia's secondary industries. Local companies showed little interest partnering with CSIRO on breakthrough research, at a time when Australian manufacturing was protected by high tariff walls. Even short-term and contractual research was restricted to just a few divisions of the organisation. Apart from a few notable exceptions such as the wool textile laboratories and the case of atomic absorption spectrophotometry CSIRO had little impact on Australia's secondary industries.

By the late 1960s the environment had changed. It was a period of slower economic growth, collapsing wool exports, and a rethinking worldwide of the roles of public research institutions. This led to changes in CSIRO's relationships with secondary industries reflected in its patenting and licensing activities and increased commercial collaboration. There were with notable successes in self-twist yarn spinning, plastic banknotes, and in minerals exploration and processing. Even so, change was gradual, and restricted by an inward-looking manufacturing sector.

An important marker was the 1977 Birch Report that emphasised the importance of strategic, applications-oriented research and relationships with industry. This led to the Government amending CSIRO's legislation in 1978 and specifying the importance of technology transfer. It provided the framework for CSIRO to further adapt in response to the wide-ranging microeconomic reforms in Australian during the 1980s.

In summary the approach to technology transfer adopted by CSIRO in the 1950s and 1960s was quite successful for primary industries, but less so for secondary industries. The unresolved challenge the Organisation faced in the late 1970s was how to strengthen its links with companies. CSIRO was coming under pressure to engage directly with the users of its research.

Conflict of interest

The author declares no conflicts of interest. This research did not receive any specific funding.

Note on references

CSIROpedia contains information about scientific and technical achievements by CSIRO scientists. It was devised by CSIRO office Dr Colin Ward in 2007, developed and maintained by him until his death in 2017, and is now maintained by the organization as a resource. The information it contains has been drawn from many sources. References to CSIROpedia have been incorporated in footnotes and not in the list of references.

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