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Historical Records of Australian Science

Realignment and change: CSIRO and industry 2000–10

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ABSTRACT

In the first decade of the twenty-first century, CSIRO's role broadened toward national mission-oriented research, less directly focused on supporting Australian industry. In terms of its legislated mandate, it deliberately placed increased emphasis on 'contributing to the achievement of national objectives' and less emphasis on 'assisting Australian industry'. This change was accompanied by an organisational restructuring with the introduction of a national flagships' research program and a matrix management structure. We analyse this process of change and the reasons behind it and we investigate the effects of the new approach on CSIRO's relationship with industry, and its technology transfer activities. While there was continuity in its commercial performance, the pattern of CSIRO's client-directed research changed substantially, with a reduction in manufacturing-related research, and a notable growth in health- and environment-related research, in the main part for government agencies and departments. By the end of the decade the organisation had established a clear role for itself in the national innovation system, in which its relationship with Australian industry was no longer the dominant feature. It was a disruptive decade for CSIRO, but one in which the organisation demonstrated its capacity to adapt to a changing external environment.

Keywords: history of Australian science, matrix management, national innovation system, national research priorities, public research policy, technology transfer.

Introduction

In this paper we look at the relationship between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and industry in the first decade of the twenty-first century and address the questions of how it changed and why. This complements and extends the coverage of three earlier papers that address the periods 1926–49 (for CSIR), and 1949–80 and 1980–2000 (for CSIRO).[1]

For the period 1926–78 CSIR/CSIRO took as its primary function[2] 'the initiation and carrying out of scientific researches in connection with, or for the promotion of, primary or secondary industries in the Commonwealth', which was the first listed function set out in its legislation.[3] In 1978, CSIRO's first listed function was broadened:

(a) to carry out scientific 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;

[1]Upstill and others (2021). Upstill (2019). Upstill and Spurling (2020).
[2]The powers and functions of the organisation remained unchanged from 1926 to 1978. Other functions related to research training, making of grants for research, recognition of industry bodies for cooperation and grants, testing and standardisation, and the collection and publication of scientific information and reports.
[3]Commonwealth of Australia (1920). Commonwealth of Australia (1926). Commonwealth of Australia (1949).

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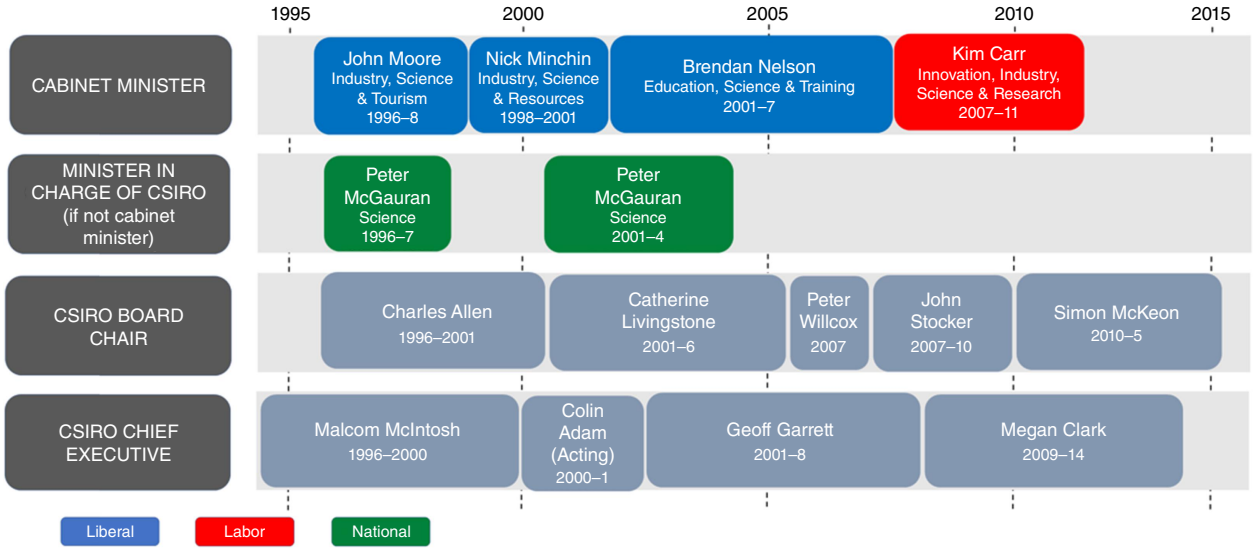


Fig. 1. CSIRO ministers, chairmen and CEOs 1996–2010.

- any other purpose determined by the Minister and a specific technology transfer function was added;

(b) to encourage or facilitate the application or utilisation of the results of such research.[4]

In 1986, these two functions were designated 'primary functions'. The three earlier papers analyse the way that CSIR/CSIRO carried out its legislative mandate to assist Australian industry and how it adapted to shifts in the economic environment and to changing views on the contribution of public research to national development. Initially, the focus of CSIR/CSIRO was on the agriculture and manufacturing sectors, but this broadened later in the century to include other industry sectors. The earlier papers tracked the way CSIR/CSIRO adapted as the Australian economy matured and new challenges arose. For much of the twentieth century the organisation was the dominant provider of public scientific research for industry, although this diminished somewhat from the 1980s. It played an important role in providing scientific and technological solutions to Australian industry. Examples include bolstering the nation's agricultural export industries in the pre-war era, promoting industry self-sufficiency during World War 2, sustaining the wool industry post-war, and lifting the technology performance of Australian industry following the major economic reforms of the early 1980s. We adopt a similar approach in this paper. The next two sections look at the way CSIRO changed in the first decade of the new century and then the economic environment that drove this change. The ensuing sections analyse the reorganisation and restructuring of CSIRO during this period and how this affected CSIRO's interactions with industry. Finally, we analyse the organisation's technology transfer during the decade and then offer some concluding remarks.

Fig. 1 shows federal ministers responsible for CSIRO over this period, together with CSIRO board chairmen and chief executives. As we report below, this period was a time of change for CSIRO. It was also a period of considerable change in political and corporate leadership.

Realignment

Soon after 2000, CSIRO began to redefine its national role, and consequently its relationship with Australian industry. This came after the decades of the 1980s and 1990s in which CSIRO adopted a strong industry focus across most of its research portfolio. This followed several organisational reviews, notably the Birch report,[5] and revision of the legislation for CSIRO that broadened the scope of its activities and made technology transfer one of its prime functions.[6] This shift in approach was a response to the policy changes of the incoming Labor government in 1983, a major economic reform program that included floating the dollar, slashing tariffs, reforming the financial industry, and deregulating industry. The government looked to public-sector providers to help lift the technology performance and competitiveness of Australia's industries, notably manufacturing. Speaking to CSIRO in 1985 the Industry Minister, John Button, said:

> Our contemporary and future needs lie not so much in demonstrating our excellence in research, but in adopting

[4]Commonwealth of Australia (1978). Commonwealth of Australia (1986).
[5]Birch (1977).
[6]Commonwealth of Australia (1978).

> a national effort and cooperative approach between scientists and Australian industry. CSIRO has a huge contribution to make in this area … (CSIRO) has a great responsibility to work creatively in an area critical to the revitalisation of Australia's industrial performance, an area in which we have lagged behind many other countries.[7]

CSIRO's response was led by Chief Executive John Stocker and a new CSIRO board.[8] In 1986, the board chairman Neville Wran stated:

> the past year has been one of critical change for CSIRO—new legislation, a new Board, a new organisational structure and, more recently, inclusion in the Industry, Technology and Commerce portfolio. CSIRO has, of course, a long and proud history of contribution to Australia's development, but its role has never been more important than now with the need to restructure and revitalise Australia's manufacturing and service industries and to develop new export industries …. The decision to restructure CSIRO is an historic one. It reflects recognition of the intrinsic role of fundamental research whilst committing CSIRO to an important role in the current restructuring of Australian industry.[9]

Introducing amended legislation for CSIRO,[10] Minister Barry Jones said the government's intention was to strengthen links between CSIRO and the private sector:

> To help CSIRO place more emphasis on the application of its research, the Organisation is being encouraged to take on more short-term problem-solving projects, to be paid for largely by the individual companies concerned. An important objective of this is to gain a better knowledge of industries' needs, and to foster mutual respect and confidence. It is not intended that CSIRO substitute for industry performing its own research and development, but rather that it backup and stimulate industry to do more for itself.[11]

In addition, in 1988 the federal government introduced a 30% external earnings target for CSIRO. CSIRO became increasingly engaged with companies in the private sector, as demonstrated by a surge in industry-related activity and increased commercial technology transfer to local industry.[12] CSIRO also made major organisational changes to build closer linkages with industry. This was evident in its priority setting processes. In 1996, the organisation's triennial priority setting framework was centred on twenty-two industry-based sectors, drawn from across the national economy. The sector advisory committees all included strong industry representation and signed off on the sectoral plans which were consolidated in the organisation's triennial plan.

Calls for a for a strong industry support role remained strong into the late 1990s. For example, the 1997 Mortimer report called for CSIRO and other public research organisations to grow external funding through increased industry funding and for CSIRO to double its existing support for spin-off companies. Perhaps surprisingly though, CSIRO took a new course soon after the turn of the century.[13]

Setting the scene for change

In 2001, CSIRO began to redefine its national role. Catherine Livingstone, CSIRO chair at that time, described it as a response to a single event, specifically the release in January 2001 by the federal government of the report *Backing Australia's Ability*,[14] prepared after a national innovation summit held in Melbourne in 2000. Livingstone noted the report:[15]

- announced programs to strengthen Australia's ability to generate ideas and undertake research, accelerate commercial application of these ideas, and develop and retain Australian skills.

She went on to observe:

- incredibly—and shockingly—despite a pool of $2.9 billion funding over five years, nowhere in the package was there a funding line item for CSIRO. To its credit CSIRO saw this as a burning platform event.
- At the core of the problem was a lack of clarity as to what CSIRO was trying to achieve, and hence its inability to articulate its role in the national innovation system. There was a clear imperative, therefore, to go back to the basics and develop a strategic view and framework that would resonate both internally and externally.

She described this as the spur for organisational change in CSIRO and a re-envisioning of its national role: one that

[7] Button (1985).
[8] The Board was created in 1986, see Commonwealth of Australia (1986).
[9] Wran (1987).
[10] Commonwealth of Australia (1986).
[11] Jones (1986).
[12] Upstill and Spurling (2020).
[13] Mortimer (1997).
[14] Commonwealth of Australia (2001).
[15] Livingstone (2012).

gave greater attention to national objectives in research and to its unique role within the national innovation system. In fact this meant reinterpreting CSIRO's relationship with Australian industry, and putting it in a broader national context. Or, in terms of the prime functions, specified in its legislation (see above), it meant increased emphasis on:

- furthering the interests of the Australian community, and
- contributing to the achievement of Australian national objectives or the performance of the national and international responsibilities of the Commonwealth,

and, by default, less emphasis on:

- assisting Australian industry.

The changes in CSIRO's directions and structure that followed were substantial, and for many they were unexpected. They did not follow an external review of CSIRO, such as had been the case for changes in the past, nor were they driven by ministerial intervention or government policy announcements. In the next section we look at the factors behind this change. What seemed to many as an abrupt change, may be seen in hindsight as an unavoidable response to a changing environment, and adaptive reform.

A changed environment

The repositioning of CSIRO was a response to three major changes in its environment: a shift in the national economic outlook, a change in CSIRO's national role and a reframing of the role of public research within a broader innovation system.

Improved national economic outlook

The competitiveness of Australian industry and the national economy had improved by the late 1990s. The balance of payments pressures of the early 1980s had eased, in large part in response to the government's economic reforms. Manufacturing exports had doubled as a proportion of national exports between 1980 and 2000,[16] and the share of services exports (including tourism and education) had also grown (Fig. 2).[17] Australia's annual multifactor productivity rate rose rapidly during the decade,[18] and GDP growth (per capita) reached an historically high level of 3.2% per annum in the second half of the 1990s.[19] Australia was at the beginning of a long uninterrupted period of national

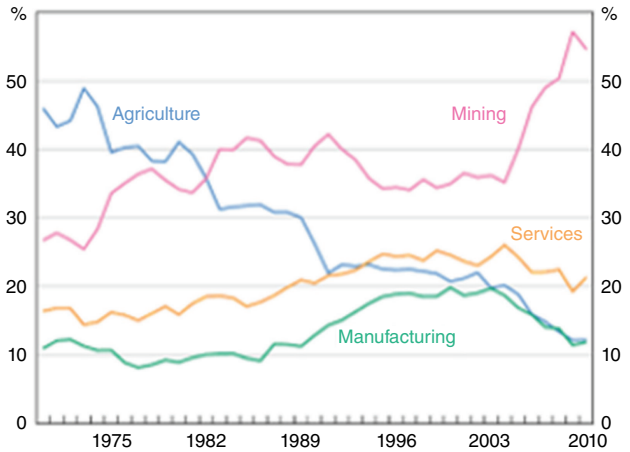


Fig. 2. Sectoral share of Australian exports (financial years).

GDP growth, which was underpinned by strong commodity exports, particularly minerals.

Changing national scientific landscape

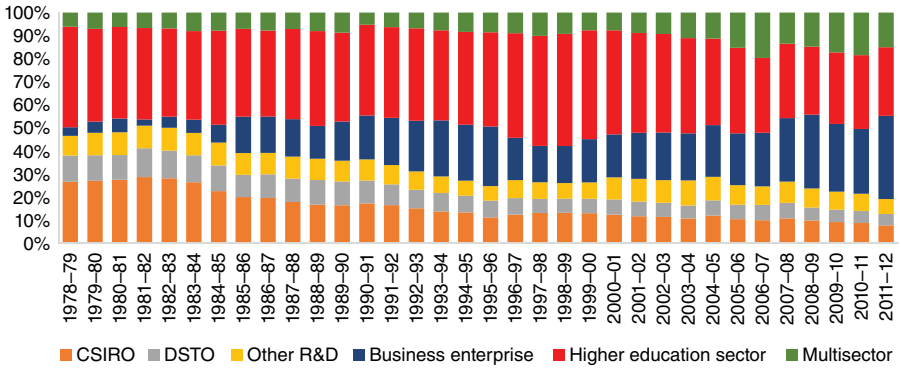
The national scientific landscape had also changed. The dominant role that CSIRO had traditionally played in national research and development (R&D) had shrunk progressively with the growth of private sector R&D and other government funded research, particularly in the higher education and medical sectors. Inevitably this required CSIRO to rethink its position in the national innovation system.

Fig. 3[20] shows the allocation of government funding for research and development (GOVERD) over the period 1978–2020. CSIRO's proportion of the total fell steadily from the early 1980s—from 29% in 1981–2 to just 7% in 2011–2 and the share of funding for the business sector (industry R&D tax measures) rose considerably.

Changing views on public research

Following the work of Freeman, Nelson and Lundvall in the 1990s,[21] there was a worldwide move to see public research in the context of 'national systems of innovation'(NIS).[22] National innovation was seen as an expression of a systemic process where a wide range of actors including firms, research organisations, universities and users shaped the innovation outcomes. It focused on learning and interactions among players in the national system and paid more attention to incremental innovation and diffusion instead of just R&D. This called for public research organisations like CSIRO

[16]Manufacturing exports declined after 2000, as in other industrialised countries, with surging manufacturing exports from China.
[17]Connolly and Lewis (2010).
[18]Productivity Commission (2009) p. xii.
[19]Department of Treasury (2001).
[20]Department of Industry, Science, Energy and Resources (2021).
[21]Freeman (1987). Lundvall (1992). Nelson (1993).
[22]OECD (1995).



Footnote: Total health research accounted for 10% of GOVERD in 2010–1

Fig. 3. Australian government investment in R&D (GOVERD) by sub sector 1978–9 to 2010–1. Footnote: Total health research accounted for 10% of GOVERD in 2010–1.

to pursue their agendas within an integrated national perspective. Public research institutions were under pressure to become more collaborative, and nimbler in their research. Developments in information technology enabled easier collaboration and networking with other institutions and with the private sector. Equally companies were better able to work with both local and overseas research providers.

> Industry is shifting from the central R&D laboratory to the global R&D network. In the past, corporations could internalise research and technology development, but as the sources of technology have become more decentralised and distributed, the challenge has become how to manage external sources of technology. To cope with these changes, corporations are developing new collaborative relationships, alliances and partnerships; relying more upon their suppliers, customers and users as sources of technology; establishing overseas R&D laboratories; and increasing their partnerships with universities and government laboratories.[23]

The repositioning of CSIRO after 2000 was in response to these factors—a means of accommodating and adapting to a changed environment. The challenge was to do it in a way that drew on the strengths of the organisation: the breadth of its socio-economic sphere of operation, its scientific depth and performance and its strong commercial and international relationships.

Reorganisation

The organisational restructuring in CSIRO—introduction of national flagship research programs and a matrix management and accounting system—reshaped its operations including its relationship with industry.

National flagships

The flagships were large mission-driven research programs, each addressing an important national challenge and were central to 'a more clearly defined role for CSIRO in the national innovation system',[24] and a more focused organisational strategy.[25]

The flagship program was introduced by CSIRO Chief Executive, Geoff Garrett, and led by Deputy Chief Executive, Ron Sandland. An early initiative of Garrett had been to set up large multidivisional projects with ambitious goals, as a way of overcoming what he saw as 'research silos' in CSIRO. In 2003, this approach morphed into the flagships program.[26] Flagships were defined by CSIRO to be:

> multidisciplinary research partnerships that align Divisions across CSIRO and external agencies to tackle big, audacious goals in areas of major national significance. Their larger scale, longer timeframes and clear focus on adoption of research outputs are designed to maximise their impact on their goals.[27]

The first six flagships—Light Metals, Preventative Health, Energy Transformed, Food Futures, Water for a Healthy Country, and Wealth from Oceans—were launched in 2003 and 2004 and the number grew to ten by 2010 (Table 1).[28] The flagships were the vehicles for CSIRO's interaction with key government policy areas and they were framed in terms of national objectives rather than industry outcomes (Box 1). They typically involved partnerships with other research providers and users of research

[23]Branscombe and Florida (1998).
[24]Garrett and Livingstone (2004) p. 4.
[25]CSIRO depicted its role in the NIS via a 'role house model' which showed how its core scientific research, fitted alongside its satellite roles such as research services, national facilities and national collections and support services (CSIRO 2006, p. 7).
[26]See Sandland and Thompson (2012). Shih and others (2012).
[27]Sandland and Thompson (2012) p. 48.
[28]Australian National Audit Office (2011) p. 14.

Table 1. CSIRO flagships.

Flagship	Goal	Launch date
Light Metals	To lead a global revolution in light metals, doubling export income and generating significant new industries for Australia by the 2020s, while reducing environmental impact.	June 2003
Preventative Health	To improve the health and wellbeing of Australians and seeking to save $2 billion in annual direct health costs by 2020 through the prevention and early detection of disease.	September 2003
Energy Transformed	To halve greenhouse gas emissions and double the efficiency of the nation's new energy generation, supply and end use.	October 2003
Food Futures	To transform the international competitiveness of the Australian agrifood sector, adding $3 billion annually, by applying frontier technologies to high-potential industries.	March 2004
Water for a Healthy Country	Aims to provide Australia with solutions for water resources management, creating economic gains of $3 billion a year by 2030, while protecting or restoring the country's major water ecosystems.	May 2004
Wealth from Oceans	To position Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.	August 2004
Minerals Down Under	To assist the Australian minerals industry to exploit new resources with a value (measured, indicated and inferred) of $1 trillion by the year 2030 and to more than double the size of the associated services and technology sector to $10 billion a year by 2015.	May 2008
Climate Adaptation	To equip Australia with practical and effective adaptation options to climate change and variability and in doing so create $3 billion per annum in net benefits by 2030.	July 2008
Future Manufacturing	To provide transformational innovation for the Australian manufacturing industry, enabling outcomes that will ensure global competitiveness, enhance the manufacturing value chain and deliver high-value export-oriented environmentally sustainable products and services.	September 2009
Sustainable Agriculture	To secure Australian agriculture and forest industries by increasing productivity by 50 per cent and reducing net carbon emissions by at least 50 per cent by 2030.	February 2010

Box. 1. **Economic rationale**

The underlying rationale for the flagships can be explained in terms of the two main justifications for public support of science and innovation set out in 2007 by the Productivity Commission:

> The first is that publicly funded R&D is a significant contributor to innovation in the functions performed by government. Governments need to invest in research to improve the products and services they offer or to better discharge their functions, just as does the private sector. … The second significant rationale is the existence of 'spillovers' from innovation. ... Spillovers may arise through the development of basic knowledge capabilities or diffusion of new ideas among firms and others. Such spillovers arise from research undertaken in universities, businesses and public sector research agencies (Productivity Commission 2007, p. xviii).

Note that of the first six flagships (Table 1) three (Preventative hHalth, Water for a Healthy Country and Wealth from Oceans) were clearly aimed at helping the government to carry out its national responsibilities more effectively, one (Energy Transformed) was aimed at benefiting industry as well as assisting the government and the other two (Light Metals and Food Futures) were aimed at private benefit.

The Productivity Commission report also listed reasons 'of weak validity' for intervention (p. 53) including the 'aspiration' to achieve a transformation of Australia's industry away from its present structure. In many instances, they would entail completely different support arrangements than those currently observed. The Light Metals flagship (Shih and others 2012) is probably an example of a research organisation trying to transform an industry.

Of the four flagships added in 2008–10, three (Minerals Down Under, Future Manufacturing, and Sustainable Agriculture), were aimed at benefiting industry and one (Climate Adaptation) at national objectives/government responsibilities.

outputs—research institutions, firms, government agencies, and international research collaborators. In 2004, the federal government targeted extra funding to support CSIRO's implementation of flagships. Announcing the funding, Minister McGauran said: 'CSIRO has been placed at the centre of the government's science and innovation strategy.'[29] A matrix management system was introduced combining flagship and divisional leadership. This meant two lines of authority. Flagships were responsible for research outputs and outcomes; divisions were responsible for the development of research capabilities and their own research programs and held functional authority for staff.

[29]McGauran (2004).

Flagships were multidisciplinary and drew on scientists from different divisions across CSIRO. An individual research scientist often contributes to more than one project in more than one flagship, as well as to a divisional project. A time-accounting process to register time spent on different projects was incorporated in a newly introduced integrated finance and human resource management system. Both divisions and flagships were funded directly: the bulk of CSIRO's appropriation funding during in the early years of the decade was channelled to divisions, but the annual share of flagship research rose to about 50% by 2010.

Organisational priorities were established through an organisation-wide annual process, known as the Science Investment Process, which allocated resources across research activities. The process comprised assessment of CSIRO's scientific capabilities and the potential impacts of different areas of research across key socio-economic areas, and involved consultation with stakeholders (industry, higher education institutions and community groups). Research priorities were guided by sectoral advisory committees spanning seven socio-economic areas: agribusiness; energy and transport; environment and natural resource management; health, information, communication and services; manufacturing; and minerals resources. In addition, there were external advisory committees for each of the national research flagships.

The economic rationale for the flagships is discussed in Box 1.[30] CSIRO's strategy at the time had a strong internal focus, directed at organisational reform, rather than external parties. This was difficult to explain to external stakeholders and contributed to some ongoing confusion about CSIRO's role.[31] One of CSIRO's strategic goals was to 'grow its financial foundation' through increased funding under contractual arrangements with industry and government partners, provision of services, and increasing royalty flows—namely, external earnings. The government-imposed 30% external earning target was abolished in 2003 following a review by the Chief Scientist Robin Batterham.[32] The report found that the target had succeeded in developing industry-CSIRO relationships but that it had sub-optimal, unintended consequences.[33] CSIRO, nonetheless, decided to keep external earnings at a high level. Sandland and Thompson noted:

> external revenue remained as probably the strongest driver for chiefs in CSIRO when the flagship initiative kicked off. They saw it as an important tool for balancing their divisional budgets; it also gave them the flexibility to develop new research or business initiatives in its research funding allocation and its staff management.[34]

The earnings were considered by CSIRO to be important for its independence and flexibility and any risks were seen to be more manageable in the new organisational structure.

Matrix management challenges

The introduction of the matrix-based structure was disruptive. On the one hand bringing together skills from across CSIRO (difficult before the new arrangement) led to a number of successful large-scale research projects, one of which was the Murray–Darling basin sustainable yields assessment,[35] a critical input to policy on future security of water resources in Australia's largest river catchment. Sandland and Thompson noted several other successes:[36]

- an international hub for solar-thermal energy production;
- modelling and prediction tools to provide a world-leading approach for predicting ocean climate;
- modelling of Australia's energy futures to enable effective evidence-based policy making;
- using advanced statistical tools to identify biomarkers for the early detection of colorectal cancer;
- engineering a new form of canola oil, rich in omega 3 oils, through gene manipulation techniques;
- developing new production processes for titanium and titanium products;
- building a systems-level understanding of Perth's water supply to make it more robust and sustainable following major long-term reductions in rainfall.

On the other hand, there were challenges that accompanied the introduction of this structure, as noted by Sandland and Thompson:[37]

> the flagships undoubtedly ushered in one of the most tumultuous, even chaotic, periods in CSIRO's 80-year history. The early days of the flagships were testing for both the flagship directors and their divisional partners. CSIRO was moving into new territory and the maps available to help them on their journeys were less than complete.

[30] Productivity Commission (2007).
[31] The goals set out in the CSIRO Plan 2003–7 were: Focus & building critical mass; Growing our financial foundation; Looking out for our science and our people; Partnerships; One CSIRO, and Service delivery from science: CSIRO (2003).
[32] Batterham (2002).
[33] Productivity Commission (2007). These were noted to be: encouraging short-termism at the expense of longer-term planning, focusing effort to areas more likely to provide a financial return, limiting collaborations with SMEs, restricting optimal performance in CRCs and creating difficulties in building the value of intellectual property (p. 470).
[34] Sandland and Thompson (2012) p. 159.
[35] Hatton and Young (2011).
[36] Sandland and Thompson (2012) p. xix.
[37] Sandland and Thompson (2012) p. 69.

Matrix structures are traditionally hard to manage. CSIRO responded to the challenge by introducing standardised planning, management and time accounting and reporting processes for flagship and divisional platforms.

The 2011 review of the national flagships program by the Australian National Audit Office (ANAO) reported recurrent uncertainty within CSIRO surrounding roles and responsibilities in the new structure. It acknowledged the complexity involved in undertaking and administering research in a matrix environment and reported that CSIRO had advised it that: 'The matrix is a difficult organisational form to implement and that there were very few precedents for CSIRO's approach to Flagships, therefore a period of evolution and fine tuning was inevitable.'[38]

Getting accurate costing for research requires time accounting and this poses challenges when scientists may have their time split between multiple projects. For individual scientists there can be lack of clarity over responsibilities in relation to multiple supervisors and projects as well as performance measurement. An unintended consequence for CSIRO was that individual researchers had less opportunity to develop new lines of research outside of the defined projects. The matrix approach could also pose difficulties for data collection and reporting. In its audit, the ANAO noted inconsistent reporting of financial information for Flagships and lack of access to consistent client contract information.[39] The authors of this paper also encountered difficulties in obtaining consistent information on commercial contracts for flagship and non-flagship research during this period. The problems with dual management streams eased, to a degree, over time with increased experience and as the growing proportion of funds going directly to flagships reduced the complexity of arrangements. The matrix management model was abandoned in 2014.

Relationship with Australian industry

Three ways that CSIRO's relationship with Australian industry changed during the decade 2000–10 were: the proportion of research expenditure directed toward industry; the share of external earnings from industry; and the pattern of CSIRO's engagement with industry. Table 2[40] shows the proportions of CSIRO's research expenditure over the period 2000–11 by main socio-economic objective. During this time the share of manufacturing research within CSIRO declined from almost 24 % to 7%, health research increased from nearly 2% to over 7% and environment research from 20 to 25%, while plant- and animal-related research and minerals research remained broadly steady. The table also shows a notable increase in research classified as expanding knowledge, not linked to research users.

One factor contributing to CSIRO's diminished manufacturing research was the divestment of the National Measurement Laboratory in 2003. This led to a consolidation of chemical, physical, biological and legal metrology in a single national measurement institute outside CSIRO and effectively hollowed out a substantial part of the organisation's physics capability. During the decade, the discipline-based or manufacturing-facing divisions were combined with a more general manufacturing focus and this meant a falling proportion of CSIRO research funding to these industries, and in particular to manufacturing (Table 2). Another indicator of change is the source of CSIRO external revenue. Table 3[41] shows the revenue (in current dollars) for CSIRO from 2001–2 to 2010–11 from federal appropriation and from other, external sources. External earnings remained at a high level through the decade, notwithstanding the abolition, in 2003, of the mandatory earnings requirement imposed by government. Over the decade,[42] the proportion of total revenue from external sources averaged 38%. Excluding intellectual property revenue, approximately 80% of this income was from co-investment and 20% from the provision of services and consulting.[43] Table 3 provides evidence for the major change that took place in CSIRO post-2000, namely the shift toward research to support national objectives and areas of government responsibility, and (in relative terms) the shift away from research to assist Australian industry. There was, a large increase in the funding from commonwealth, state and local governments. This is separate from the annual appropriation funding for CSIRO and essentially comprising direct government grants and contract funding to address government policy responsibilities. The amount of funding from these sources almost tripled over the decade. By contrast there was relatively little change in the income from other sources, namely Australian private industry and government programs, notably Rural R&D corporations and Cooperative Research Centres (CRCs).[44] While funding from Australian industry remained relatively steady in current dollar terms, in relative terms it shrank as a proportion of CSIRO's client-directed research.

The relatively unchanged level of funding from Australian industry is a little surprising because the overall level R&D investment by the private sector ballooned over the decade, in response to—among other influences—federal government

[38]Australian National Audit Office (2011) p. 56.
[39]Australian National Audit Office (2011) pp. 20, 22.
[40]Steele, unpubl. data.
[41]CSIRO (2006). CSIRO (2011).
[42]Excluding 2008–9; the exceptional intellectual property (IP) revenue in that year is discussed below.
[43]Figures for 2002–3 to 2006–7: Productivity Commission (2007) p. 479.
[44]Funding from overseas entities increased toward the end of the decade from contracts with multi-national companies.

Table 2. CSIRO research funding by socio-economic objective, 2000–11.

Socio-economic objective (ANZSRC 2008)	2000–1	2002–3	2004–5	2006–7	2008–9	2011–2
	% of $ spent	% of $ spent	% of $ spent	% of $ spent	% of $ spent	% of $ spent
81 Defence	0.6	0.4	0.3	0.4	1.2	0.7
82 Plant production and plant primary products	14.5	13.7	13.9	12.8	8.6	13.9
83 Animal production and animal primary products	10.6	11.2	9.3	6.0	4.3	11.2
84 Mineral resources (excl. energy resources)	6.3	7.4	7.7	7.7	6.2	7.8
85 Energy	7.9	7.1	7.5	8.3	8.8	11.4
86 Manufacturing	23.8	22.4	21.4	20.5	11.9	7.3
87 Construction	3.3	3.7	3.8	2.9	1.3	1.0
88 Transport	0.5	0.5	0.7	0.7	0.2	0.7
89 Information and communication services	5.0	5.2	3.8	4.9	7.5	1.7
90 Commercial services and tourism	0.8	1.0	0.7	0.8	0.6	0.4
91 Economic framework	1.8	1.9	0.3	1.1	1.0	1.0
92 Health	1.7	1.6	2.6	3.6	5.0	7.3
93 Education and training	0.1	0.1	0.1	0.3	0.1	0.3
94 Law, politics and community services	0.6	0.4	0.8	1.1	0.9	0.3
95 Cultural understanding	0.0	0.0	0.0	0.0	0.7	0.2
96 Environment	20.0	20.0	23.1	24.3	28.5	24.8
97 Expanding knowledge	2.6	3.5	3.8	4.5	13.2	10.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 3. CSIRO financial summary 2001–10: Revenue sources, $M.

	2001–2	2002–3	2003–4	2004–5	2005–6	2006–7	2007–8	2008–9	2009–10	2010–1
	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m
Comm, State, Local Govts	75.6	76.8	87.0	89.7	96.5	116.0	119.5	148.3	169.8	188.6
Aust private industry	68.6	77.8	79.6	63.9	67.6	58.0	68.2	76.3	71.8	81.6
Rural R&D corps	41.6	42.6	40.0	48.0	44.3	43.2	30.2	36.5	31.8	34.4
CRCs	26.7	32.0	33.1	35.2	35.2	39.8	38.2	40.3	42.3	34.8
Overseas entities	35.3	34.3	33.0	33.5	36.4	37.2	35.3	61.0	78.3	72.8
IP revenue	16.9	13.8	22.0	20.4	37.0	30.6	81.7	229.6	46.7	29.2
Other	58.5	37.0	23.8	33.7	43.9	44.5	41.3	31.3	28.3	47.9
Total external revenue	325.5	312.4	319.9	314.6	352.9	363.6	428.6	634.8	459.2	500.2
Commonwealth appropriation	509.5	532.3	568.6	577.1	593.9	610.1	663.2	668.1	704.9	720.4
Total revenue	835.0	844.7	888.5	891.7	946.8	973.7	1091.8	1302.9	1164.1	1220.6

incentives to promote innovation and technology performance. Total private sector R&D rose from $4.5 bn in 2000–1 (0.72% of GDP),[45] to $17.9 bn in 2010–1 (1.28% of GDP).[46] However, the proportion of this private sector R&D outsourced to CSIRO fell. For the main part this reflects changed behaviour on the part of industry rather than CSIRO. There was little demand for large scale research projects, or for the longer-term collaborative research that

[45] Australian Bureau of Statistics (2001).
[46] Australian Bureau of Statistics (2011).

had been the traditional strength of CSIRO. Rather there was a shift toward incremental research, supply chain innovation, and access to consulting and research services from an increasing range of sources in Australia and abroad. CSIRO was less suited to projects of incremental innovation, and, according to the Productivity Commission an area of risk for public funded research that encroached on activity that private firms would otherwise have undertaken.[47]

CSIRO engagement with Australian firms

In post-2000 CSIRO, greater emphasis was placed on identifying and developing research capabilities in key areas—such as advanced materials, transformational biology, and large-scale sensor networks—and less on identifying, and responding to Australian industry needs. This was reflected in CSIRO's reporting during most of the decade. The absence of systematic and accessible reports on CSIRO interactions with private industry, such as public CSIRO-wide customer data is itself an indication of the lower importance placed on delivering commercial impacts for local companies. This may also reflect some of the turbulence experienced by the organisation during the introduction and progressive improvement of its matrix-based management system. An increased proportion of the organisation's research was directed toward national objectives and government-related research during the decade but industry-targeted research remained important for agriculture, minerals, manufacturing, and information technology divisions. In addition, CSIRO had been a major player in the CRC program since its inception in the early 1990s and in mid-2009 was a member in 27 of the 51 current CRCs. Each of these typically involved private sector companies and universities.

The Manufacturing, Materials and Minerals group continued to maintain extensive industry relationships. These included a long-standing research alliance with Boeing, across activities such as painting and materials, and assembly and maintenance management, that had underlain the establishment of Boeing operations in Australia. Other strategic alliances were established with Orica and General Electric. The group assisted more than 700 small-medium sized enterprises (SMEs) in 2011. Some of the commercial achievements arising during the decade are shown in Table 4. Also notable was the RAFT platform technology[48] developed by CSIRO and now being exploited commercially. This technology profoundly improves the level of control over polymer structure and function, and allows polymeric materials to be tailored for wide range of applications such as drug delivery systems, next generation cosmetics, biomedical materials, new agrochemicals, solar cells and improved industrial chemicals.

Overall, the shift during the decade was toward a much more transactional relationship with companies. An unintended consequence of strict time accounting for research projects was the pressure it put on informal interactions with industry. These have traditionally been an important channel for support for smaller companies,[49] including the 'black market' practice of SMEs contacting their professional colleagues in a CSIRO division to see if some procedure or analysis was worth doing, and the carrying out of some preliminary experiments. This practice often led to substantial contracts.

Technology transfer

The 1978 legislation for CSIRO lists as a prime function to encourage or facilitate the application or utilisation of the results of its research. This function remained unchanged throughout the period 2000–10. It has very wide coverage and includes all forms of technology-transfer to Australian industry, as well as the transfer of the results of scientific research results to government agencies and departments (CSIRO statistics relating to patents and licences do not distinguish between those kinds of users, in cases where such rights remain unencumbered by contractual arrangements). The basic principles underlying CSIRO's approach to technology-transfer did not change in the period 2000–10. However, the way the principles were applied in practice did change because of the steady increase in financial reliance by CSIRO on contractual arrangements with intended users. These arrangements were normally supported by formal agreements that provided for the allocation of rights to the results of the research, including ownership of any new intellectual property. Under those arrangements, CSIRO would often contribute to the costs of the research and seek a reasonable return in the form of a royalty if the research were successful. On the other hand, where CSIRO produced research results that were unencumbered by contractual arrangements, intellectual property protection would normally only be sought where this was necessary to protect investment by future users in the development and marketing of products and processes based on the research. In most other cases, CSIRO's preference was to publish its research and allow free use. An exception was possible where significant income was likely to be available. In 2002–4, following a centrally managed exercise, CSIRO identified, for potential monetisation, a number of 'residual' patents in its portfolio that fell outside CSIRO's ongoing R&D activities. Candidates were classified as RIPPERS (Reclaimed Intellectual Property Promising Extraordinary Revenues). In the event, only one RIPPER was proceeded with and financially successful: see

[47] Productivity Commission (2007) p. 474.
[48] CSIRO (2022).
[49] CSIRO (1995).

Table 4. Selected commercial achievements, CSIRO 2000–10.

Product	Technology
Ultrabattery™[A]	Hybrid energy storage device combining ultracapacitor and lead-acid battery technologies in a single cell with a common electrolyte, that is being manufactured under licence in the US and Japan
QEMSCAN[B]	Technology for rapid mineral analysis, being commercialised by a CSIRO spin-off company
Bleomycin process[C]	Novel, fast & efficient purification system for making the anti-cancer palliative care drug, bleomycin, taken up by Faulding Pharmaceutical company.
Cotton breeding[D]	Continuing research program responsible for release of over 100 cotton varieties to the Australian market. 2007 joint venture with Cotton Seed Distributors.
Biodegradable packaging[E]	Developed with the 'CRC for Packaging'—commercialised via the spinout 'Plantic'
LANDTEM[F]	Device using highly sensitive sensors to detect magnetic fields and map underground ore bodies
Silviscan[G]	Non-destructive technology for estimating wood quality of standing trees and aiding in future planning for plantations.
Wireless technology[H]	World's fastest wireless link in 2006—development of a new signal processing method for 6 Gbps system which was the world's fastest and most spectrally efficient system for wireless communications.

[A]https://csiropedia.csiro.au/ultrabattery/ (viewed on 9 November 2022).
[B]https://www.csiro.au/en/work-with-us/industries/mining-resources/qemscan (viewed 9 November 2022).
[C]Hart, N. Bleomycin and other bioactive compounds: chemical studies and production [Unpublished PhD thesis, Swinburne University of Technology] http://hdl.handle.net/1959.3/395833 (viewed 15 October 2022).
[D]https://csiropedia.csiro.au/cotton-breeding-and-new-cotton-varieties/ (viewed 9 November 2022).
[E]https://plantic.com.au/technology/research-development.html; https://plantic.com.au/company/history.html (viewed 8 November 2022).
[F]https://csiropedia.csiro.au/landtem (viewed 9 November 2022).
[G]https://csiropedia.csiro.au/silviscan-rapid-wood-analysis/ (viewed 9 November 2022).
[H]https://csiropedia.csiro.au/wireless-network-gigabit/ (viewed 9 November 2022).

Box. 2. **CSIRO and Wi-Fi**

In February 2005, CSIRO embarked upon a litigation journey that would last a decade, cost many millions, and result in returns to CSIRO of more than $600 million.

At stake in the litigation were royalties due to CSIRO for use of its patented wireless local area technology, now known as Wi-Fi. Conventional technology-transfer approaches had failed, and litigation was the last resort. Initially, CSIRO began a test case in Texas against a mid-size Japanese company. Within three months, it had been counter-attacked by six of the largest companies in the world. Instead of buckling, the board of CSIRO held firm. To do otherwise, the board reasoned, would weaken CSIRO's position in all future commercial negotiations involving its technologies.

CSIRO's invention was made in 1991–2 and the first patent was granted in 1996. By 2000, patents had been granted for the invention in 19 countries. Despite numerous determined attacks, at the end of the litigation, all of CSIRO's patents remained intact, with key ones strengthened. In June 2012, CSIRO and the five inventors of the Wi-Fi technology were given the prestigious inventor of the year award by the European Patent Office in a ceremony in Copenhagen. CSIRO was especially commended on its use of patents to support world-class technology transfer, and for 'laying the foundation for today's wireless networking technology (Wi-Fi).

The royalties came in several tranches and the first was used to revitalise the Science and Industry Research Fund (SIEF). The Fund was created by statute in 1926, in parallel with CSIR (the predecessor of CSIRO). SIEF's original grant of capital had been eroded by inflation over about 80 years. CSIRO gifted $150 million to SIEF in 2009. SIEF used the gift to support a broad range of nationally important scientific research projects conducted by universities and CSIRO.

Wi-Fi technology (Box 2). This involved CSIRO in a major legal action, and a historically important case in patent litigation, to defend the Wi-Fi technology patents that it had taken out in the 1990s.[50] At the heart of the dispute was the unauthorised use of the wireless network technology as an industry standard on most computers and laptops. The action involved several global computing giants and was settled in favour of CSIRO. The total royalty income to CSIRO amounted to over $600 million with the first tranche of $230 million delivered in 2008–9 (Table 3).

The commercial transfer of research that occurred during the decade is shown in summary form in Table 5.[51] The number of contract and consultancy agreements with private sector clients remained relatively steady over the

[50]Healy (2019).
[51]Department of Education, Science and Technology (2004). Department of Education, Science and Technology (2007). Department of Innovation, Industry, Science and Research (2011).

Table 5. CSIRO commercialisation indicators 2001–9.

	2001[A]	2002	2003	2004	2008	2009
Commercialisation staff	153	185	196	199	156	153
Start ups	10	3	7	2	0	0
Licences/options/assignments executed	158	188	146	50	109	102
Patent and plant breeder rights issued	150	148	317	237	186	174
Contracts and consultancy agreements	n.a.	n.a.	2375	2111	2148	2259
Licence income	15.2	10.2	14.4	17.5	12.4	239.0

[A]All entries are for calendar years.
n.a., not available.

decade at over 2000 each year. The number of patent and breeder rights issued rose slightly, and there a was a slight decline in the number of licences, options and assignments executed. Licence income remained relatively steady, apart from the exceptional inflow in 2009, which is discussed in Box 2. Following a surge of new company creation in the late 1990s there was a notable decline in the employment of spin-off company creation as a means of technology transfer, a trend also observed in other public research institutions.

The internal management of CSIRO's relationships with Australian and overseas businesses continued to be developed in the decade 2000–10. This followed some negative experiences for the organisation in the 1990s, leading to disputes, court cases and settlements. Learnings from these incidents were captured in a comprehensive commercial practice manual and templates for legal agreements covering contract research, collaboration, patenting and licensing, company formation and the like. Staff responsible for providing specialist services in law, business development and commercialisation were located primarily in the divisions of CSIRO and were complemented by specialists in the corporate centre. Increasingly, these staff provided support for interactions between CSIRO and various government departments and other public sector bodies.

CSIRO's patenting performance over the period from 1990 to 2010 is shown in Fig. 4.[52] Table 6[53] offers some insight into this patenting activity, and displays the leading categories filing patents for the period 2000–12, based on an analysis of patent applications pending and granted.

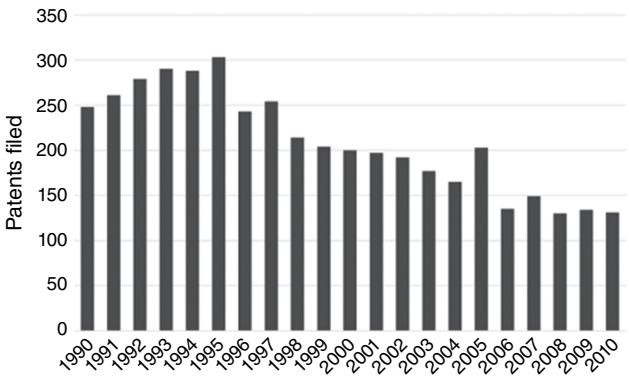


Fig. 4. CSIRO patents filed from 1990 to 2010.

Summary and conclusions

In the first decade of the twenty-first century, CSIRO deliberately rebalanced its activities. In terms of its legislated mandate this meant more emphasis on *contributing to the achievement of national objectives* and less investment in *assisting Australian industry*. This was a change for an organisation (as CSIR 1926, and as CSIRO since 1949) that had traditionally been primarily directed toward assisting Australian industry. The way CSIR/CSIRO adjusted its role in response to national challenges up to 2000 has been addressed in previous papers. These include the broadening of its role in support of primary export industries, to include secondary industry support in the late 1930s and addressing the industry challenges faced by Australia in the Second World War. CSIRO played a major part in support for the wool industry, the nation's dominant export industry in the 1950s, and more recently responded to government calls to lift the technology performance and competitiveness of Australian industry, notably manufacturing, in the light of the major economic reforms of the early 1980s. The realignment embarked upon by CSIRO soon after 2000 was not directly driven by government but was rather a corporate response to a changing environment and adjustment to new realities. Thus, CSIRO had to adjust its research more towardnational objectives and play its part as an important, but not a dominant, contributor to Australia's national innovation system.

The changing environment was one in which the external threats to the national economy had diminished, with

[52]IP Australia (2022).
[53]Wells and others (2015).

Table 6. CSIRO patent categories 2000–12.

Category	Total	Category	Total
Fermentation (incl. vaccines, antibodies, cells, genes)	645	Data and communication	119
Pharmaceutics (natural products and polymers)	420	Separation, crystallisation, extraction (gases, liquids, solids)	118
Biotechnology (plant genetics and vet vaccines)	374	Polymers (medical, dental, vet, cosmetics)	105
Digital computers	364	Aviation, marine, radar	104
Scientific instrumentation	256	Photographic, optical	93
Plant culture: dairy	214	Medical equipment (electrical)	93
Foodstuffs (milk preservation, oils, beverages, animal feed)	181	Engineering instrumentation	92
Conductors, resistors, capacitors, batteries and fuel cells	166	Non-metallic elements, semi metals	89
Radio transmission	145	Electrochemical storage	88
Chemical engineering (catalysis, colloids, encapsulation)	125	Powder metallurgy	87

national economic growth and rising mineral exports, and there was growing self-sufficiency in industry research as private sector investment in R&D rose rapidly. The shift in industry structure towards a greater role for services, health and information technology (IT) industries, and after the 1990s, a shrinking manufacturing sector, played to the disadvantage of CSIRO's traditional role. The changes that were introduced by CSIRO were designed to give it an updated role as part of the national innovation system, provide a unified face in dealings with business and government, and to be more distributed and more responsive to national issues that arose.

The process of change is briefly discussed in this paper. A set of national flagships, which directed multidisciplinary research toward important national challenges was introduced alongside CSIRO's traditional divisional research. A matrix management system was introduced. CSIRO chose a high growth path and relied on high level of external earnings from government and industry partners. The restructuring and the matrix management system, although progressively refined, made for a complex and an often-stressful environment. While the organisation was able to record important achievements from its national flagship research, getting there was not without cost. A consequence of CSIRO's national realignment was a decrease, in relative terms, of industry-focussed research. National flagships were, in the main part, directed toward national objectives and government responsibilities rather than support for industry, so the share of government-related research grew. Nonetheless, industry research remained important. The number of industry contracts remained relatively steady over the decade, as the organisation's budget grew, and exceeded 2200 (Table 5) in 2009. CSIRO continued to make important contributions in areas of agriculture, minerals, manufacturing and information technology and to contribute to pathbreaking manufacturing research, for example through RAFT technology. Moreover, this was underpinned by a strong record in intellectual property management, one indication being the successful pursuit of Wi-Fi licensing, leading to royalties of over $600 million flowing into CSIRO (see Box 2).

An enduring feature of CSIR/CSIRO is the way it has been able to re-form and reconceptualise its role in response to changing national challenges. As its external environment has changed the organisation has adapted. CSIRO entered the second decade of the twenty first century with a clearer view of its place in the new national innovation system but still needing a major overhaul of its overly complex systems of management.

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