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Cross-sector research collaboration in Australia: the cooperative research centres program at the crossroads

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Abstract

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Keywords

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Cross-sector research collaboration in Australia: the Cooperative Research Centres Program at the crossroads

Tim Turpin, Sam Garrett-Jones and Richard Woolley

In this article we trace changes in the institutional and social dynamics that have steered cross-sector R&D collaboration in Australia. Public policy provided the initial push toward cross-sector collaboration. The Cooperative Research Centres (CRC) Program is Australia's most longstanding national arrangement for industry–university–government research collaboration. Over the past two decades the program has grown to become the dominant model for cross-sector R&D cooperation in the country. Because of the size of the program in the Australian innovation system it has also become a major focus for debate about science policy. Universities have now institutionalised this imperative in all sorts of ways that steer research funding and career opportunities for their academic staff. Expectations and aspirations of CRC staff, doctoral students and potential staff and students are now deeply embedded in centres' evolutionary processes.

OVER THE PAST two decades, research policies in most OECD countries have sharpened their focus on the generation of economic benefits from investments in scientific research. Strategies for achieving this have included:

- Offering academic researchers tied government–industry research grants;
- Tying public research institute budgets to industry funding targets;
- Establishing collaborative industry–government-sponsored postgraduate scholarship programs;
- Putting in place national and institutional planning exercises such as foresight and scenario planning; and
- Forming cross-sector cooperative research and engineering centres (OECD, 2007).

As initiatives of this nature have spread internationally and endured, science policy researchers have sought explanations as to how they developed and, more importantly from a policy perspective, their implications (Gray, 2000).

Changes have been perceived in both the social and the intellectual organisation of the sciences (Whitley, 2000). Descriptive models of the changing contexts and forms of interaction said to characterise 'new' organisational arrangements have emerged. Gibbons *et al.* (1994) described emerging research organisation and policy trends as reflecting a shift from 'Mode 1' to 'Mode 2' systems of knowledge production. Etzkowitz and Leydesdorff (1997) offered a 'triple helix perspective of university–industry–government relations' as a frame to explore the implications of emerging inter-sectoral dynamics. These, and other, perspectives have generated considerable debate (Weingart and Stehr, 2000). It is not our intention to revisit these debates in this article; rather, we are concerned to examine the genesis and adaptation over time of one particular policy initiative specifically designed to promote change in the organisation of R&D in Australia, the Cooperative Research Centres (CRC) Program.

The Australian CRC Program commenced in 1991 as a whole of innovation system approach to

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the institutionalisation of cross-sector collaboration in R&D. In this article we explore its evolution in response to changing expectations and policy demands and consider the current historical juncture. Although a national trend toward concentration and collaboration in university-based research centres was under way well before the CRC Program emerged, CRCs were concerned explicitly to institutionalise collaborative, end-user-driven, or relatively 'demand-pull' R&D activities. The designer of the CRC program envisaged:

a cooperative team of researchers and research users, drawn from various organisations, and of adequate size and composition to have a real and continuing impact in the sector where it was located ... research organisation participants would undertake mainly long term strategic research — in other words work at the R end of the R&D spectrum — and the research users would work mainly at the D end. (Slatyer, 2000, cited in O'Kane, 2008: 11)

The activities of CRCs were thus seen as providing a complement to the science research system, with additionality in terms of benefit to private firms, industrial sectors, research concentration and training pathways. The strategic objective was both to deepen current strengths and expand the scope of the national science and technology (S&T) capability (OECD, 2004; O'Kane, 2008).

The CRC Program changed the face of research in the Australian system in important ways. First, CRCs introduced intermediate management structures that

transcend university, industry and other public sector research organisations. Although centre funding through the program is finite, the program itself has endured for 20 years. CRC management structures are now quite deeply embedded across university and public sector agencies.

Second, as the program has evolved and the range of CRCs has grown, so too has the diversity of their research objectives and the number and structure of their partnerships, expanding the patterns and purposes of connections between actors.

Third, CRCs offer a training ground for postgraduates that is quite different from a traditional academic faculty experience. CRCs have effectively introduced a new range of career steps for Australian (and international) researchers, diversifying the stock of human capital within the system and providing newly minted S&T human resources (HRST) with greater awareness and understanding of end-user issues and requirements.

Of course, such changes have not come without problems. First, the tendency of CRC structures to embed themselves in universities, in particular, has led to a tension between organisational stability and the responsiveness to changing demands required of an end-user-focused program. Pressure for stability comes from several quarters:

- Stability in terms of funding and organisational management which the universities desire;
- Stability in terms of guidelines, contractual and organisational arrangements and performance measures on the part of government administrators of the program; and, lastly,
- Desire for stable employment or, at least, clear career pathways on the part of individual researchers (Steenhuis and Gray, 2005; Turpin and Garrett-Jones, 2010).

CRCs have, to some degree, cemented and institutionalised the requirements of the universities, partner organisations and government stakeholders. This has been at the cost of on-going flexibility and consequently organisational dynamism.

Second, the proliferation of CRCs has inevitably led to overlap across research fields and organisations. Many centres have found themselves in highly contested funding domains, blurring the boundaries between the traditional roles of universities, public sector research universities and industrial firms.

Third, CRC-based training and CRC-focused employment involves ambiguities around individual and organisational goals, which can lead to researcher concerns about potential career risks and rewards and hence individual and institutional 'role strain'. Perceptions of career risk can impact negatively on the quality of talent entering CRCs and on the medium-term commitment of individuals to centres (Garrett-Jones *et al.* 2010).

In this article we address some of the points of tension within the Australian CRC Program. The

program has been in place now for two decades, but we argue that it has reached something of a 'cross-roads' in its evolution. We draw on our previous research to highlight several seemingly intractable problems faced by CRC personnel and management in relation to human resource issues. However, prior to this we discuss the process and rationale through which the CRC Program and its various actors originally emerged. Following this we describe the evolution of the program objectives in the context of changing societal and policy demands. We then discuss HRST issues in more depth, before concluding with a discussion of the CRC Program at the cross-roads. In this section we also consider recent modifications to the program guidelines in response to the most recent review (O'Kane, 2008).

Context and rationale for the Australian CRC Program

In 1982, a national research centres program was launched in Australia to provide a new research focus that would strengthen national research capacity and forge links between researchers in public sector institutions, universities and private sector firms. A three-point policy was quite explicit in the rationale for the program of centres. The first objective was to maintain a greater *concentration* of research resources to help build up centres of expertise within universities. The second objective was to provide greater autonomy and flexibility in the *management* of institutions to allow universities to develop distinctive characteristics appropriate for their location or individual capacity. The third objective was to foster better *linkages* between universities and industry. Research centres were thus seen as a mechanism for:

- Concentrating research funding into programs rather than an array of discrete projects;
- Enhancing collaboration between universities, other public sector research institutions and with industry; and
- Generating new autonomous approaches to research management.

The first research centres program included a category of centres for research teaching and learning and a second group defined as special research centres, targeted primarily toward concentrating scholars in selected areas towards basic research.

Clearly some very strong imperatives, beyond simply the promise of government funding, were driving the trend toward a centres model. One was the demand for problem-oriented, cross-disciplinary organisational units which were separate from the constraints of the traditional discipline-based structures of universities. An early example of these was the Centre for Resource and Environmental Studies, established by Fenner at the Australian National

University in 1973. Moreover, there was concern among many university managers to establish rules for the formation and, importantly, the closure of centres when and if this might be deemed necessary. Also, from the mid-1980s university researchers could, for the first time, bid for large federal government project grants in industry-related R&D areas like biotechnology, information and communications technology and new materials, provided they brought an industry partner. As it turned out, several of these partnerships were the genesis for the first CRCs.

The Australian CRC Program is now probably the single most important (and undoubtedly the most complex) policy measure undertaken by Australian governments in the interests of raising the level of public/private sector research collaboration and improving the interaction between researchers and organisations within the innovation system. Weak linkages between public researchers and industry, in particular, constituted a rationale for the program (OECD, 2004). The program was viewed as complementing policies designed to support private sector R&D (e.g. tax concessions) and smoothing the entry of multinational firms to capitalise on Australia's relatively strong supply of skilled human capital.

In its initial guise, the CRC Program was aimed squarely at the establishment and institutionalising of patterns of communication, interaction, cooperation and research collaboration between researchers based in publicly funded organisations and the private sector (OECD, 2004; O'Kane, 2008). The program was introduced with four objectives:

- Research excellence;
- Effective collaboration;
- Creation of new educational opportunities; and
- The translation of research outputs into economic, social and environmental benefits to Australia (O'Kane, 2008).

These objectives have remained constant despite quite marked shifts over time in the program's focus, as we shall describe in the following section.

The Cooperative Research Centres Program sought to institutionalise cross-sector collaboration by providing incentives to encourage existing actors to establish relationships and undertake a sustained program of activities within a national interest framework

The CRC Program thus sought to institutionalise cross-sector collaboration by providing incentives to encourage existing actors to establish relationships and undertake a sustained program of activities within a national interest framework. The advent of significant program funds created a strong incentive for involvement among a range of existing actors; but also introduced the requirement for a new form of innovation actor, namely CRC management structures. The creation of this new form of intermediate management structure marked a substantial policy innovation. The importance of governance models to the subsequent operation of the CRC Program is made clear below; however, it is important to note that while this aspect of the program was entirely new, prior policies had paved the way, by seeking to institutionalise a culture of contact and cooperation between researchers and to build research concentrations through a centres model and through large-scale university–industry collaborative project grants.

The CRC Program thus promised to offer a mechanism for further institutionalising collaborative cross-sectoral and inter-organisational research and for enlarging its scale and scope in areas of national interest. The program design followed the example of centres like the US NSF Engineering Research Centers and the UK Science and Engineering Research Council's Interdisciplinary Research Centres in the mid-1980s. All potential bidders for funding were required to develop a management plan under common guidelines but with considerable autonomy in their management approach. In this sense the program led the way in readjusting the institutional boundaries of Australian research.

In terms of scale, in 12 rounds of funding from 1991 the program established 168 centres: 102 as new centres (each funded for a seven-year term, renewable in some cases) and 66 formed from pre-existing CRCs (O'Kane, 2008). Since the commencement of the CRC Program, all parties have committed more than AU\$12.3 billion (cash and in-kind) to CRCs. This includes almost AU\$3 billion from CRC Program funds, AU\$3.1 billion from universities, AU\$2.5 billion from industry and AU\$1.2 billion from CSIRO, the main government research organisation (CRC, 2010). The most recent round of applications announced in 2009 funded (or refunded) seven centres with a government investment of AU\$130 million.

In terms of scope, as of June 2010 the 42 CRCs in operation covered a wide range of industrially oriented and 'public good' research. They are grouped in four 'sectors': agriculture, forestry and fishing (11 centres); manufacturing (five centres); mining (four centres); and services (22 centres). Included in the services category are CRCs focused on the environment, indigenous health, infrastructure, and medical science and technology. The longest-running among current CRCs were funded in the ninth round and commenced in 2005–06.

Annual government funding to the program of around AU\$200 million accounts for about 3.5% of funding for science and innovation in the national budget (CRC, 2010). However, government funding for the CRC program has not increased markedly over the life of the program. One possible interpretation of this lack of growth is that the innovation system (or higher education system) has a finite 'carrying capacity' for this type of centre. That is, although the number of students has grown considerably over the past 20 years, the extent to which the government can 'engage' industry and universities in Australia to form these quite complex research arrangements has limits. Universities have committed at least one-fifth of the resources to CRCs in each funding round and in the 2000 and 2002 rounds this exceeded 30% (O'Kane, 2008: Appendix 4).

A second interpretation is that centres are thereby encouraged to grow with non-government funding, and indeed the leveraging of program funds has generally increased through the life of the program. Program funds are only available for a limited period; and the extension of centre activities, which can continue under the CRC banner, requires other sources of investment or income if CRCs are to become self-funding as they exit the program (O'Kane, 2008). However, as we shall see in the following section, the push toward making CRCs a different kind of economic actor has not been confined to the post-program phase alone.

The changing focus of the Australian CRC Program

The success or otherwise of a policy initiative of the scale and scope of the Australian CRC Program is not easily established. Figure 1 shows the amount of business funding of R&D conducted in Australian universities and its proportional contribution to total higher education R&D (HERD).

Over the life of the CRC Program the level of business funding for R&D conducted in Australian universities has grown substantially, particularly since 2000. The proportion of total HERD funding sourced from business peaked at 6.13% in 2006, prior to the global financial crisis. These data would suggest that university–industry activities have significantly expanded in the period coinciding with the existence of the CRC Program. A further contributing factor is the relative contraction of the government research sector in Australia over the same period.

In terms of its major aim, to improve the level of interaction and coordination between publicly supported researchers and private industry and other research users, the Australian CRC Program has been considered a success at several junctures in its evolution. A 1995 review found:

[the] major success of the CRC Program [has been] in producing a culture change in Australian

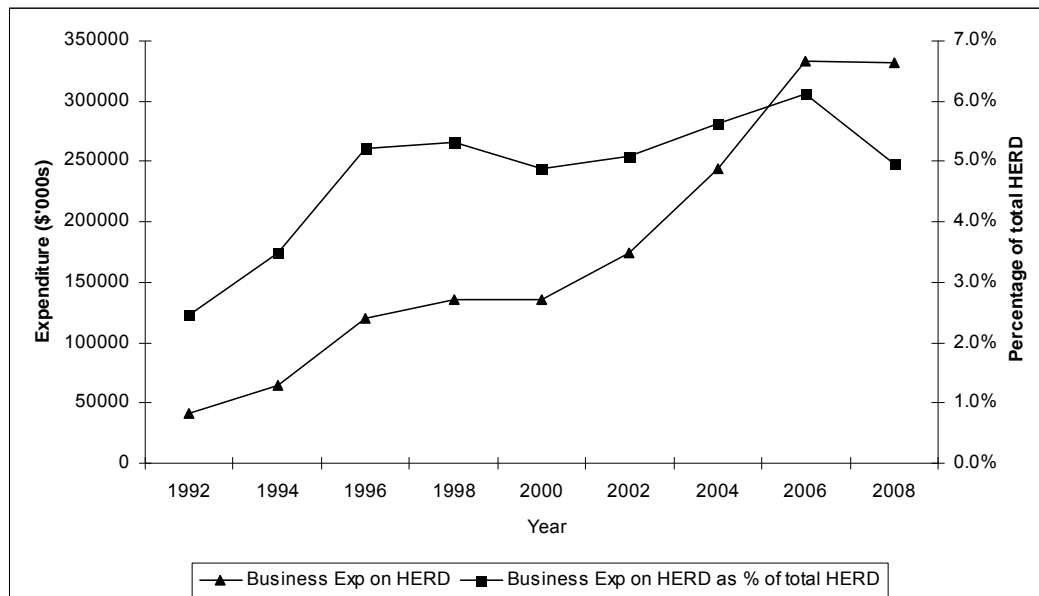


Figure 1. Business funding of higher education research and development, 1992–2008

Source: ABS (2010)

research and education activity in support of research and development and especially in interaction with industry and other research users. (CRC Program Evaluation Steering Committee, 1995)

A narrower 1997 review of CRC commercialisation activity concluded that important benefit was ‘already evident in the changed attitudes and perspectives in industry and research organizations’ (Mercer and Stocker, 1998: v). There seems little doubt that the CRC Program has institutionalised greater levels of cross-sector interaction and cooperation and built new bottom-up innovation system actors, even in its earliest phase.

Shifting program objectives

As the program has matured an increasingly pertinent issue has been the extent to which cross-sector activities satisfy evolving program objectives and whether the specific organisations that have emerged are sufficiently flexible and adaptable to deal with emerging challenges in end-user-focused activities. Table 1 summarises CRC Program objectives from inception to the most recent funding round (March 2010).

The objectives of the CRC Program have changed substantially over time, notably becoming far more condensed as program thinking moved from implementation toward outcomes. The O’Kane review (2008: 22) assessed the most significant change in emphasis as occurring around 2004–06, finding it:

quite marked: on growth, research users, and research adoption/commercialization ... the focus was on harder-edged outcomes for end-users.

The Productivity Commission, in its earlier (2007) review of public support for science, also noted the move away from foci on research excellence and postgraduate training, and broad-based definitions of national and social benefit. The Productivity Commission (2007) argued that the emphasis on commercialisation over early-stage R&D was risky from a public investment perspective. It created a strong likelihood that CRC collaborations were substituting for R&D that firms or industries would have conducted anyway, in the absence of CRCs, and that selection committees would favour ‘collaborations that pursue less risky project outcomes involving lower levels of spillover benefits’ (PC, 2007: 447–448).

The response of the Australian Government to these independent reviews, and the substantial weight of support for these views contained in stakeholder input to them, was to move the program objectives back toward their earlier focus. This included a reinstated emphasis on public good outcomes (social and environmental benefit), end-user-focused education and training programs, and small and medium-sized enterprise (SME) strategies designed to augment firm R&D capacity and innovation capability. The most recent program guidelines also de-emphasise commercialisation and shift toward a broader basket of activities to ‘deploy research outputs and encourage take up by end-users’ (DIISR, 2010a: 1). The definition of end-user includes all public organisations, communities or private industries *capable* of deploying research outputs from CRCs. For example, an end-user of a health-focused CRC’s research output may be a public health authority, just as it may be a private pharmaceutical firm or a not-for-profit organisation.

It is interesting to consider how changes in program objectives reflect policy-maker expectations in terms of the actors engaged with centre activities.

Table 1. Evolving CRC Program objectives over the 12 funding rounds, 1990–2010

1990–92	2000–02	2004–06	2009–10
To support long-term high-quality S&T research which contributes to national objectives, including economic and social development, the maintenance of a strong capability in basic research and the development of internationally competitive industry sectors	To enhance the contribution of long-term S&T research and innovation to Australia's sustainable economic and social development	To enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation	To deliver significant economic, environmental and social benefits to Australia by supporting end-user-driven research partnerships between publicly funded researchers and end-users to address clearly articulated, major challenges that require medium- to long-term collaborative efforts
To capture the benefits of research, and to strengthen the links between research and its commercial and other applications, by the active involvement of the users of research in the work of the centres	To enhance the transfer of research output into commercial or other outcomes of economic, environmental or social benefit to Australia;		
To build centres of research concentration by promoting cooperative research, and through it a more efficient use of resources in the national research effort	To enhance the value to Australia of graduate researchers;		
To stimulate education and training, particularly in graduate programs, through the active involvement of researchers from outside the higher education system in educational activities, and graduate students in major research programs	To enhance collaboration among researchers, between researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources		

Source: O'Kane (2008); DIISR (2010a)

The earlier incarnations of the CRC Program envisaged hybrid actors formed through bottom-up initiatives among coalitions of researchers and organisations. As economic actors these early CRCs could be considered science-push joint ventures, with expectations of their activities more about system co-ordination, capacity-building and emergent collaborations than about direct market impact. In more recent times expectations became framed more strongly by demand-pull initiatives, particularly once activities were explicitly expected to produce a direct financial return on public investment.

CRCs became faced with challenges presented by a range of economic activities that can broadly be referred to as 'marketization' activities (Çalışkan and Callon, 2010). These include activities such as venture capital sourcing, market feasibility studies, promoting prototypes, licensing products, etc. which are required to bring a product to the attention of financiers, buyers and other types of commercial actors operating in and around markets. CRCs, instead of being intermediate organisations producing outputs for commercialisation by specialist marketisation actors, were expected to become *directly*

involved in carrying out these activities themselves. The policy re-orientation was probably partly due to a continuing perception of weak science output commercialisation capabilities among Australian SMEs (OECD, 2004). However, the focus on commercialisation activities provided a range of significant challenges to CRCs, including broadening the expertise required within the organisation, with the accompanying risk of weakening the focus on research excellence, training and other missions.

The relationships between the evolution of program *objectives*, expanded centre *activities* and forms of *organisation* structure are important to note here. Perhaps the clearest example in this regard is in relation to intellectual property (IP) arrangements. In general, CRCs are either incorporated tax exempt legal entities or unincorporated joint ventures. While incorporated CRCs can act fully as a commercial agent and directly hold IP, unincorporated joint ventures have a principal agent and administering authority (usually a university) and often establish an external legal entity for commercial transactions including IP. From 2002, the government preference was for CRCs to become incorporated (OECD, 2004), fitting with the vision of CRCs becoming economic actors more fully engaged with marketisation activities. Despite this, many CRCs preferred at this time to remain unincorporated, with a key public sector member holding IP developed within the CRC. Instead, legal entities were spun off from CRCs to deal with the challenges associated with holding IP and negotiating commercial agreements.

In effect, CRCs appeared somewhat ambivalent on the question of functioning as economic actors fully engaged in marketisation activities, preferring rather to create a third-party structure to cope with

It is interesting to consider how changes in program objectives reflect policy-maker expectations in terms of the actors engaged with centre activities

extended commercial imperatives. However, as older CRCs finished their funding period and newer CRCs came into existence the overall balance of the program shifted toward incorporated structures. By mid-2010, just eight of 42 CRCs (19%) were *not* incorporated (DIISR, 2010b), indicating the previous program objectives had influenced CRC structures in the medium term. It will be some time before the marketisation capabilities of current CRCs can be realistically assessed. With the most recent changes to program objectives de-emphasising commercialisation, it also remains somewhat unclear as to what extent incorporated CRCs will pursue this activity directly.

Changing management structures and commercial directions

The evolution of program objectives has meant changes in indicators of successful performance. A commercialisation focus implies greater interest in patents and licensing income as benchmarks of success. This both advantages and disadvantages established CRCs, some of which will have already been directly involved in marketisation activities, while others remaining less engaged.

The first analysis of emerging CRC management structures described a research type, a corporate type and an integrated type as having emerged (Liyana and Mitchell, 1992). The *research* type emphasised key individuals or researchers, offering them a high degree of autonomy but with highly structured program goals. The *corporate* type emphasised business management above research and education with management structures oriented towards the market. In this model committees and units tended to be specialised with clearly differentiated tasks and goals. The *integrated* type emphasised a balance between research, education and commercial functions, with a high degree of vertical integration of tasks and networking between units within the organisation.

Among the first round of CRCs funded in 1991 the *research* model predominated, with just under half of the 34 centres falling in this category. Seven reflected the *corporate* mode and 11 an *integrated* mode. It should be recalled that the first guidelines for the CRCs did not require a commercial partner and thus opened the door to the *research* model, in contrast to the mature program guidelines with their increasing calls for a road to commercialisation to be mapped out by the partners. Unsurprisingly then, it would appear that in the early stages of the program few CRCs had significant 'marketisation' capabilities.

A later review by Howard Partners (2003) described three differentiated forms into which CRCs had evolved:

- National benefit research centres (focused on environment, resource and sustainability related activities);

- Industrial research collaborations (mature commodity-based sectors with activities focused on productivity, quality and competitiveness); and
- Business development centres (focused on commercialising and business creation).

Howard Partners found that the program over time had become weighted toward national benefit, and that successes and failures were determined to a significant degree on the pre-existing match between the research base and the requirements of research users. Mining and the environment were pointed to as arenas in which CRCs exploited a strong match and were successful in research, collaboration and training objectives. Business development centres such as Vision and Cochlear had been successful in the creation of business and ongoing product earnings. However, overall CRCs have been neither efficient nor effective in commercialisation activities (PC, 2007). With a small number of exceptions then, it appears CRCs had not evolved into capable marketisation actors in the more mature phases of the program.

The extension of the range of program activities, from promoting cross-sector cooperation and collaboration right across the innovation system space to delivering products to commercial markets, has the inevitable consequence of increasing the difficulty of evaluating what constitutes policy success. A more diverse program is more likely to be overlapping or competing with other innovation system policy measures (CRCA, 2008). As mentioned earlier, the Australian Government appeared to accept the recommendation of the O'Kane review (2008) that the program had drifted too far toward a focus on commercialisation activities, in describing 'utilisation activities' in more general terms in the most recent program guidelines (DIISR, 2010a). Nevertheless, it is difficult to escape the conclusion that the CRC Program stands at something of a crossroads in its history and evolution.

The O'Kane review came close to recommending that the program be dissolved into other policy frameworks, notably the Centres of Excellence Program, but stepped back from this decision. It is unclear whether the revised program objectives and principles will revitalise the program. There had been an appearance of disjuncture between a policy trend toward commercialisation and the bulk of the program actors as they had come to be institutionalised. Re-focusing on 'pre-competitive and pre-applicative' research (O'Kane, 2008) may resolve this emergent tension in the program, with all sectoral participants seeming to be in agreement that CRCs were best suited working in relatively early stage R&D (PC, 2007; O'Kane, 2008).

However, it still remains to be seen if long-standing tensions between participants' desires for organisational stability and continuity and the program's end-user focus valuing flexibility and adaptability can be better managed. We illustrate

unresolved problems in this regard by focusing attention in the following section on the human capital issues confronting both CRC management and research staff.

CRCs and human capital issues

At the outset of the CRC Program, institutionalising new patterns of cross-sector relationships between researchers was a fundamental goal of policy. So too, were goals of creating concentrations of complementary human capital with expertise relevant to end-user problems, and of building a postgraduate education and training program that would provide end-users with outputs in the form of researchers with capabilities well-matched to end-user requirements and with experience of end-user knowledge use and modes of innovation. The CRC Program thus addressed a critical policy issue affecting the innovation system as a whole, namely how to diversify the human capital structure and to multiply the directions and numbers of links and connections.

Individual CRCs were, in effect, vehicles for mobilising an array of complementary human resources for science and technology, including research scientists; engineers; technicians; and, importantly in many cases, skilled tradespersons (Toner *et al.*, 2010). From the human capital point of view, CRC structures could be argued to have constituted a large-scale experiment in institutionalising distributed human capital collectives, stretching across and genuinely connecting up previously disparate and isolated pockets of innovative activity into something approximating a system. However, one of the major reasons we argue that the CRC program stands at a crossroads today is the patchy success of this policy aim. In particular, a number of barriers to effective human capital outcomes in CRCs have emerged, as we discuss below. In addition, the struggle to move from *institutionalising* forms of cooperation and interaction to *organising* purposeful knowledge co-production and use activities remains ongoing.

In terms of bringing into existence new concentrations of public and private sector researchers the CRC Program has undoubtedly been successful. As we have argued elsewhere (Garrett-Jones *et al.*, 2010; Turpin *et al.*, 2005; Turpin and Garrett-Jones, 2010), individuals have been motivated to join CRCs mainly due to the promise of intangible benefits. These include widening the range of scholars available for collaboration, better access to industry partners, and working with a larger cohort of scholars with similar scientific interests. These expectations were expressed in similar terms by CRC personnel irrespective of their sectoral (university or government) research background (Turpin *et al.*, 2005). Similar results were revealed by Riedlinger and colleagues (2004) who found that one of the greatest benefits of CRC participation for researchers was the opportunity to interact face-to-face with

fellow researchers from different organisations and disciplines (Riedlinger *et al.*, 2004: 71; also Toner *et al.*, 2010). In short, the expectation of intensive research cohesion built around a group of researchers from government, universities and industry was the main attractor for most participants.

Researchers in CRCs valued highly the improvement in their interactions with a diversified scientific community. In particular, they rated highly what researchers from other disciplines and institutions brought to *their* research, and the view of 'different ways of doing things' that interaction with commercial firms gave to *their* research. They expressed awareness of the personal benefits of these interactions in extending their skills, enhancing their standing within their 'home' organisation and the broader research community, and opening up of broader career prospects. While they valued the cohesion that the focus of CRC work gave to their research group or department, they rarely expressed benefit in terms of advantage to research end-users or their organisation *per se*. Rather, CRC researchers' perception of benefit remained more focused on 'scientific' or 'academic' forms of recognition and reward.

These findings suggest that the collaboration opportunities brought into being by CRC structures help researchers to augment their scientific and technical human capital through access to industry, but perhaps that these structures can also be a substitute or 'safer' option compared to taking a job within industry (Dietz and Bozeman, 2005). These data thus also reflect the principal problem that besets the CRC Program in relation to human resources, in that most CRC workers are employed by, and spend the majority of their time in the service of, other organisations. There are good reasons for this. Riedlinger *et al.* (2004: 73) argue that because many CRCs were in effect networks and embedded with considerable functional diversity, the basis for a shared identity was slim. This was particularly true in cases where multiple partners and multiple disciplines were involved.

From a CRC management point of view, this problem has potentially serious consequences. It can reduce the extent to which researchers involved in CRCs commit their own intellectual capital or department's material resources to joint activities. Their explicit allegiance and relevant (for them) performance benchmarks may be located outside the CRC. For example, there is some evidence that individual universities prefer their talented researchers to apply for prestigious Australian Research Council competitive grants than to go through the labour-intensive CRC selection process (which lies outside the National Competitive Grants program that underpins research performance data and recurrent funding). This lessens the talent pool moving through CRCs and creates competition between innovation system policies that should be complementary and, ideally, synergistic (CRCA, 2008). It also creates 'role strain' for CRC personnel pulled by

diverging organisational logics (Boardman and Bozeman, 2007).

On the other hand, researchers hired using program funds, including postgraduate students, are seen as the 'glue' that holds effective cooperation together (OECD, 2004). Incorporated CRCs can hire directly, which may benefit organisational independence and the commitment of staff. However, direct hire through a CRC also implies potential career risks for individuals to the extent they are located outside normal academic faculty channels of scientific recognition and promotion (Garrett-Jones *et al.*, 2010; Turpin *et al.*, 2005). There can be program benefits in research personnel remaining employed with one or other of the partner organisations *or* making a transition to a partner in a different sector. However, for those employed directly by the CRC there is potential to be caught between the two.

A further factor to consider is the structural dynamism of individual centres. CRCs are not 'cooperatives' in the sense of being member-based, democratically controlled organisations. They may start this way, recruiting voluntary participants in the bid for grant funding, but inevitably must develop more top-down management and coordination to be effective. Many operate more as networks than as integrated organisations. This can raise problems, as Nooteboom (2000) has observed, because if networks are too cohesive they may become exclusionary and if too durable they can create inertia. They may be very effective for particular well-defined tasks, but in the process they lose flexibility and ability to change.

At the extremes, two scenarios may play out in the life cycle of a CRC. The first is 'disintegration', where ground rules are either too weak or not accepted or adhered to by all partners and individual participants. The second is 'integration', extending the *integrated* model of management observed by Liyanage and Mitchell (1992), where the rules are so effective that they stifle change — perhaps for good reason, such as a focus on commercial production. In either circumstance, the structure of CRC employment relationships means the majority of researchers have the option of retreating to their 'parent' organisation and leaving the collaboration once they perceive the collaboration is becoming unproductive or of little benefit to their career.

These individual career and organisation structure factors can become mutually reinforcing, leading to a tendency toward stability and risk aversion. Responsiveness, dynamism and embracing necessary change is less likely to occur where these represent a significant cost for the individual researcher. In summary, CRCs are potentially vehicles for mobilising highly skilled, complementary human capital for specific knowledge production and/or use activities. However, the entrenched nature of some barriers to effective human capital mobilisation suggests that policy initiatives other than the CRC Program may be better suited to achieving this aim.

The CRC Program at the crossroads

The original unitary CRC Program met its purpose admirably, which was to inculcate a culture of structured collaborative research between publicly funded researchers, industry, and public sector and non-profit end-users. As discussed in this article, three broad influences have been important in shaping the structure and operation of CRCs: the changing policy focus of the CRC Program; the very wide diversity of missions, objectives and outputs of CRCs; and the expectations of researchers within CRCs which emphasise scientific norms, careers and collegiality. While the quest to institutionalise cross-sector collaborative relationships and activities has been successful, the program also carries the baggage of a range of problems, many of which have not been adequately resolved despite repeated identification in program reviews. In particular, we refer here to:

- Problems fitting the program governance model to the diverse missions and objectives of individual CRCs;
- An extensive management burden;
- Overlap and even competition between the CRC and other programs; and
- Problems of eroded collegiality and individual career progression and articulation.

At times it has appeared that the program was evolving in a somewhat *ad hoc* and add-on manner.

Overall, the program in recent years has appeared to steer away from 'speculative and more risky' research and the encouraging of potentially valuable, but less obvious, lateral connections between research disciplines, industry sectors and applications (Garrett-Jones and Turpin, 2009; PC, 2007). In short, the program has become conservative in both structure and objective.

A number of options have been suggested as a counter to the tendency toward conservatism. For example, the diversity of missions within CRCs could be matched with a greater diversity of structures (see Garrett-Jones and Turpin, 2009). This would require a greater variety of institutional arrangements to take into account the objectives of the R&D collaboration. Moreover, arrangements for individual career progression and articulation (such as portable scholarships and fellowships) could be introduced at the national level. A more diverse approach to the program could assist with 'progression and succession' arrangements for mature CRCs and their personnel, whether towards a more commercially oriented organisation or toward seed collaboration in related areas (Garrett-Jones and Turpin, 2009; O'Kane, 2008).

From a policy perspective, we concur with the O'Kane review (2008) that in the future the primary objective of CRCs should be purposeful collaboration around end-user problems or risks, with careful allocation of management responsibilities for the

various tasks involved. The institutionalising of cross-sector interactions should now constitute a secondary objective, avoiding the temptation of collaboration becoming something of an end in itself (Katz and Martin, 1997). The program guidelines for the most recent round of CRC funding (DIISR, 2010a) reflect the government's response to both the O'Kane (2008) program review and the broader Cutler innovation system review (DIISR, 2009). Major changes include extending the possible term of a centre to 10 years (extended to a maximum 15 years only in exceptional circumstances and following competitive selection), restoring the eligibility of 'public good' objectives, and expanding the scope of the program to cover fully the social sciences and humanities. The guidelines also include a reformulated series of core activities, including:

- Medium- to long-term end-user-focused research;
- An end-user-focused training program that builds engagement, innovation and R&D capacity *within* end-users;
- Building international engagement and inward investment;
- SME strategies that build their R&D and innovation capacity; and
- Utilisation activities to deploy research outputs and encourage take-up by end-users (DIISR, 2010a).

It is too soon to judge the effect of refocusing program objectives and adjusting core activities, and whether these changes will lead to greater organisational flexibility and expanded collaboration with other funders, which the CRC Association and we have argued for. In addition, the vexatious issue of career structures for research and technical staff in CRCs remains to be resolved. It seems likely that the 'one size fits all' approach of the CRC Program has run its course and become a limiting factor in the further development of cross-sector collaboration in Australia.

At the same time it has become difficult to envisage what type of economic and innovation system actor CRCs could and should be in the future. It may simply be that the idea of a discrete program that can *manage* the diversity of missions encompassed by

It is too soon to judge the effect of refocusing program objectives and adjusting core activities, and whether these changes will lead to greater organisational flexibility and expanded collaboration with other funders

the CRC Program today is unrealistic. The CRC Program thus appears poised at the crossroads. Future policy initiatives aimed at developing and nurturing forms of cross-sector collaboration in S&T, R&D and innovation in Australia are likely to take some new turns regardless.

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