THE BUILT ENVIRONMENT SECTOR IN AUSTRALIA

R&D INVESTMENT STUDY: 1992-2010

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SUMMARY

Australian industry has experienced a marked interest in construction R&D over the past twenty years. 'Construction' was designated as a socio-economic objective for nearly 7% of Australian business R&D in 2009-10, up from just 1% in the early 1990s. This transformation appears to date from around 2000-01. Australian business R&D focused on the socio-economic objective of 'construction' grew in line with total business R&D during the 1990s, but then surged dramatically between 2000-01 and 2009-10.

This change, moreover, has been closely aligned with the Australian construction industry, as opposed to other industry sectors in the Australian economy. In 1992, at least 43% of Australian business R&D focused on the socio-economic objective of 'construction' was performed outside the construction industry; yet by 2009-10, it is possible that as little as 13% of Australian business R&D focused on this socio-economic objective was performed outside the construction industry. R&D in the construction industry also appears to have grown far more rapidly than that in those specific areas of manufacturing involved in the creation of inputs to the construction sector.

As a consequence, by 2009-10, the Australian construction industry's R&D expenditures exceeded $975 million. Remarkably, in that year, R&D in the Australian construction industry occurred on a scale that was in excess of that in the motor vehicle manufacturing industry and also with that in pharmaceutical manufacturing, pharmaceutical wholesaling, and medical devices manufacturing combined. The growth in R&D investment within the construction industry has also recalibrated Australia's intensity of investment relative to international competitors. R&D expenditure in the Australian construction industry rose from 0.02% of value added in 1990 to 0.6% in 2006 – in line with that in other leading nations, such as South Korea and Finland.

By any measure, this represents a remarkable change, and it is only natural to wonder what might have caused such a transformation. Contrary perhaps to expectation, at first glance there are reasons for scepticism about the potential role of researchers in the public sector. Over this same period, construction seems to have lost favour in many public institutions. Indeed, it has been a socio-economic objective for an ever-reducing proportion of R&D in universities and government agencies.

Between the early 1990s and 2010, although absolute spending in universities rose, the proportion of Australian university R&D focused on the socio-economic objective of 'construction' fell from 2.3% to 1.4% of total Australian university R&D expenditures. Worse still, government intramural spending on 'construction' R&D actually declined from $40 million in 1992 to $17 million in

2008, and the proportion of government sector R&D focused on the socio-economic objective of 'construction' plummeted from 2.2% to 0.5% of total government sector R&D expenditures.

In light of these trends, business has supplanted the public sector as the major player in construction R&D in Australia. In the early 1990s, Australian public institutions were spending 2.9 times more on construction-related R&D than Australian businesses did; yet by 2008, Australian businesses were spending 7.9 times as much on construction-related R&D as public research institutions. This recognised though, there is tentative evidence for a potential public sector influence on the growth in R&D activity that has occurred within the construction industry – or at least within one part of it.

The construction industry can be divided into three sectors: (i) the building construction sector, (ii) the heavy and civil engineering construction sector, and (iii) the construction services sector. If one studies the distribution of R&D investment by field of research within these sectors, it turns out that:

(i) the *building construction sector* has a strong emphasis in the fields of 'civil engineering' and 'built environment and design', but very modest activity in other areas;

(ii) the *heavy and civil engineering construction sector* has an equally strong emphasis on 'civil engineering', some emphasis on 'interdisciplinary engineering' and 'resources engineering' and in 'information and computing sciences', but only negligible investment in the field of 'built environment and design'; while

(iii) the *construction services sector* has only moderate activity in 'civil engineering' and in 'built environment and design', but supports an eclectic range of disciplines with a particular emphasis on 'information and computing sciences' and 'mechanical engineering'.

Using these fields as broad markers of relevance, we are able to identify the extent to which Australian public researchers are working in fields broadly relevant to the industry. Furthermore, given that the vast majority of public sector R&D relevant to the construction industry now occurs in universities rather than in government agencies (such as CSIRO) we focus our attention for this analysis on universities.

By doing this, we reveal that although universities now perform relevant research on a scale that is small relative to total spending within their local construction industry, they do still have sufficient scale in relevant fields to be visible to the construction firms in their region.

In all states, the amount of university R&D in fields relevant to the construction industry as a whole appears roughly comparable with the level of R&D specifically within the *construction services sector*. Furthermore, with the exception of Queensland (where university investment is relatively low and

business investment is extremely high), there appears to be a geographic relationship between the volume of university R&D in construction-related fields and the volume of R&D performed within the construction industry.

Interestingly, we also find that the discipline portfolio specifically in the *building construction sector* has converged remarkably closely with that found in universities over recent years, with strong growth in the 'building' field, which is a subset of the field of research category known as 'built environment and design'. We reveal that there has also been strong growth in ARC funding into this field, largely driven through ARC Linkage Project grants, suggesting that some of the expansion in private sector research specifically in the *building construction sector* may have had implications for the university sector and vice versa.

Finally, we also note a potentially unique role for the CRC for Construction Innovation over the decade from 2001. The CRC operated as a national research network involving 28 member organisations. When it was founded, the scale of its own, internal research activity was quite significant in the Australian context – roughly equivalent to 10% of Australia's business R&D relating to construction. It may be no coincidence that the year this CRC was founded (2001) was also the year that Australian construction businesses first began to ramp up their own R&D investments.

1. BACKGROUND

Between the early 1990s and the present, there has been tremendous growth in Australian industry investment in research and development (R&D) relevant to the built environment. This is true in absolute terms, in the level of R&D growth relative to that in other industries, and in the level of R&D growth relative to that in the public sector.

In this context, the Sustainable Built Environment National Research Centre (SBEnrc) is undertaking a major project to examine the R&D and innovation activities of firms and organisations operating in the construction and built environment space. This project will develop a research roadmap for the Australian built environment sector, and will propose public and private policies to improve returns from R&D investment in this area. As an input to this larger project, our report provides a background analysis of underlying trends in Australian R&D investment for the period 1992 to 2010.

1.1 Justification for the work

There has been a notable increase in business investment relating to the built environment over recent times. Table 1.1 summarises this transformation by presenting R&D expenditures across the public and private sectors within the socio-economic objective of 'construction' as defined in the Australian Bureau of Statistics (ABS) R&D surveys.

Table 1.1 – National R&D trends in 'construction' socio-economic objective

	Business R&D		Public R&D	
	$	**As % of Aus. business total**	**$**	**As % of Aus. public total**
1992-93	27 million	0.9%	78 million	2.2%
2008-09	1.12 billion	6.5%	136 million	1.2%
2009-10	1.13 billion	6.8%	*Not yet available*	

Note: (i) Derived from ABS 8112 and ABS 8104. (ii) Shows R&D expenditures by sector focused on the socio-economic objective 'construction'. (iii) 'Public R&D' counts R&D from the university sector and from state and federal government agencies. (iv) Dollar values are shown in current terms – i.e. without the use of multipliers to account for inflation.

Some of the noteworthy points raised in this table are:

- *High business expenditure* – Australian businesses reported over $1 billion in R&D projects focused on 'construction' objectives in 2008-09 and in 2009-10.

- *Growing business focus on construction R&D* – 'Construction' was also a socio-economic objective for nearly 7% of business R&D in 2009-10, up from less than 1% in the early 1990s.

- *Diminishing public focus on construction R&D* – Over the same period, however, 'construction' was a socio-economic objective for an ever-reducing proportion of R&D in universities and government agencies.

The aim of this report is to explore the nature of these trends in a quantitative manner. The ensuing analysis sets out to present new and detailed information about the different levels of R&D investment in the public and private sectors, and the different focus within these sectors by field of research.

1.2 Analytical approach

There are many ways to contrast R&D investment, but in this report we have kept things simple. Section 2 looks specifically at what has happened in the private sector since the early 1990s. Section 3 studies trends in the public sector. While section 4 seeks to compare trends across sectors, highlighting gaps, and making recommendations.

The analysis in this report uses data derived from a variety of sources, the main datasets being:

- the Australian Bureau of Statistics R&D expenditure surveys (ABS 8112, ABS 8104, ABS 8111, and ABS 8109);

- the Organisation for Economic Cooperation and Development STAN Database for Structural Analysis (OECD STAN);

- the Australian Research Council data on national competitive grant funding (ARC 2010); and

- CRC programme data.

The data have been analysed to show trends over the past decade (and where possible trends from the early 1990s), to break down R&D activity by field of research, socio-economic objective, and industry sector. Values are universally presented in current dollars (i.e. without adjusting for inflation). Investment in built environment R&D has also been normalised in certain instances against the relative significance of the construction industry in the broader economy.

Much of the data used in this report is publicly available. Some of it however is derived data. In this respect, a note must be made about the information on Australian business R&D spending by industry sector and field of research. These data have been derived from the ABS survey of business R&D expenditures using a proprietary model developed over several years by the author, and are not

publicly available. This particular model, however, has been used by many organisations operating in the Australian innovation system over recent years.

It should also be recognised that the dependence on ABS R&D surveys provides indicative information only. Surveys are a useful but imperfect mechanism for collecting data on R&D. They are influenced by different interpretations of what constitutes R&D – despite the common acceptance by Australian and international policy makers of an established definition (OECD Frascati). As a consequence these data are more useful in identifying the direction of trends than in pinpointing their exact magnitude.

The approach, in other words, cannot be seen as definitive. The main benefit of this sort of analysis is in pointing to the key issues, and in highlighting some of the questions that need to be answered through other, more qualitative forms of research. The implications of this study then are clear, but they are not definitive. This report should be read in the context of SBEnrc's other, ongoing research on Australia's built environment R&D system.

1.3 Definitions

This analysis looks at R&D activity, predominantly as reported by three broad sectors: Australian businesses, Australian universities, and government agencies. The latter category includes both state and federal agencies. Within the business sector broadly, we also look at several industry sectors. In doing this, we adhere to the classification systems developed by the ABS, first in 1993 and then in 2006. Where there is a change in classification, and we present a trend in the data, we have tried to present these transitions in a rational way.

According to the ABS methodology, within the construction industry there are three sectors. For future reference, these are summarised in table 1.3a, which contrasts the classification system we use for the construction industry with an equivalent scheme for the mining industry.

Table 1.3a – Industry sector classification for construction and mining

Industry	Sectors
Construction industry	Building construction
	Civil & heavy engineering construction
	Construction services
Mining industry	Coal mining
	Oil and gas extraction
	Metal ore mining
	No-metallic mineral mining & quarrying
	Exploration & other mining support services

Note: Category names are derived from the ANZSIC06 classification scheme as used in ABS 8104.

Note that the ABS over the years has used various category terms in order to classify Australian industry. In this report, following the practice established in

table 1.3a, we will refer to the 'construction industry' when talking about the industry as a whole, but will refer to the *building construction sector*, or the *civil and heavy engineering construction sector*, or the *construction services sector* when dealing more specifically with those specific subsections of the industry.

In addition to looking at patterns of activity by sector of performance, we also present data (as in table 1.1) that classifies R&D according to socio-economic objective. Table 1.3b lists the key categories for socio-economic objective as used by the ABS. In our analysis we look at R&D reported under the category 'construction', which is listed as one of the objectives under 'economic development'. Note that any organisation can report R&D under the 'construction' socio-economic objective. It is not necessary for it to be part of the construction industry to do so.

Table 1.3b – Socio-economic objective categories

Objective
Defence
Economic development
Plant production and plant primary products
Animal production and animal primary products
Mineral resources (excl. energy resources)
Energy
Manufacturing
Construction
Transport
Information and communication services
Commercial services and tourism
Economic Framework
Society
Health
Education and training
Law, politics and community services
Cultural understanding
Environment
Expanding Knowledge

Note: Derived from ABS 8104, ABS 8109, ABS 8111, and ABS 8112.

Another definitional matter relates to the designation of fields of research. Fields of research are typically associated with a particular expertise or discipline and are quite distinct from the other categories we deal with, such as sectors or socio-economic objectives.

Unfortunately, over the period of our analysis, the ABS used three different classification schemes for field of research, with one transition occurring after 1998 and a second in 2008. The first of these transitions is not important for our

analysis, but the second creates some complications, not least in the latter part of this report, where we compare R&D investments by field of research in 2008 with R&D investments made in earlier years. For this reason, we provide below two correspondence tables showing the relationship between two important field categories in the 1998 and 2008 classification schemes.

Table 1.3c shows the concordance between the 1998 and 2008 classifications of the field of 'civil engineering'. Here there is only one minor difference relevant to our analysis. This is the transfer of one part of the field of 'geotechnical engineering' into the field of 'resources engineering and extractive metallurgy' in 2008. With this minor change, it would seem that it is quite appropriate to compare R&D activity classified as 'civil engineering' in 2008 with that classified in a similar way in previous years.

Table 1.3c – Field of research classification schemes, correspondence table for the field of 'civil engineering'

1998 RFCD classification	2008 FOR classification	FOR code 2008
Civil Engineering	**Civil Engineering**	**0905**
Structural engineering	Structural engineering	090506
Water & sanitary eng.	Water quality engineering	090508
	Water resources engineering	090509
Transport engineering	Transport engineering	090507
Construction engineering	Construction engineering	090502
Civil engineering n.e.c.	Construction materials	090503
	Earthquake engineering	090504
	Infrastructure eng. & asset mgmt	090505
	Civil engineering n.e.c.	090599
Geotechnical engineering	Civil geotechnical engineering	090501
	Resources eng. & extr. metallurgy	**0914**
	Geomechanics & resources geotech. eng.	091412

Note: (i) Derived from ABS 1297. (ii) The Field of Research (FOR) classification replaced the Research Fields, Courses and Disciplines (RFCD) classification in 2008. Fields are shaded, while their subfields are grouped so as to reflect concordance across the two time frames. (iii) FOR codes for the 2008 classification scheme are shown in the final column. (iv) Abbreviations: eng. stands for engineering; mgmt stands for management; extr. stands for extractive; geotech. stands for geotechnical; and n.e.c. stands for "not elsewhere classified".

The situation is slightly more complicated in the field of 'built environment and design'. Table 1.3d shows that this classification was created in 2008 by merging the previous field of 'architecture, urban environment and design' with selected fields from 'arts' and 'engineering and technology'. In this instance, there is good concordance between 'architecture' in 1998 and 'architecture' and 'urban and

regional planning' in 2008. There is also good concordance in the research field of 'building' across both classification schemes.

This observed, though, the 2008 fields of 'other built environment & design', 'design practice and management' and 'engineering and design' all incorporate activities from 'arts' and 'engineering and technology' in the 1998 classification scheme. This means that one has to be careful about comparing R&D expenditures reported in the field of 'architecture, urban environment and building' prior to 2008 with those classified within 'built environment and design' in 2008. In interpreting trends over time, we are very sensitive to these classification changes.

Table 1.3d – Field of research classification schemes, correspondence table for the field of 'built environment and design'

RFCD classification 1998	FOR classification 2008	FOR code 2008
Architecture, urban environ. & blg	**Built environ. & design**	
Architecture & urban environment	Architecture	1201
	Urban & regional planning	1205
Building	Building	1202
Other architecture, urban environ. & blg	Other built environ. & design	1299
Arts		
The Arts n.e.c.		
Engineering & technology		
Engineering & technology n.e.c.		
Arts		
Design studies	Design Practice & mgmt	1203
Engineering & technology		
Other engineering & technology	Engineering & design	1204

Note: (i) Derived from ABS 1297. (ii) The Field of Research (FOR) classification replaced the Research Fields, Courses and Disciplines (RFCD) classification in 2008. Fields are shaded, while their subfields are grouped so as to reflect concordance across the two time frames. (iii) FOR codes for the 2008 classification scheme are shown in the final column. (iv) Abbreviations: environ. stands for environment; blg stands for building; mgmt stands for management; and n.e.c. stands for "not elsewhere classified".

There are two final comments to be made about research fields. First, throughout our text, we use single quotation marks when discussing a field of research, as a way of flagging our use of specific ABS categories. Second, the ABS tracks field categories using numerical codes, customarily referred to as "FOR codes". Researchers used to dealing with these codes will think of some fields as "2-digit", others as "4-digit", and still others as "6-digit" depending upon their place in the classification hierarchy used by the ABS. In our analysis we deal with fields

at all levels of this hierarchy, and sometimes we group fields in novel ways order to aggregate data to illustrate particular trends. Where we do this, and where we also give a name to such a cluster of fields, we will again use single quotes to indicate that we are talking about a precisely defined term.

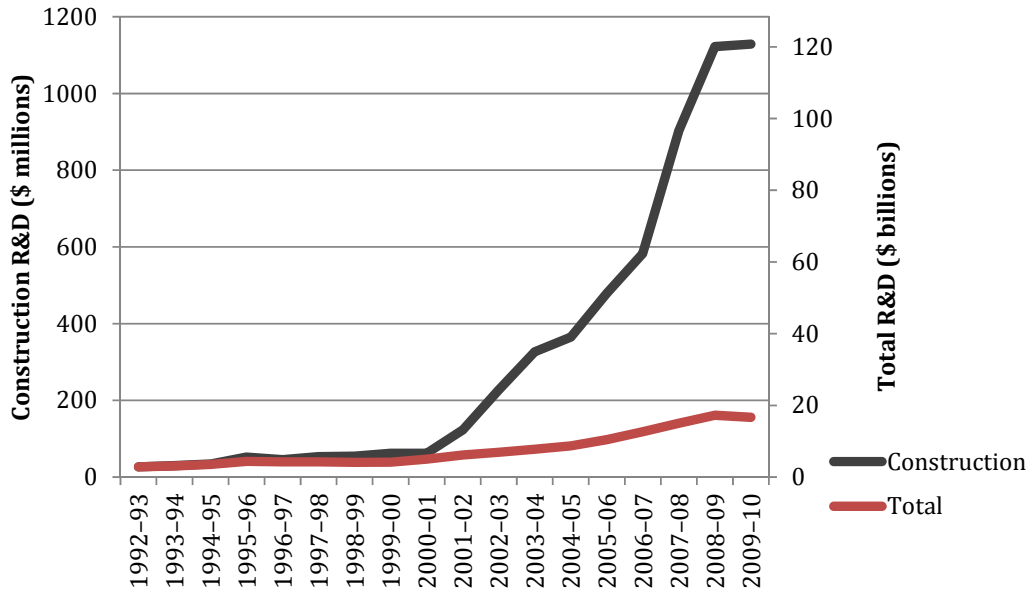
2. TRENDS IN THE PRIVATE SECTOR

There are several ways of presenting the growth in Australian private sector R&D relevant to the built environment. Here we look at the growth in investment using data on socio-economic objective, industry sector, and field of research. We make comparisons with international trends, and with trends in other sectors of Australian industry. We show that private sector R&D activity relevant to the built environment has expanded dramatically over the past decade.

2.1 The growth of private sector R&D investment

From the early 1990s to the present, there was a remarkable transformation in the scale and intensity of business investment focused on the built environment. This is illustrated in figure 2.1a, which compares Australian business R&D expenditures focused on the socio-economic objective 'construction' with total business R&D expenditures across on all socio-economic objectives.

Figure 2.1a – Growth in 'construction' R&D relative to total business R&D



Note: (i) Derived from ABS 8109. (ii) Compares business R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total business R&D expenditures (right axis). (iii) The right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

In interpreting this figure, one must acknowledge that business investment in construction R&D started from an extremely low base in the early 1990s. Nonetheless, this graph provides an intuitive impression of the rapid growth in construction R&D relative to the growth in total Australian business R&D. It also highlights an interesting facet of this expansion: the sudden increase in construction R&D activity at the turn of the century.

- *Business R&D focused on construction surged after 2000-01* – Business R&D focused on the socio-economic objective of 'construction' grew in line with total business R&D during the 1990s, but then surged dramatically between 2000-01 and 2009-10.

What is true, moreover, of socio-economic objective broadly applies to the construction industry more specifically. Table 2.1b compares total Australian business R&D investment in the 'construction' socio-economic objective with R&D investment specifically in the Australian construction industry. It is useful to look at the trends across both these dimensions as (a) some proportion of R&D in the construction industry will be focused on other socio-economic objectives and (b) some of the R&D focused on 'construction' objectives will occur outside the construction industry.

Table 2.1b – Business R&D trends in construction

	Socio-economic objective: construction		**Industrial sector: Construction industry**	
	Current $	**As % of Aus. business total**	**Current $**	**As % of Aus. business total**
1992-93	$27 million	0.9%	$15 million	0.5%
2009-10	$1.13 billion	6.8%	$977 million	5.9%

Note: (i) Derived from ABS 8104. (ii) Shows Australian business R&D expenditures focused on the socio-economic objective 'construction' and reported by the construction industry.

Significantly, if unsurprisingly, the data in this table indicate that most of the growth in investment focused on the socio-economic objective of 'construction' has occurred within the construction industry. From this table, we can deduce the following:

- *Business R&D growth in the construction industry has been dramatic* – Between 1992-93 and 2009-10, the construction industry increased its R&D spending from $15 million to $977 million, growing its share of total Australian business R&D expenditure from less than 1% to nearly 6%.

- *Coalescence of activity within the construction industry* – In 1992-93, at least 43% of Australian business R&D focused on the socio-economic objective 'construction' was performed outside the construction industry. By 2009-10, however, it is possible that as little as 13% of Australian business R&D focused on the socio-economic objective 'construction' was performed outside the construction industry.

Given the apparent dominance of the construction industry in construction-related R&D, it would seem reasonable to assume that most of the major trends in business R&D that are relevant to the built environment will be revealed through an analysis of the construction industry. Later in this section, we will make the argument that four other industry sectors are responsible for most of the construction-related R&D that occurs outside the construction industry in Australia. These are the ABS industry categories: (i) the *professional, scientific*

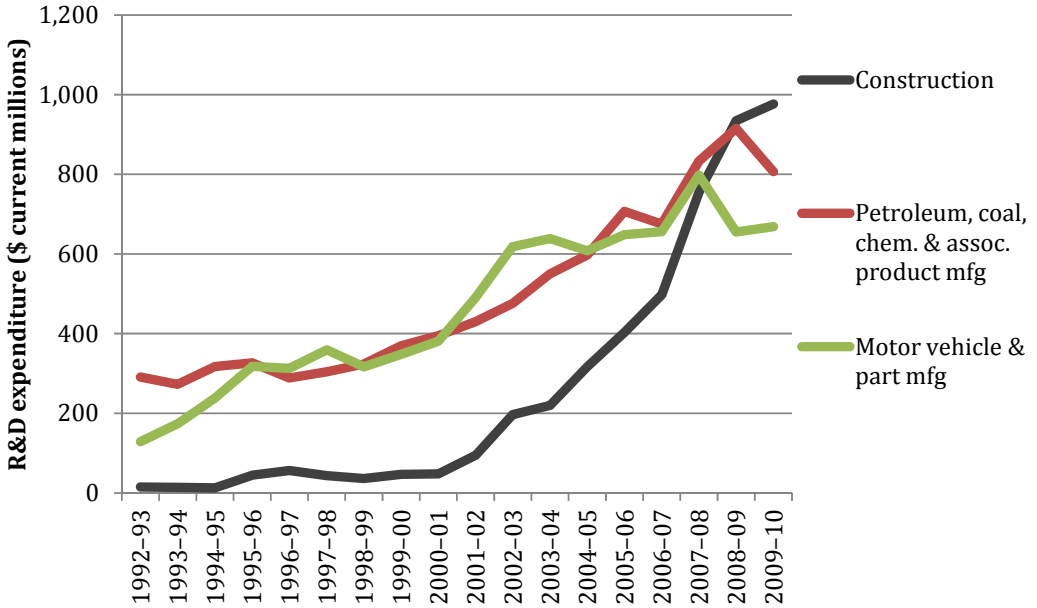
and technical services industry; (ii) the *mining industry*; (iii) the *manufacturing industry*; and (iv) the *transport support services industry*. In the meantime, though, it seems justifiable to focus our analysis on the construction industry.

2.2 Comparisons with other industry sectors

The construction industry was not alone among Australian businesses for the dramatic surge in R&D investment it reported between 2000-01 and 2009-10. Figures 2.2a and 2.2b contrast the growth in R&D spending within the construction industry with that in five other sectors of the Australian economy. These graphs enable some interesting comparisons.

On the one hand, figure 2.2a shows that the growth in R&D spending in the construction industry was very strong in comparison to that in chemical manufacturing (including pharmaceuticals) and in comparison to that in motor vehicle manufacturing. Indeed by 2009-10 the level of R&D expenditure in the construction industry was on a par with that in both these other sectors – although the R&D in those other areas arguably still retains much greater visibility in the wider Australian community.

Figure 2.2a – Comparing the construction industry with chemical and motor vehicle manufacturing

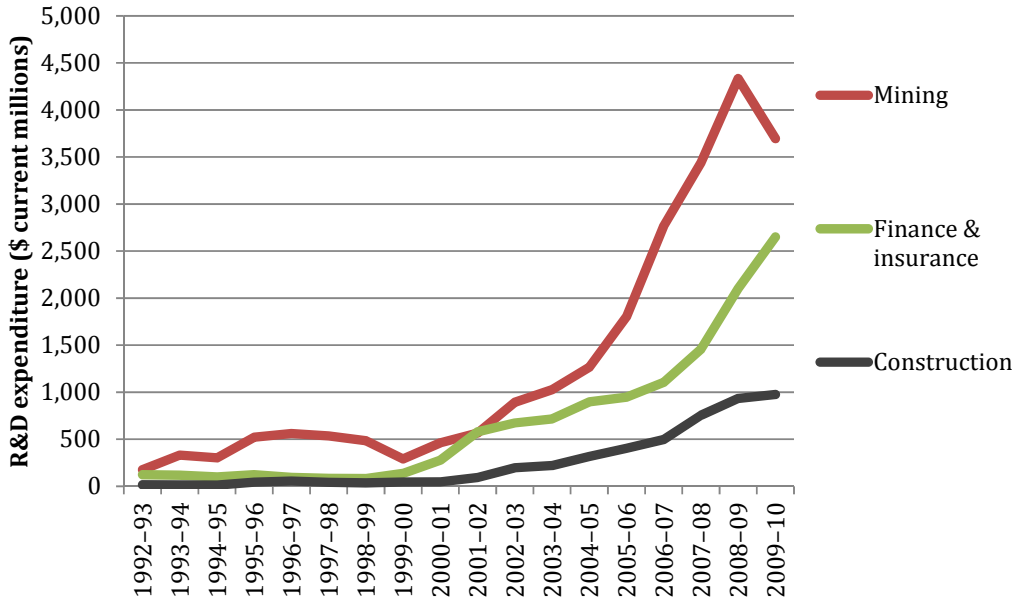


Note: (i) Derived from ABS 8104. (ii) There was a classification change in the definition of industry sectors after 2006-07.

Figure 2.2b, by contrast, shows that other industries also experienced a dramatic expansion in R&D activity, closely analogous to that in the construction industry. Although not immediately obvious from the figure, between 1992-93 and 2009-10 the growth rates in R&D investment within the construction industry were actually higher than those in the mining sector or the finance sector. But as figure

2.2b reveals, in 2009-10 the absolute spend on R&D in these other sectors still remained considerably greater than was true in the construction industry.

Figure 2.2b – Comparing the construction industry with mining and finance



Note: (i) Derived from ABS 8104. (ii) There was a classification change in the definition of industry sectors after 2006-07.

Unfortunately, it is not possible to unpack the industry R&D data over this extended timeframe using more detailed industry classifications than those shown above, but there is interesting data available at the level of industry subsectors from 2005-06 to 2009-10.

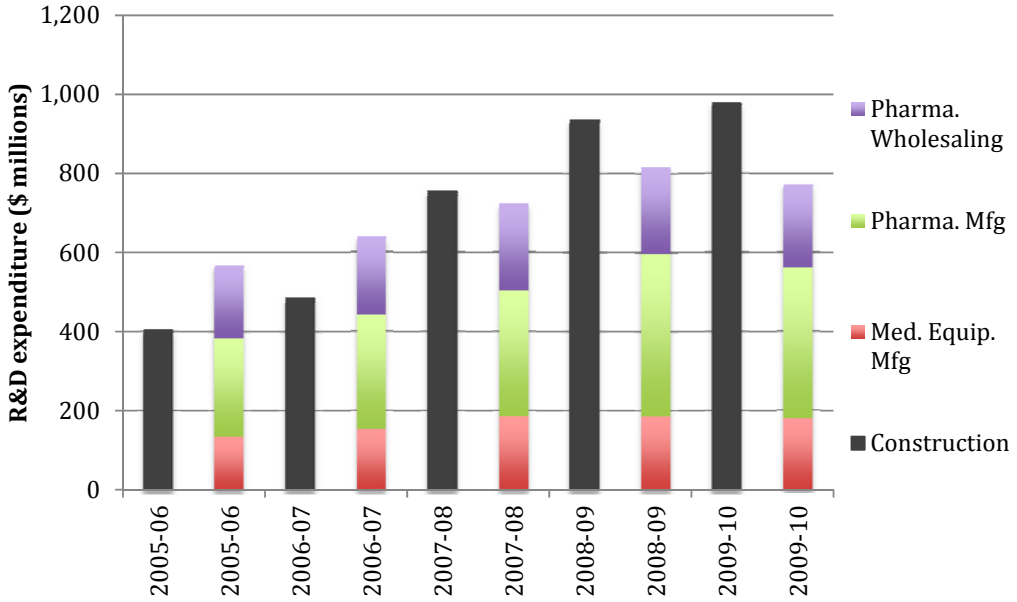
Figure 2.2c presents some of this data by contrasting R&D spending in the construction industry over this five-year period with that reported in (a) pharmaceutical manufacturing, (b) pharmaceutical wholesaling, and (c) medical and surgical equipment manufacturing. These are especially interesting industry sectors to point to, as they are commonly regarded as high-tech areas, responsible for high levels of R&D investment in the Australian economy. Yet the data show that a transition occurred in 2007, so that there is now more R&D expenditure in the Australian construction industry than in these three other sectors combined.

- *A favourable comparison with other industry sectors* – R&D in the Australian construction industry now occurs on a scale that is comparable with that in the motor vehicle manufacturing sector and also with that in pharmaceutical manufacturing, pharmaceutical wholesaling, and medical devices manufacturing combined.

It should be recognised that there are complications in interpreting these trends. Australian businesses in the scientific research services sector reported R&D expenditure of $724 million in 2008-09 and $666 million in 2009-10. Some of

this activity would have had a focus on pharmaceuticals or on medical biotechnology. Because of their business model, many of Australia's biotechnology companies are likely to have classified themselves within this industry sector, rather than as pharmaceutical manufacturers or wholesalers.

Figure 2.2c – Comparing the construction industry with high-technology medical manufacturing



Note: (i) Derived from ABS 8104. (ii) Does not include data reported by firms in the 'professional, scientific and technical services' sector.

There is also a distinction to be drawn in the levels of research versus development in all these sectors. Typically, 'research' is considered a process for acquiring new knowledge, while 'development' involves the systematic exploitation of existing knowledge. For the five years to 2009-10, only a third of R&D expenditures reported for the construction industry were designated 'research' as opposed to 'development'. This was a higher share than was true for the motor vehicle manufacturing industry, but a lower share than was the case in either the medical equipment manufacturing industry or the pharmaceutical manufacturing industry.

Nonetheless, the data do tell an interesting story. They point to potential innovation and knowledge-intensity in the Australian construction industry. They provide surprising comparisons with other sectors of Australian business. They suggest that the Australian construction industry has potential to emerge with a new reputation for dynamism and ingenuity over the coming decade.

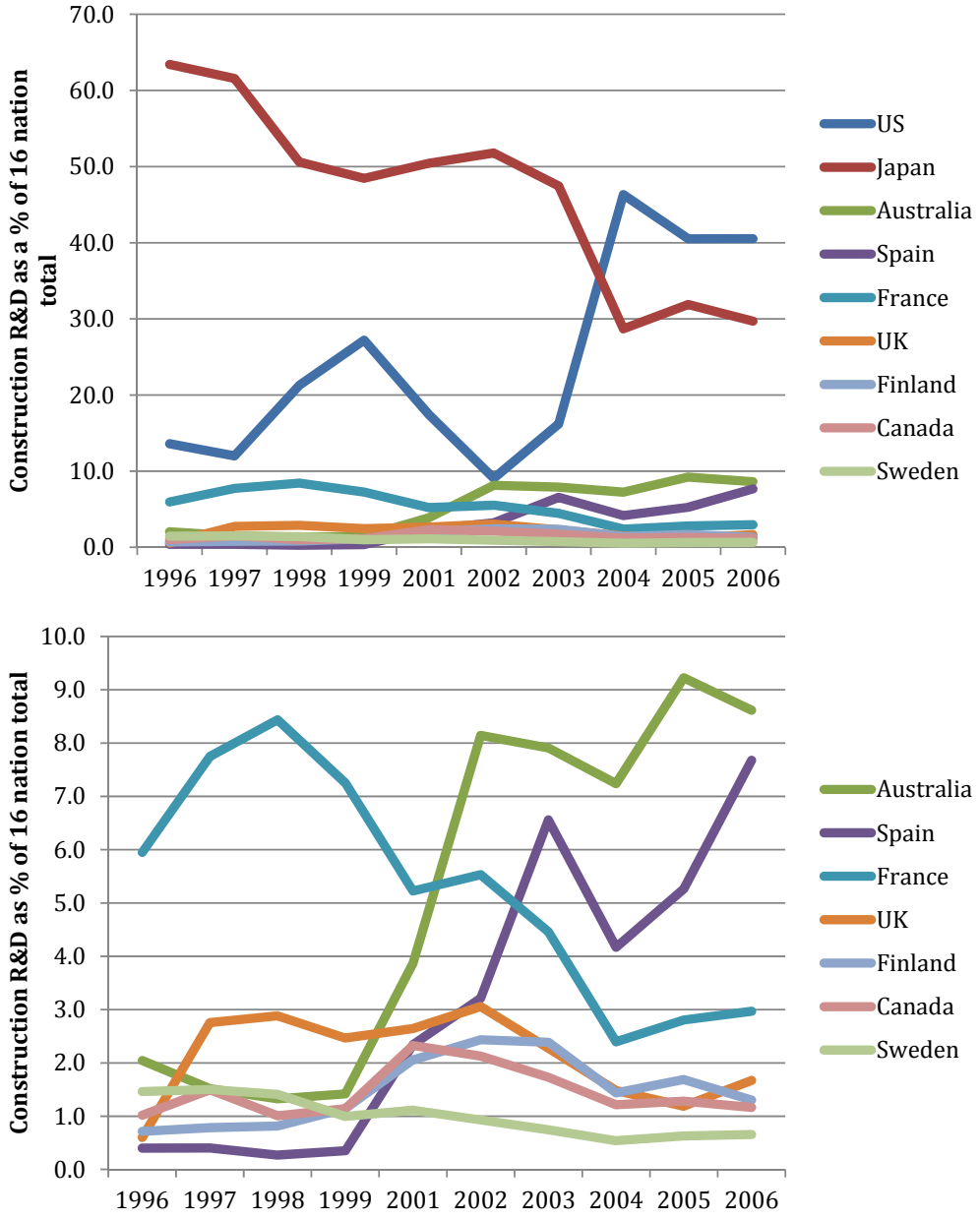
2.3 International comparisons

What is true at the national level appears to be confirmed, too, from an international perspective. Through its structural analysis database, the OECD collates data on industrial R&D activity in a format designed for international

comparisons. Figure 2.3a uses this dataset to show how the R&D activity of the Australian construction industry has grown in comparison with selected other OECD nations. It shows an interesting transformation.

- *Growing scale relative to international competitors* – Over the past decade, Australian businesses have dramatically increased their share of global construction R&D.

Figure 2.3a – R&D in construction industry as a share of 16 OECD nations



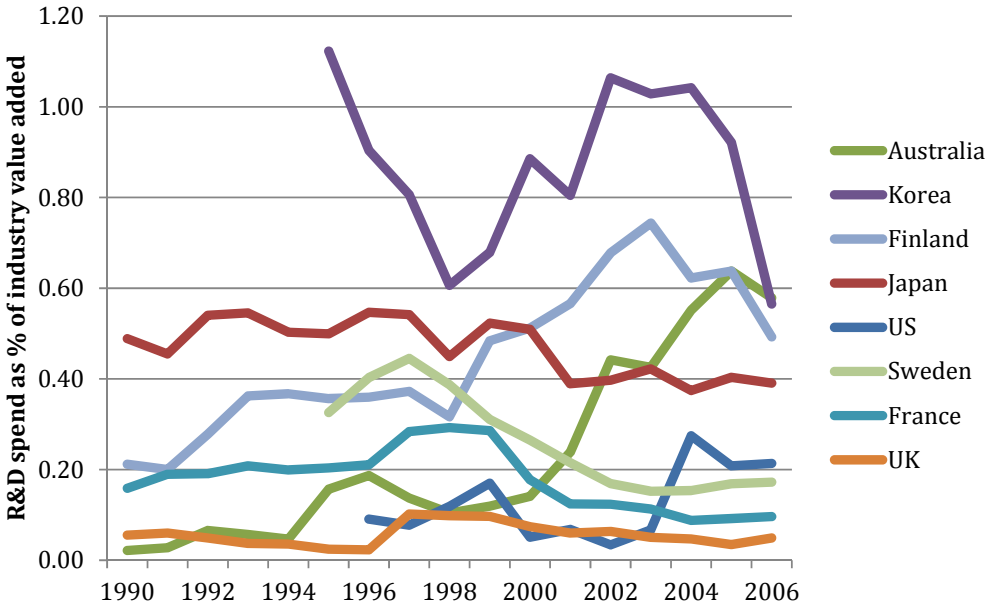
Note: (i) Derived from OECD STAN. (ii) R&D expenditures in the construction industries are shown as a % of that of 16 OECD nations combined: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Turkey, UK, and the US.

Mirroring this expansion, it is worth noting that the Australian construction industry has also increased its intensity of investment in R&D. Figure 2.3b shows R&D expenditure in the construction industry as a share of industry value added for several nations. Note that industry value added is measure of an industry's net output within the economy – i.e. it is a measure of an industry's share of the economy.

Figure 2.3b thus provides an effective indicator of the role of R&D within the business models of construction firms in different countries. It shows that R&D investment in the Australian construction industry has been growing considerably faster than net construction industry output. It shows that the growth in Australian construction R&D is due not only to the economic expansion of the sector, but also to a growing commitment to R&D within the industry.

- *Growing intensity of R&D investment relative to international competitors* – R&D expenditure in the Australian construction industry rose from 0.02% of value added in 1990 to 0.58% in 2006, in line with that in other leading nations, South Korea and Finland.

Figure 2.3b – R&D intensity in the construction industry



Note: (i) Derived from OECD STAN. (ii) Industry value added is an industry's net output within the economy – i.e. it is related to an industry's share of GDP. (iii) The nations shown include the four with the highest R&D intensity in the construction industry: South Korea, Australia, Finland and Japan.

The construction industry is not a high-technology sector. In all countries, R&D spending as a share of industry value added is low in the construction industry compared with the intensity of R&D investment in high-technology manufacturing. In very high-technology industries, for example, R&D investment as a share of industry value added can exceed 10%.

It is important to be aware of this; yet we should not let it detract from our essential finding here. By benchmarking like with like, we have uncovered an important development. The Australian construction industry is emerging as a sector where Australia's intensity of R&D investment is on a par with world leaders.

2.4 An industry transformed

Every indication is that Australian industry has transformed its investment in construction R&D to a remarkable degree over the past two decades. This appears to be true both in the scale of investment in construction-related R&D across the Australian economy and in the intensity of investment within the Australian construction industry compared with international leaders.

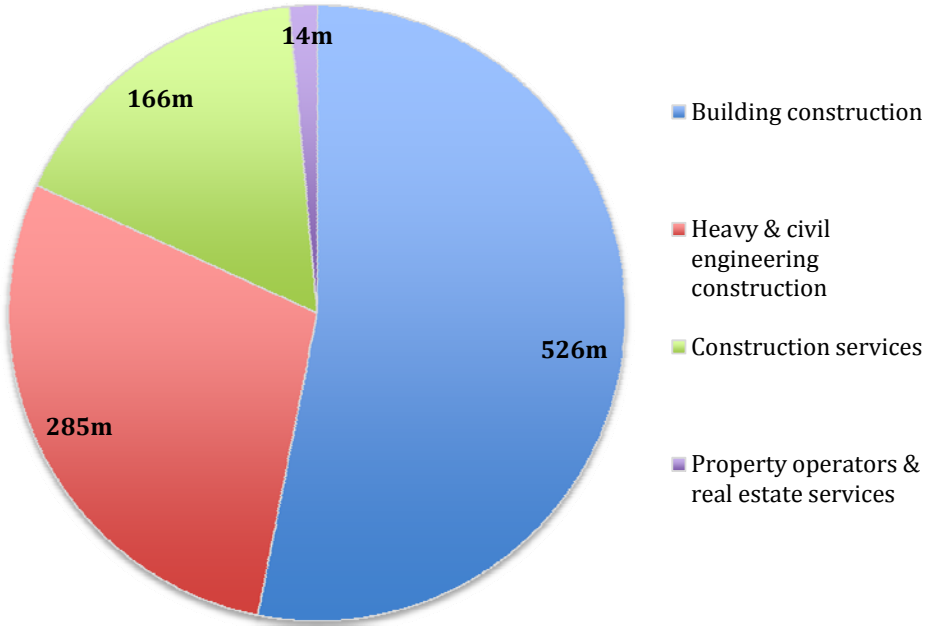
3. INDUSTRY FOCUS BY FIELD OF RESEARCH

Business R&D relevant to the built environment can be segmented by industry subsector and by field of research. Here we disaggregate the data in order to reveal the different roles in R&D investment played across different sectors of the construction industry, and to identify the key fields of research in which these sectors are focusing their efforts. In this section we focus largely upon a 2008-09 dataset originally released in 2010 (ABS 8104) and analysed to derive the fields of research in which different sectors concentrate their R&D resources (Barlow 2011). We demonstrate that the various segments of the construction industry have different technological foci in their R&D activity.

3.1 R&D investment by industry sector

The construction industry is broken up in the most recent ABS classification system into three sectors: the *building construction sector*, the *heavy and civil engineering construction sector*, and the *construction services sector*. Figure 3.1a shows the breakdown of R&D expenditure across these sectors in 2008-09. It reveals substantial R&D investment across all parts of the industry.

Figure 3.1a – Construction R&D by subsector, 2009-10



Note: (i) Derived from ABS 8104. (ii) *Property operators & real estate services* is a sector of the Rental, hiring and real estate services industry. The other three categories are sectors of the construction industry. (iii) Labels show business R&D expenditure by subsector in 2008-09.

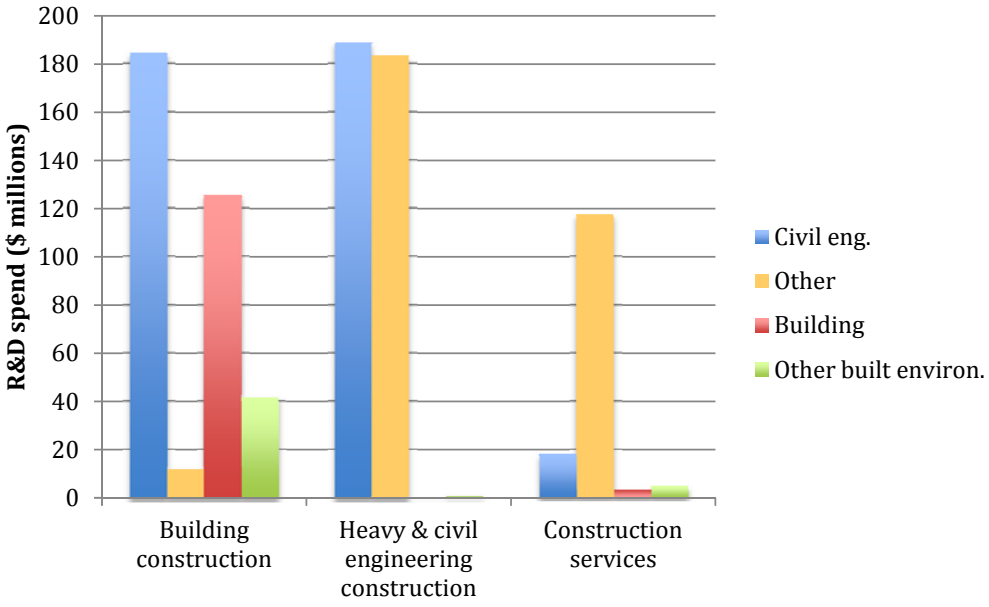
Also included in this figure is data on the property operators & real estate services sector. This is a sector of the rental, hiring and real estate services industry. This is included in the figure to show how modest the R&D activities

are in this industry, and to justify their exclusion from the subsequent analysis. Just for the record, though, over half the R&D in this sector is in focused around information, computing, and communications technologies.

Given the scale of R&D across the three sectors within the construction industry, it is useful to ask whether they have a similar or a distinctive disciplinary profile. Figure 3.1b addresses this issue, in a preliminary sense, by presenting R&D activity in each of these sectors by scale of investment in various fields of research, notably in the fields of 'civil engineering', 'building', and 'other built environment'.

In interpreting this figure, particular care should be taken to differentiate between the *building construction sector* (which is an industry classification) and 'building' (which is a field of research classification associated with a particular or domain of knowledge).

Figure 3.1b Construction R&D by industry sector and dominant field of research, 2008-09



Note: (i) Derived from ABS 8104 and Barlow 2011. (ii) 'Civil engineering' and 'building' correspond to ABS field of research categories, however: 'other built environment' refers to all built environment and design fields other than 'building'; and 'other' refers to all fields outside of civil engineering and built environment and design. (iii) For further background on definitions refer back to section 1.3.

It is clear from this figure that there are broad differences in R&D emphasis across different parts of the construction industry.

- *Building construction* – The *building construction sector* has a strong emphasis on civil engineering (51%), building (34%), and other built environment (12%), but very modest activity in other fields.

- *Heavy and civil engineering construction* – The *heavy and civil engineering construction sector* has an equally strong emphasis on civil engineering (51%), but only negligible investment in the field of built environment and design.

- *Construction services* – The *construction services sector* meanwhile has only moderate activity in civil engineering (13%) and in building and other built environment and design (6%), and has by far its strongest focus in other fields.

The different disciplinary mix observed in figure 3.1b implies that the nature of the R&D in each sector of the construction industry is quite different in style and objective. It also implies that opportunities for partnerships with public sector institutions will vary considerably by field across different parts of the industry. We turn now to look at this issue in greater detail.

3.2 Field focus by industry sector

If one studies the disciplinary portfolio – or, to put it another way, the emphasis by field of research – across the construction industry as a whole, one observes that there is a very strong focus on engineering, with 'civil engineering' (~$390 million) and other miscellaneous forms of engineering (~$240 million) accounting for the lion's share of R&D expenditures.

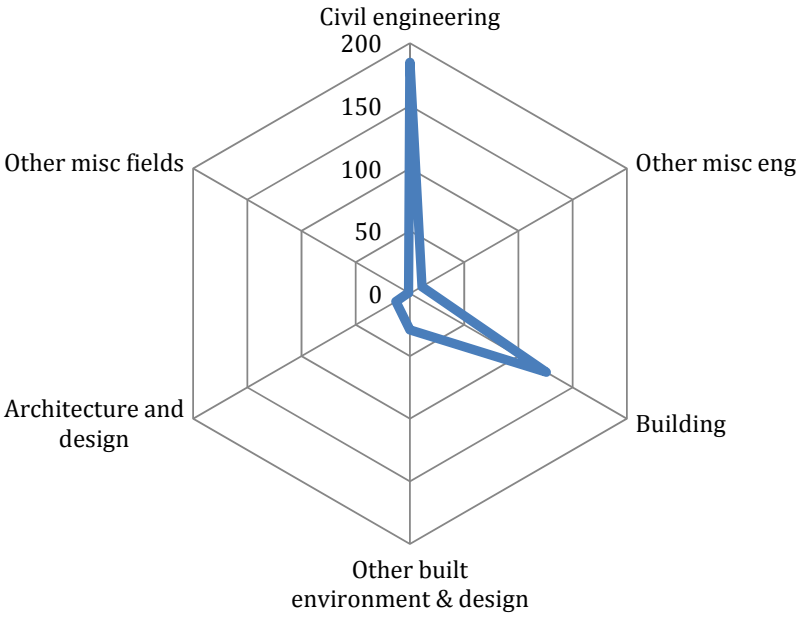
There is also strong activity in those fields relating to the built environment and design, with 'building' (~$130 million) and other areas of 'built environment and design' (~$50 million) accounting for most of the balance in R&D expenditures. Beyond these fields, the only area of substantial activity is in 'information and computing sciences' (~$45 million). Altogether, these fields account for 97% of all R&D expenditures in the construction industry.

As we have observed though, there are differences in emphasis by field of research across the three sectors of the industry. Figures 3.2a, 3.2b, and 3.2c show this in greater detail. In these diagrams, the critical fields of research are identified for each industry sector, and investment in each of these fields is shown.

These diagrams serve a dual purpose, for not only do they reveal the scale of investment in different fields within each sector, but they also indicate the degree of specialisation. Sectors with spikey graphs tend to have a high degree of disciplinary focus, while sectors with broader distributions are obviously making R&D investments across a wider range of disciplines.

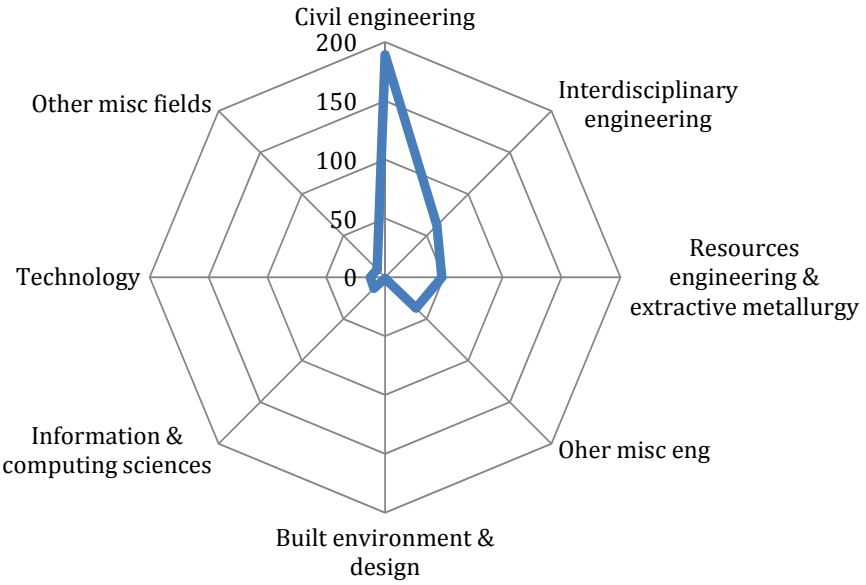
Figure 3.2a shows those fields of research where businesses in the *building construction sector* are focusing their efforts. Figure 3.2b shows those fields of research where business in the *heavy and civil engineering construction sector* are focused. While figure 3.2c shows those fields where businesses in the *construction services sector* are strongest.

Figure 3.2a – Fields focus in building construction sector



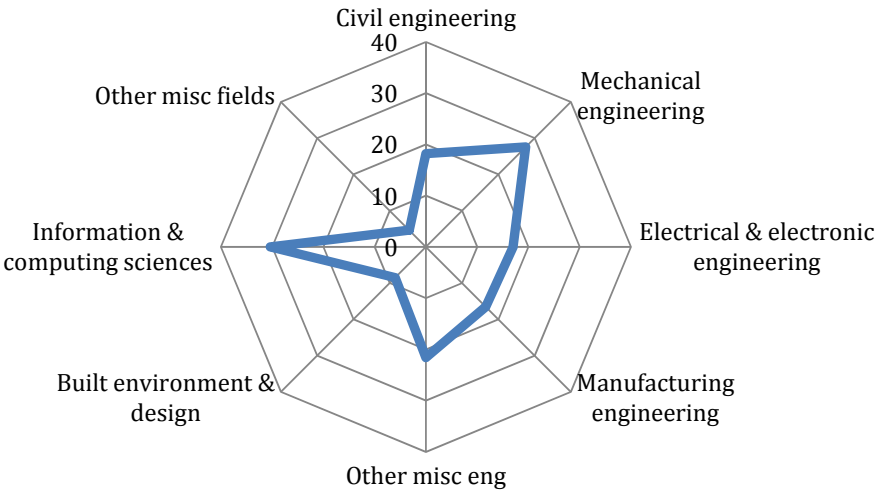
Note: (i) Derived from ABS 8104 and Barlow 2011. (ii) 2008-09 R&D expenditures are shown in $ millions. (iii) Fields correspond to ABS categories, with these exceptions: 'other misc eng' means all engineering fields apart from 'civil engineering'; 'other built environment & design' means the field of 'built environment and design' once the fields 'building' and 'architecture and design' have been excluded; and 'other misc fields' means miscellaneous fields other than those shown along other axes.

Figure 3.2b – Field focus in heavy and civil engineering construction sector



Note: (i) Derived from ABS 8104 and Barlow 2011. (ii) 2008-09 R&D expenditures are shown in $ millions. (iii) Fields correspond to ABS categories, with these exceptions: 'other misc eng' means all engineering fields apart from 'civil engineering', 'interdisciplinary engineering' and 'resources engineering & extractive metallurgy'; and 'other misc fields' means miscellaneous fields other than those shown along other axes.

Figure 3.2c – Field focus in construction services sector



Note: (i) Derived from ABS 8104 and Barlow 2011. (ii) 2008-09 R&D expenditures are shown in $ millions. (iii) Fields correspond to ABS categories, with these exceptions: 'other misc eng' means all engineering fields apart from 'civil engineering', 'mechanical engineering', 'electrical & electronic engineering', and 'manufacturing engineering'; and 'other misc fields' means miscellaneous fields other than those shown along other axes.

From these figures, it is clear that (i) the *building construction sector* emphasises 'civil engineering' and 'building' R&D, (ii) the *heavy and civil engineering construction sector* is heavily focused on 'civil engineering', 'interdisciplinary engineering' and 'resources engineering', with a smidgeon of 'information and computing sciences' activity included, while (iii) the *construction services sector* supports an eclectic range of disciplines, with a particular emphasis on 'information and computing sciences' and 'mechanical engineering'.

These comparisons will be very useful in the next section, where we consider the orientation of public R&D in Australia, and its relevance to the construction industry. A key marker that we will use in this respect is the ratio of investment between 'civil engineering' and the field of 'built environment and design' (which encompasses the field of 'building').

3.3 Outside the construction industry

The above analysis is inevitably incomplete. First, there would be research that some businesses classify within the fields of 'civil engineering' or 'building' which might equally be categorised as 'information science' or 'materials engineering' or within some other field. The nature of the R&D survey run by the ABS, and the classifications used, probably makes the construction industry's R&D portfolio appear narrower than is true in practice.

Second, we know there is considerable R&D relevant to the built environment, taking place across industries other than the construction industry. We know this from the discrepancy between the data on socio-economic expenditure and the data on expenditure by industrial sector, as presented previously in table 2.1b.

There is not a lot that can be done in relation to the first of these points. R&D expenditure analysis is useful for identifying trends, but more specific issues would need to be teased out using case studies or through independent consultation with firms active in R&D. It is possible, however, to make some comments in relation to the second issue. One can, for example, use the fields of research identified above to get a handle on which other industries are most likely to be involved in construction-related R&D.

Using R&D investment in 'civil engineering' and 'built environment and design' as markers of greatest relevance, the key industries that stand out as having some relation to the construction industry are as follows.

- *Mining* – The mining industry spent $85 million on 'civil engineering' R&D in 2008-09. It also spent $26 million in 'built environment and design'. However, spending in this latter field was all within the subfield of 'engineering design' and probably is not directly relevant to the built environment sector.

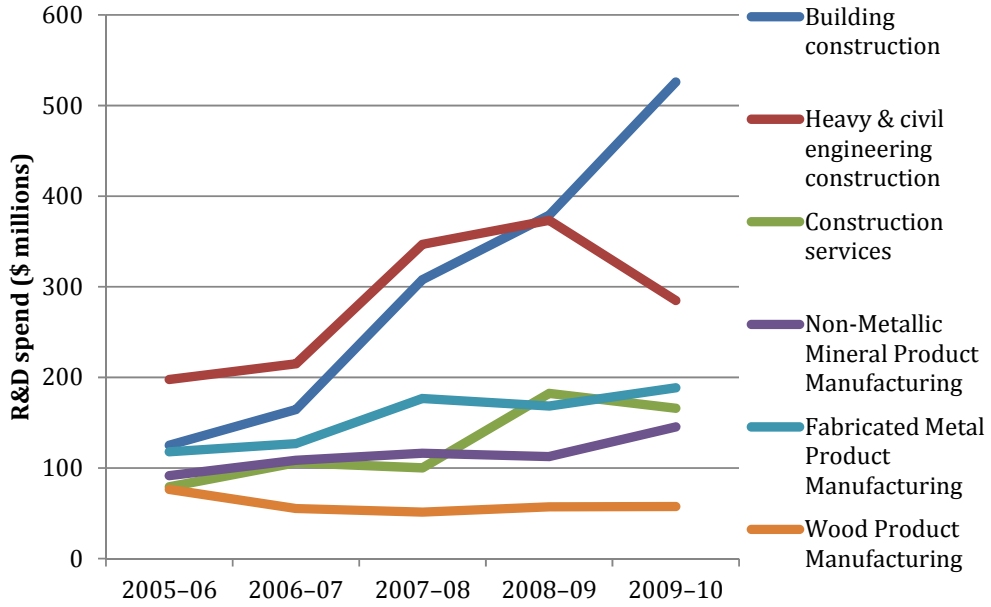
- *Manufacturing* – Several areas of manufacturing supported R&D relevant to our study in 2008-09. The non-metallic mineral product manufacturers spent $110 million on R&D, of which an estimated $15 million was designated 'civil engineering'. The fabricated metal product manufacturers spent $170 million on R&D, of which an estimated $6 million was designated 'civil engineering' and $3 million was designated in the field of 'building'. The wood product manufacturers spent $45 million on R&D, of which $4 million was spent in the 'building' field.

- *Services* – There are two additional industries that must be mentioned. In transport support services, with total R&D spending across all fields of $120 million, an estimated $30 million was spent in the field of 'civil engineering', and $3 million was spent in 'built environment and design'. In professional, scientific and technical services, a very large and diverse sector, there was around $110 million reported in 'civil engineering' R&D and $32 million in 'built environment' (i.e. in 'built environment and design' but not counting those expenditures in the subfield of 'engineering design').

The existence of this activity attests to the dispersal of construction-related R&D within the Australian economy. Significantly, it also implies that there is a capacity within the Australian economy for linking R&D in the core fields of 'civil engineering' and 'built environment and design' with other, quite disparate areas of expertise. Each of the industries listed above have their main R&D focus spread across other disciplines.

This observed, it should be stressed once again that most of the growth in construction R&D has occurred within the construction industry itself. Figure 3.3a shows growth in R&D investment by industry sector, contrasting growth patterns in the three sectors of the construction industry with that in three relevant manufacturing sectors. It reveals that the most rapid growth has been in the *building construction sector*. R&D spending in the *heavy and civil engineering construction sector* has also grown, although investment in this sector dropped markedly between 2008-09 and 2009-10, leading interestingly to trend growth in this sector not dissimilar to that in related areas of manufacturing.

Figure 3.3a – R&D growth trends by industry sector



Note: (i) Derived from ABS 8104.

3.4 An industry with a clear disciplinary focus

R&D relating to the built environment is supported across a range of industries in Australia. Two industry sectors, however, stand out both for the scale of their investment and for the rapidity with which they have grown their R&D investment in recent years. These are the *building construction sector* and the *heavy and civil engineering construction sector*.

Remarkably, both of these industry sectors report an extremely narrow disciplinary profile. The field of 'civil engineering' dominates across both sectors, with 'built environment and design' playing a pivotal role in the *building construction sector* and other areas of engineering accounting for most of the balance of activity in the *heavy and civil engineering construction sector*. These investment patterns will be used in the next section to evaluate the relevance to business of recent trends in R&D investment within the public sector.

4. TRENDS IN THE PUBLIC SECTOR

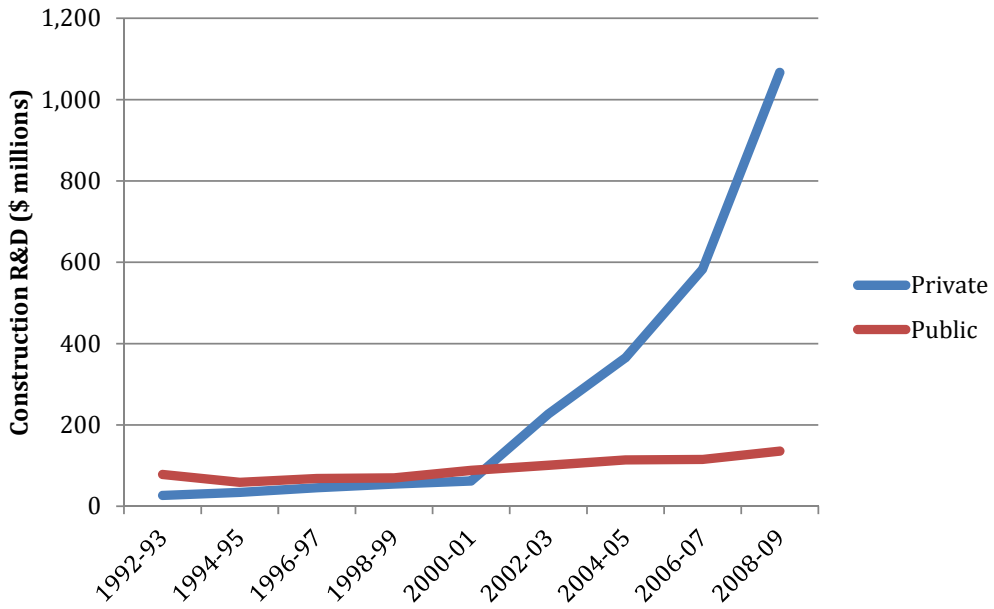
While it is natural for businesses to think in terms of market sector or socio-economic objective, this is less common at universities and even in government agencies, where R&D is most typically managed around expertise or field of research. Here we attempt to draw out some key trends in public investment in R&D relevant to the construction industry by focusing on the fields of research identified in the previous section.

We reveal that public sector investment in fields relevant to the construction industry has lagged not only in comparison to the growth in industry R&D activity but also in comparison to other areas of public-sector investment.

4.1 Public investment in construction R&D

Categorising research according to socio-economic objective is typically a more meaningful practice for researchers in the private sector than it is in the public sector. The culture in public institutions leads a proportion of researchers to prioritise the discovery of knowledge for its own sake ahead of economic or social objectives. However, a comparison of R&D investment directed at the socio-economic objective 'construction' across both the private and public sectors in Australia since the early 1990s tells an interesting story.

Figure 4.1a – Private versus public R&D on 'construction'



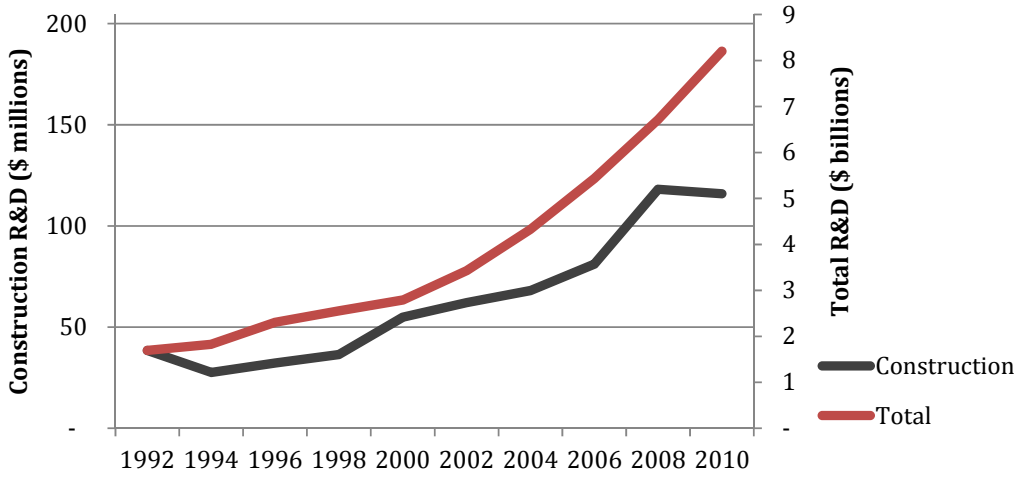
Note: (i) Derived from ABS 8112 and Barlow 2011. (ii) Shows R&D expenditures by sector focused on the socio-economic objective 'construction'. (iii) 'Public R&D' counts R&D from the university sector and from state and federal government agencies.

Figure 4.1a shows that whereas historically there has been more construction-related R&D in universities and government agencies than in business, this changed dramatically over the years 2000-01 to 2008-09. The private sector is now easily the primary location for R&D targeting the socio-economic objective of 'construction' in Australia.

- *Business has supplanted the public sector* – In the early 1990s, Australian public institutions were spending 2.9 times more on construction-related R&D than Australian businesses did. Yet by 2008, Australian businesses were spending 7.9 times as much on construction-related R&D as public research institutions.

Investment in construction R&D in the public sector, furthermore, has lagged not only compared with Australian business; it has also grown modestly compared with other areas of public research investment. Figure 4.1b shows the trend in this respect for universities. It shows how university R&D in the socio-economic objective of 'construction' has grown in comparison with total university R&D expenditures.

Figure 4.1b – University R&D focused on 'construction'



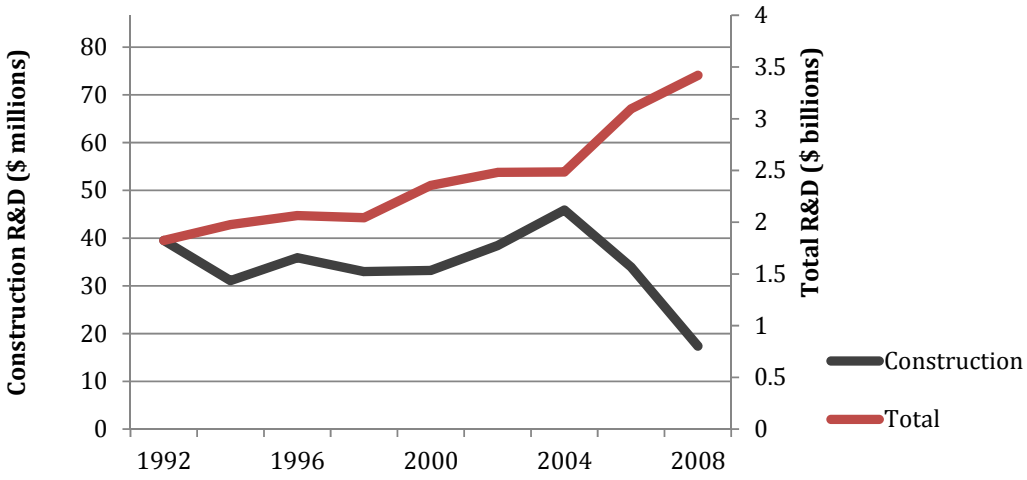
Note: (i) Derived from 8111. (ii) Compares university R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total university R&D expenditures across all objectives (right axis). (iii) The right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

On the positive side here, between 1992 and 2010, Australian universities grew their spending in construction-related R&D roughly three-fold in nominal terms. On the other hand, had growth in construction R&D trended in line with total university R&D investment, there would have been an additional $70 million in the higher education sector focused in this area. These data suggest that universities have been building capacity much faster around other objectives.

- *Universities have reduced their emphasis on construction R&D* – The proportion of Australian university R&D focused on the socio-economic objective of 'construction' fell from 2.3% to 1.4% of total Australian university R&D expenditures between 1992 and 2010.

Figure 4.1c makes a similar comparison of R&D expenditures within Australian government research agencies. The trends here are consistent with what has happened in universities – although they are also markedly more negative.

Figure 4.1c – Government agency R&D focused on 'construction'



Note: Derived from ABS 8109. (ii) Compares government intramural R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total government intramural R&D expenditures across all objectives (right axis). (iii) The right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

R&D in government agencies reported around the socio-economic objective of 'construction' held steady only in nominal terms between 1992 and 2004, and then plummeted through to 2008. Had growth in construction R&D trended in line with total government agency R&D investment, by 2008 there would have been an additional $57 million in the government sector focused in this area.

- *Government agencies have reduced their spending on construction R&D* – Between 1992 and 2008, government agency spending on construction R&D declined from $40 million to $17 million, and the proportion of government sector R&D focused on the socio-economic objective of 'construction' fell from 2.2% to 0.5% of total government sector R&D expenditures.

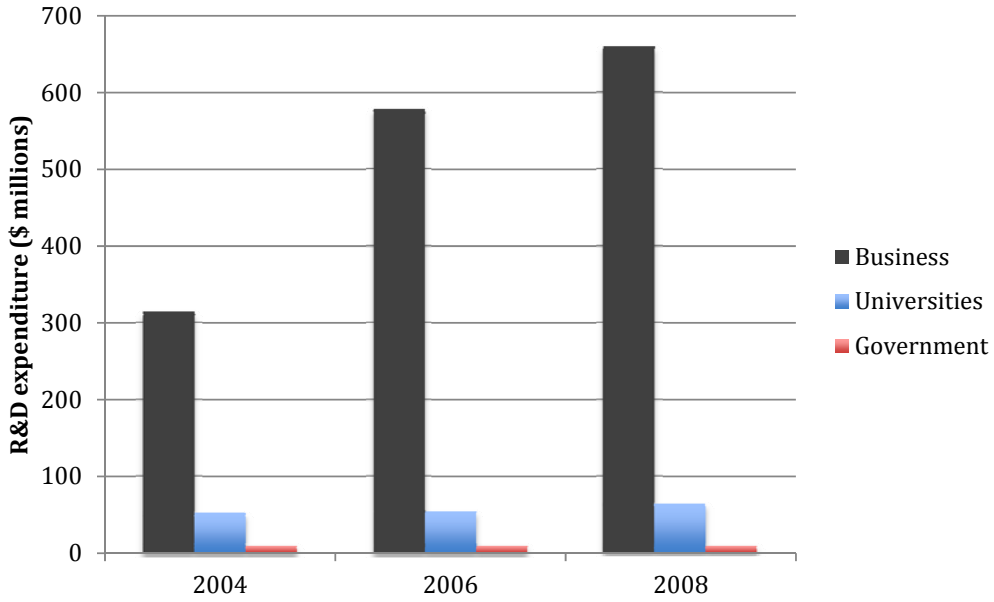
4.2 Public expenditure in construction R&D by field

The above analysis of socio-economic objective may be distorted by the way public researchers think about their work. It is more common for public-sector researchers to think in terms of fields of research than in terms of socio-economic objectives. In addition, some may work on projects that are relevant to

the construction industry, yet consider their work as sitting within the socio-economic framework of 'expanding knowledge' rather than 'economic development'. (Refer back to table 1.3b for a summary of how the socio-economic objective categories are structured by the ABS.)

For these reasons, it is useful to contrast the trends in public and private sector investment within those specific fields of research that we have identified as relevant to the construction industry. Figure 4.2a does this for the field of 'civil engineering'. It shows a disparity between the public and private sector in both scale and growth in investment in this field over recent years.

4.2a – R&D spending by sector in civil engineering



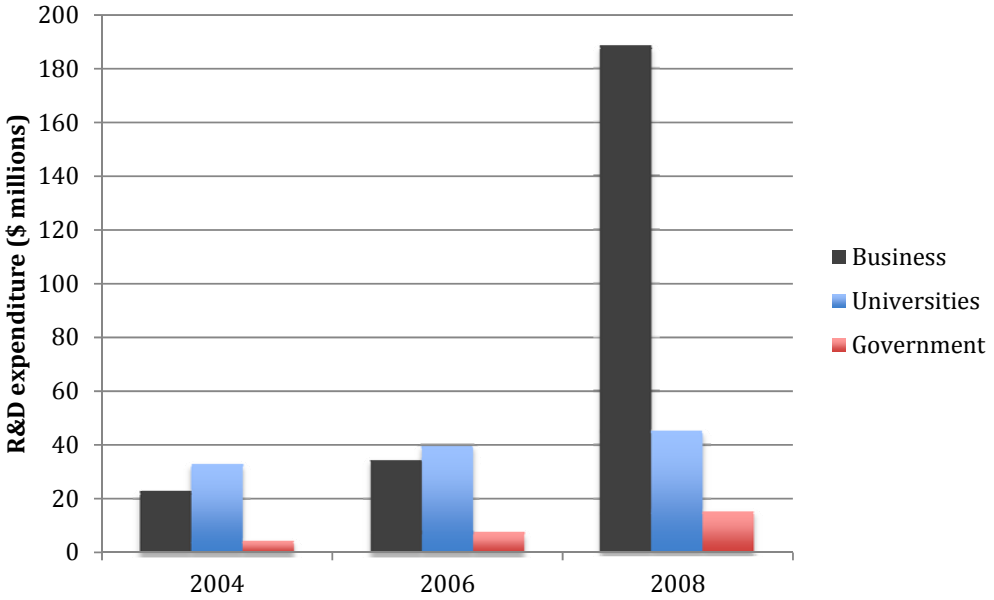
Note: (i) Derived from ABS 8112 and Barlow 2011. (ii) Data for government agencies has been estimated for the years 2004 and 2008.

In figure 4.2b, we make a similar comparison for the field of 'built environment and design'. There is a slight complication in generating this figure, due to a change in the field of research classification system used by the ABS between 2006 and 2008. In this figure, the columns for 2004 and 2006 show R&D expenditures by sector in the old research field of 'architecture, urban environment, and building', while the column for 2008 shows R&D expenditures by sector in the new field of 'built environment and design'.

It should be noted here that the latter column has included only R&D expenditures for those subfields that were inherited from the old field of 'architecture, urban environment and building'. In other words, we have subtracted out the R&D expenditures from those other subfields that were not previously associated with the field of 'architecture, urban environment and building' but which were transferred to the field of 'built environment and design' following the classification change in 2008.

This approach provides optimal comparability in the 2008 data with previous years. For further background, the reader may like to refer to the concordance of subfields between the old field of 'architecture, urban environment, and building' and the new field of 'built environment and design' as summarised in table 1.3d.

4.2b – R&D spending by sector in 'built environment and design'



Note: (i) Derived from ABS 8112 and Barlow 2011. (ii) There was a classification change in 2007-08, at which point 'architecture, urban environment and design' was re-categorised as the larger field of 'built environment and design'. To account for this, only R&D spending within the subfields of 'architecture', 'building', and 'urban and regional planning' were counted in this figure for universities and businesses in 2008.

There are several observations to be made about figures 4.2a and 4.2b.

- *Civil engineering* – Business invests in 'civil engineering' R&D on a scale that dwarfs that in public sector organisations; but growth in investment in this field has still been vastly higher in the business sector than in universities or government agencies in recent years.

- *Built environment and design* – A change in ABS classifications appears to have engendered (or at least coincided with) a dramatic shift in business R&D reporting within the code of 'built environment and design'. Thus, although this has been an area of growing expenditure in universities, public activity is now minor compared with what is reported by the private sector.

- *Universities versus government agencies* – It would also seem from these figures (consistent also with figures 4.1b and 4.1c) that the vast majority of public sector R&D in fields relevant to the construction industry occurs in universities rather than in government agencies, such as CSIRO.

The indications here are very clear, and confirm the conclusions that were drawn from figure 4.1a, which showed the slow growth in public R&D investment relative to private investment in the socio-economic objective of 'construction'. But the above analysis also enables us to make some broad comments about the relevance of public research to specific industry sectors.

For universities and the three sectors of the construction industry, table 4.2c shows the ratio of R&D investment in 'civil engineering' with that in the field of 'built environment and design'. Once again, in this table, we face the same concordance issue we came up against in figure 4.2b, and we resolve it in the same way – by using the data for the field of 'architecture, urban environment and design' in 2006, and by the selective inclusion subfield data for the field of 'built environment and design' in 2008.

Table 4.2c – Ratio of R&D spending in the field of 'built environment and design' relative to 'civil engineering'

	2006	2008
Australian Universities	0.7	0.7
Building construction	0.15	0.7
Heavy & civil engineering construction	0.0	0.0
Construction services	0.2	0.2

Note: (i) Derived from ABS 8104, ABS 8111 and Barlow 2011. (ii) The values shown are rounded to the nearest '0.05' and represent the ratio of R&D spending in the old field of 'architecture, urban environment and building' as a proportion of spending in the field of 'civil engineering'. (iii) Note that 'architecture, urban environment and building' was a field category in the 2006 R&D surveys, but was subsumed into 'built environment and design' for the 2008 survey. The ratios for 2006 have therefore been calculated using reported expenditures in 'architecture, urban environment and building'; while the ratios for 2008 have been determined by excluding the subfields 'design practice & management', 'engineering and design', and 'other built environment and design' from the values listed within the broader 2008 'built environment and design' category.

This table shows us something very interesting.

- *Industry versus university discipline portfolio* – The balance of investment between 'civil engineering' and 'built environment and design' within the *building construction sector* has converged remarkably closely with that found in universities over recent years.

The growth in private sector R&D within the field of 'built environment and design' noted in figure 4.2b, in other words, may reflect a flow of ideas from the university sector to the *building construction sector*. Certainly, it hints to an influence by public researchers on the way industry researchers classify their R&D, if not upon the actual nature of their R&D.

4.3 Bridging public and private activity in construction R&D

Now the processes by which industries change the orientation of their R&D portfolios are complex, and the direct exchange of knowledge with colleagues in the public sector is usually only of minor significance. R&D trends within corporations are typically more strongly influenced by different factors,

including levels of profitability, perceptions of changing business opportunity, the actions of competitors, the nature of the regulatory environment, underlying technological change, and the hiring of staff with new skills and ideas.

In fact, the dominant mechanism by which public sector organisations exert an influence on private companies is usually via the last of these points – the flow of trained human capital – to which end, although it is beyond the scope of this report, it may be worth some time in the future studying how the number of new employees with research degrees in fields relating to the built environment has grown in Australia over the past twenty years.

Having acknowledged this, sometimes the direct cross-fertilisation of ideas from public sector R&D into private firms can be important, and to this end we present the distribution of industry and university R&D by location in Australia, followed by the patterns of federal funding for university R&D within the main construction-related disciplines. The evidence is circumstantial, but does seem consistent with a view that universities have played an important role in stimulating an interest in R&D in the construction industry.

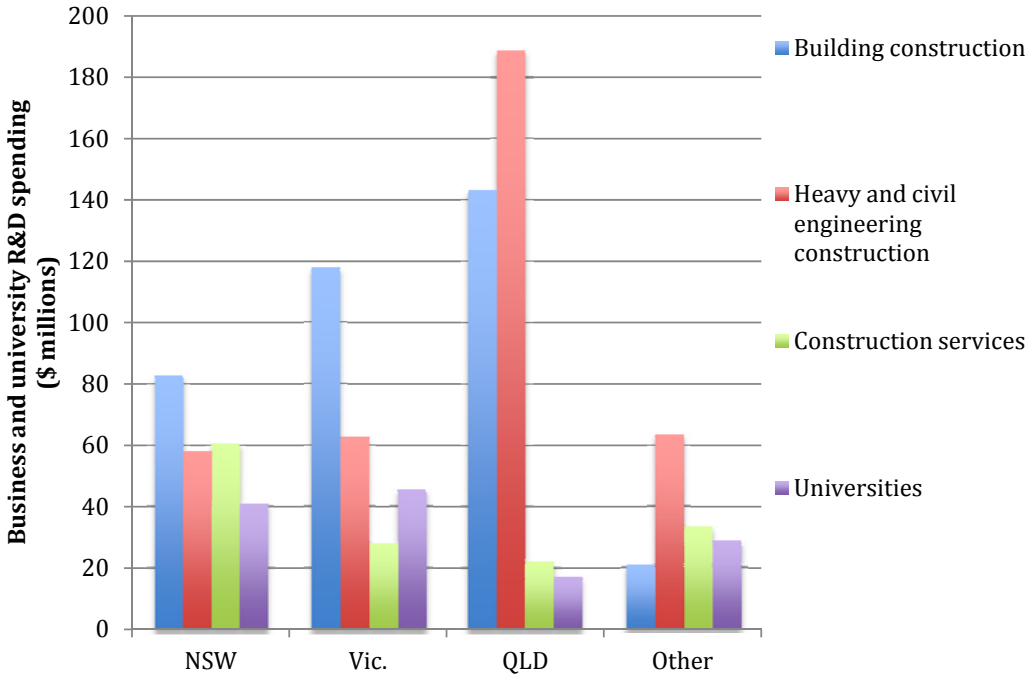
Figure 4.3a shows business R&D spending around Australia by sector of the construction industry and compares this with university R&D spending in the fields of 'civil engineering' and 'built environment and design'. There are several observations to be made from this figure.

- *Universities are as visible as construction services* – In all states, the amount of university R&D in relevant fields appears roughly comparable with the level of R&D in the *construction services sector*. Universities, in other words, are operating on a scale where they can compete for industrial contracts with Australian firms offering R&D services relating to construction.

- *Good opportunities for regional interaction* – With the exception of Queensland, there also appears to be a reasonable relationship between the volume of university R&D in a state and the volume of R&D in the construction industry. This suggests that although universities perform research on a scale that is small relative to total spending across their local construction industry, they nonetheless have sufficient scale to be visible (at least potentially) to the construction firms in their region.

- *Public-private mismatch in Queensland* – In Queensland, on the other hand, where business expenditures in both the *building construction sector* and in the *heavy and civil engineering construction sector* are extremely high, there is only modest university R&D activity. Universities in this state have clearly built some capacity – but it is not commensurate with the level of regional business activity. This may imply a high degree of concentration within one or two institutions in Queensland and a wider distribution of activity across multiple institutions in other states. It may also imply that many public-private R&D relationships involving Queensland firms are involving national rather than regional partners.

Figure 4.3a – Business and university R&D spending by location, 2008-09



Note: (i) Derived from ABS 8104, ABS 8111 and Barlow 2011. (ii) Total R&D spending by location is shown for the three subsectors of the construction industry, while for universities R&D spending by location is shown only for the fields of 'civil engineering' and 'built environment and design'.

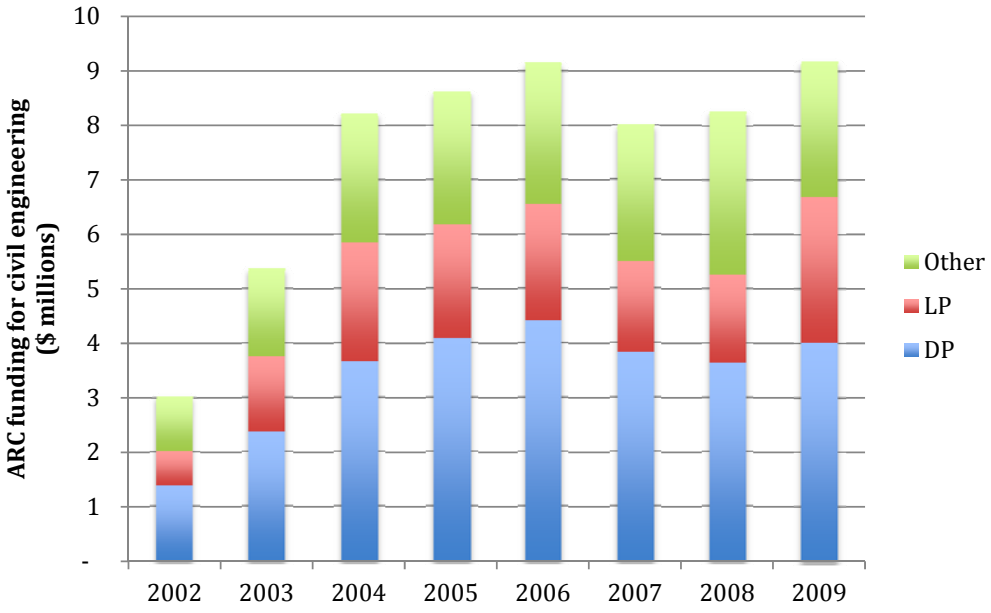
If the scale of investment in university R&D implies a potential for significant public-private R&D partnership in this area, it is also worth looking at some of the specific mechanisms that might have facilitated such partnerships in practice. Figures 4.3b, 4.3c, and 4.3d show the growth in Australian Research Council (ARC) funding to universities over recent years in three key fields. They also break down investment by type of grant (i.e. Discovery, Linkage, or other).

There are two preliminary comments that must be made about these figures. First, the ARC datasets preserve the use of the pre-2008 classification scheme for field of research. Thus, in these figures we refer to the subfields of 'architecture and urban environment' and 'building'. The latter subfield was carried over into the post-2008 classification scheme, while the former was split into two subfields. Collectively, however, it can be noted that these subfields constitute the vast bulk of national competitive grant activity in the field of 'architecture, urban environment and building', which we have previously acknowledged to be largely equivalent to the post-2008 field of 'built environment and design'.

Second, in each of these figures, grant funds are broken down into three distinct categories. The funds shown for Discovery Projects cover fundamental science projects, funds shown for Linkage Projects cover collaborations with external partners, while funds shown for other initiatives include Federation Fellowships, Centres of Excellence, and smaller external linkage initiatives. For our purposes,

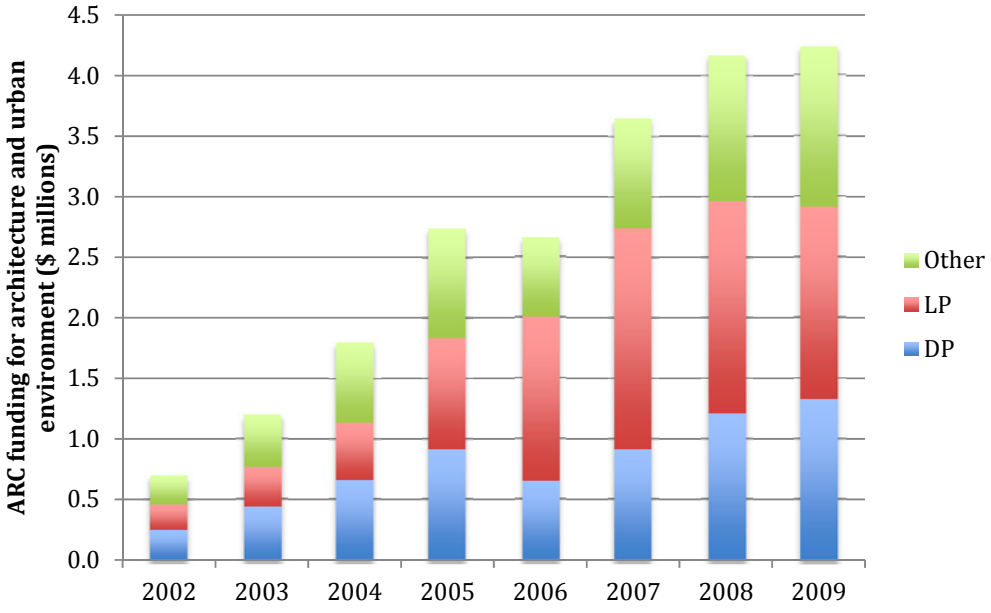
we are especially interested to track the ratio of funding for Discovery projects versus that for Linkage projects.

Figure 4.3b – Linkage versus discovery project grants in 'civil engineering'



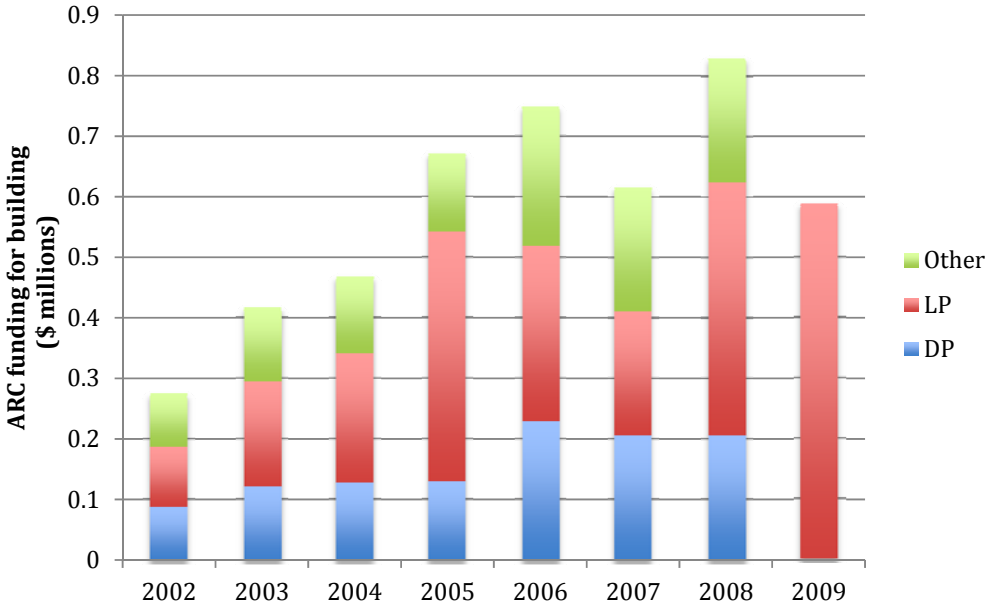
Note: (i) Derived from ARC data. (ii) Shows project funds distributed to universities in the field of 'civil engineering' as split between Discovery Project (DP), Linkage Project (LP), and Other grants, including Federation Fellowships, Centres of Excellence, and smaller external linkage initiatives.

Figure 4.3c – Linkage versus discovery project grants in 'architecture and urban environment'



Note: (i) Derived from ARC data. (ii) Shows project funds distributed to universities in the field of 'civil engineering' as split between Discovery Project (DP), Linkage Project (LP), and Other grants, including Federation Fellowships, Centres of Excellence, and smaller external linkage initiatives.

Figure 4.3d – Linkage versus discovery project grants in 'building'



Note: (i) Derived from ARC data. (ii) Shows project funds distributed to universities in the field of 'civil engineering' as split between Discovery Project (DP), Linkage Project (LP), and Other grants, including Federation Fellowships, Centres of Excellence, and smaller external linkage initiatives.

The first interesting thing to be noted about these plots is that ARC grants for 'civil engineering', 'architecture and urban design' and 'building' all grew strongly between 2002 and 2006, but then flattened out.

- *Civil engineering grants* – Between 2003 and 2006, total annual outlays via ARC grants in 'civil engineering' rose from around $5 million to over $9 million, but have held steady at this level since.

- *Architecture, urban environment and building grants* – Between 2003 and 2007, annual outlays via ARC grants in 'architecture and urban environment' and in 'building' combined rose from around $1 million to around $4 million but have flattened since.

- *"Built environment" grants* – Not shown in these figures is the fact that between 2003 and 2007, annual ARC outlays for grants mentioning "built environment" in the grant title or abstract also grew from just over $2 million to just over $3 million, but have also declined to be below $3 million since.

The lack of sustained growth after 2007 is consistent with overall funding trends at the ARC. In general, over the period, funding for 'civil engineering' tracked below the growth of ARC funds across all fields, funding for 'architecture and urban environment' tracked well above trends across all fields, while funding for 'building' tracked in line with ARC funding across all fields. The most significant

point though is that competitive ARC funding across all these fields apparently grew during the early phase of R&D expansion in the business sector as shown in figure 4.1a.

Growth in competitive funding, however, did not always correspond to an expanding capacity for university researchers to find external partners for their research. In figures 4.3b, 4.3c, and 4.3d, the breakdown of ARC funding between Discovery projects, Linkage projects, and other grants is also highly instructive.

- *'Civil engineering' lacks linkage* – Between 2003 and 2009, the ratio between Discovery and Linkage project grants remained roughly fixed in the field of 'civil engineering', suggesting no special growth in external partnerships beyond those one might expect as the sector expanded its funding base.

- *'Architecture, urban environment and building' are strong in linkage* – On the other hand, between 2003 and 2009, most of the strong growth in ARC funding for 'architecture and urban environment' and 'building' research appears to have been driven through Linkage Project grants, suggesting that some of the expansion in private sector research in the building construction sector may both have had implications for and been influenced by what was happening in the university sector in these fields.

The fact that the value of external linkage grants grew in this latter field, just prior to and then during the period when business suddenly lifted its own activities into this discipline, strongly reinforces the hypothesis that there was a relationship of mutual benefit at play here.

4.4 The role of the CRC for Construction Innovation

Another related question, of course, is the possible impact of Cooperative Research Centre (CRC) funding in this area. There have been several CRCs in the materials science area, which may have made contributions to the construction industry. Notable among these are: (i) the CRC for welded structures; (ii) the CRC for Advanced Composite Structures; and (iii) the CRC for Polymers. In addition, in the area of infrastructure maintenance, there is (i) the CRC for Infrastructure and Engineering Asset Management; and (ii) the Rail CRC. Only one CRC, however, has been focused directly on the needs of the construction industry: the CRC for Construction Innovation.

Over its lifetime, the CRC for Construction Innovation received roughly $2 million per annum in federal CRC programme funding, plus $1.5 million per annum on average from external partners. This funding commenced in 2001 and continued through to 2009. As a share of construction R&D activity nationally, by 2009 this total cash budget was equivalent to just 3% of university R&D in the socio-economic objective of 'construction', and equivalent to less than 1% of business R&D in this area. At the end of its life, in other words, the CRC for Construction Innovation was a small entity relative to the sector for which it operated.

When the CRC started out however, its direct cash inputs were equivalent to around 6% of total university R&D investment in the socio-economic objective of construction, and to around 6% also of the total level of business R&D investment in the socio-economic objective of construction. Furthermore, if one were to factor in in-kind support, particularly the costs of university staff salaries working on CRC projects (on average around $6m per year), it is likely that this CRC was actually responsible back in 2001 for something closer to 10% of Australian university R&D (or Australian business R&D) in the construction area.

The injection of such a large investment relative to other R&D providers in 2001 could reasonably be expected to have had a significant impact upon the level and nature of business R&D activity over the ensuing period. It may be just coincidence, but it is striking that the year the CRC was founded was also the year business R&D in the construction industry took off in Australia. , with this growth continuing over the life of the CRC.

One would also expect the CRC operating at this scale to have had an impact upon the capacity within the university sector for supporting industry-related projects. The federal CRC funds amounted to double the amount of ARC funding flowing to universities for Linkage projects in relevant fields in 2002; yet, due to the growth in ARC funding over the period, these funds were equivalent to just half the amount of ARC Linkage funding flowing to universities by 2008. It is possible that the CRC itself contributed to this transition both by nurturing researchers within Australian universities and by bringing new researchers into Australian universities, with an interest and capacity for attracting external partnerships.

Given these observations, the CRC for Construction Innovation may provide some particularly useful case studies – especially if one is interested not just in the direct impacts of public sector R&D for Australian businesses, but also in some of the more subtle impacts that a public organisation can have upon the mindset of a business community.

With 28 partner organisations involved in the centre nationally, and with involvement in a series of international alliances, the CRC for Construction Innovation was presumably more than just a research centre. It was also a research network and it presumably operated in some ways not just as a generator of knowledge but also as a facilitator, helping its partners to share knowledge. A study of the history of the CRC may provide insights into which of these two roles is more important for public research bodies or public policy makers with an interest in stimulating an R&D culture in industry.

4.5 Public investment in construction R&D

Over the past decade, public investment in construction R&D has not kept pace with the expansion of R&D activity in the private sector. This is especially true for the government sector, but is evident also in Australia's universities.

University investment in construction R&D has grown, but more slowly than investment targeting other objectives.

Despite this, there does seem to be some circumstantial evidence of a connection between universities and the private sector. Over recent times, the *building construction sector* in particular has lifted its investment in the research field of 'built environment and design', shifting the focus of its discipline portfolio in a way that is closely aligned with what is happening at universities. This has also coincided with a growth in the value of Linkage Project grants being funded at universities in the associated field of 'architecture, urban environment, and building'.

Looking further back, it must be noted that the massive acceleration in business R&D relating to construction began in 2001, the same year that the CRC for Construction Innovation was first funded. This CRC, in its early years, was an organisation with significant scale of funding relative to its partners, and it cultivated a strong national network of companies and organisations interested in construction R&D. It is hard to imagine that this organisation was not influential in stimulating some of the trends we have observed in this report.

5. QUESTIONS FOR THE FUTURE

This project provides background for a larger piece of research looking at the future of construction R&D in Australia. To this end, it has looked at investment trends in construction R&D in Australia since the early 1990s.

We have highlighted the massive growth in R&D in the Australian construction industry since 2001. We have pointed to the stagnation in construction R&D in government agencies, and the modest growth in construction R&D in universities (relative to the dramatic expansion in industry). But we have also suggested reasons for believing that Australian universities have played a useful role in helping to stimulate the explosion of interest in construction R&D within the private sector.

We conclude with some final observations: first, a comment about the role of the construction industry within the Australian economy; and second, a series of questions about construction R&D in Australia which might profitably be addressed as part of a larger research project.

5.1 The construction industry in the Australian economy

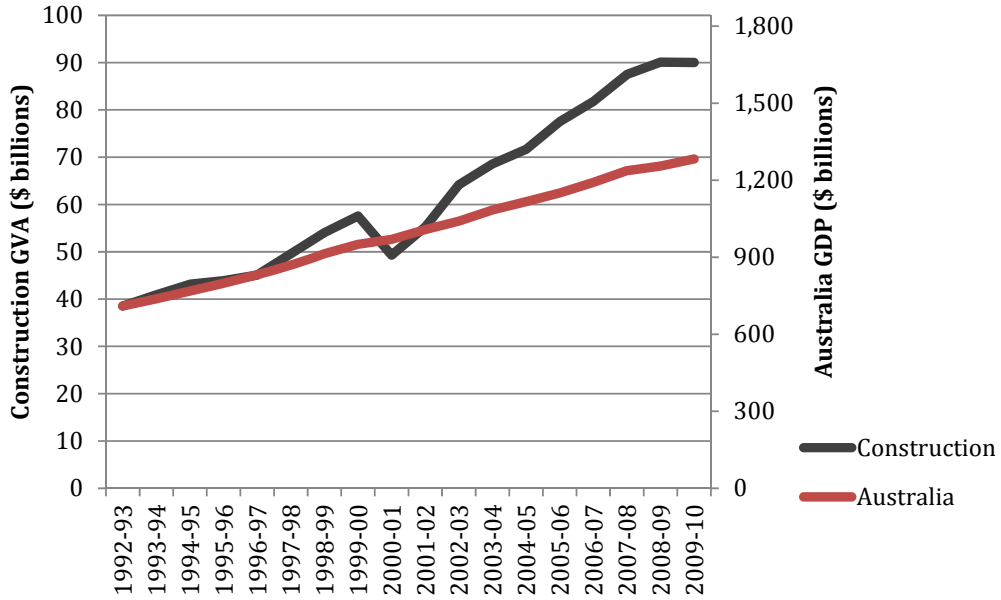
The scale of an industry, or its significance in an economy, does not necessarily have any bearing upon its need for R&D investment. Over the past two decades, the agriculture, forestry and fishing industry's share of Australian GDP has declined, but this does not tell us anything about its need for R&D. The financial and insurance services industry now contributes more to Australian GDP than the manufacturing industry, but this does not necessarily mean that Australia needs more R&D in financial services than in manufacturing.

For any industry, the returns on R&D are dependent upon a range of issues, including: the rate of technological change, the capacity to protect intellectual property and establish monopoly positions, access to skilled researchers and developers, and the attitudes of consumers. In practice, variations across these and other dimensions mean that firms in different industries will experience diverse incentives for investing in R&D, and will anticipate considerable variation in the return on their R&D investments.

In this report, we have not compared intensity of R&D investment in the construction industry (i.e. R&D investment as a share of the industry's contribution to GDP) with that of other Australian industries. As noted earlier in the report, the intensity of R&D investment in the construction industry globally is lower than in many areas of manufacturing, and is considerably lower than is true for high-technology manufacturing industries. The comparison along these lines that really matters is the one we made in figure 2.3b, where the intensity of R&D investment in the Australian construction industry was compared with that in other construction industries globally.

We do feel however that it is worth making one observation about the growth of the construction industry in the Australian economy. Figure 5.1 shows the trend in gross valued added in the construction industry (i.e. the industry's net output within the Australian economy) since 1992, and this is contrasted with the growth in Australian GDP over the same period.

Figure 5.1 – The construction industry in the Australian economy



Note: (i) Derived from ABS 1350. (ii) Construction GVA is the construction industry's gross value added, or net output within the economy. (iii) In this instance, chain volume measures are used.

From this figure it is evident that the construction industry grew closely in line with GDP throughout the 1990s, especially after one accounts for the effect of the Sydney Olympics in the lead up to 2000. Yet after 2001, the industry began to grow significantly faster than the economy as a whole. Given that 2000-01 is the same year that R&D investment in the industry accelerated, one has to question whether there isn't a relationship between this acceleration in growth across the industry and the simultaneous expansion in its R&D activity.

It is important to recognise that such a relationship could work both ways. It is possible, for instance, that the industry increased its rate of growth relative to the Australian economy as a whole because its investments in R&D paid off. But it is also possible that the industry increased its investment in R&D simply because it was growing strongly and accumulating the capital to invest. Establishing the legitimacy of either of these explanations is beyond the scope of this report, but could form an essential part of an ongoing research project.

5.2 Questions for future research

In the course of our analysis, several questions have emerged, many of which should be kept in mind as the Sustainable Built Environment National Research

Centre continues its major study of R&D and innovation in the construction and built environment sector. These questions are listed as follows.

- *What happened in 2001?* – What caused the surge in private sector R&D expenditures from 2000-01? This may reflect changes that occurred within the construction industry, including a growth in profitability; it may have been triggered by something arbitrary like changes to the R&D tax concession arrangements; or it may have been that the CRC for Construction Innovation was pivotal. Understanding the sudden increase in construction R&D in Australian industry from 2001 could provide very useful insights for policymakers interested in stimulating R&D investment in other areas of industry.

- *Why did the construction industry specifically grow its R&D investment so quickly?* – In our analysis, we have distinguished between R&D in the construction industry and construction-related R&D in other industry sectors. One way to understand why the former grew so rapidly would be to try to uncover why it grew so much more quickly than the latter. To this end, it might be useful to survey industry participants involved in construction R&D not just within the construction industry, but also in the professional, scientific and technical services industry, the manufacturing industry, or the transport support services industry.

- *What happened to government intramural R&D?* – Governments all around the world have been reducing their dependence on intramural government research agencies, but the fall in federal and state intramural spending on construction-related R&D has been particularly dramatic in Australia. It would be good to understand what is happening here, as it may provide particular insight into policymakers' perceptions of the construction industry. Is this an area where Australian governments are increasingly outsourcing to universities or to the private sector? Or is it an area where governments have simply reduced their interest and involvement?

- *Why is the construction industry not better known for its R&D, both in the community and among policymakers?* – There are two dimensions to this question. First, why has the built environment sector received so much less direct attention from governments interested in stimulating innovation in the Australian economy than, say, the automobile sector or the pharmaceuticals sector? Second, despite the growth in R&D expenditures within the construction industry and the growing intensity of R&D investment in the construction industry, why has public sector R&D relating to this industry lagged behind public sector expenditures in other areas? Answering these questions could shed a new light on current innovation policy in Australia.

- *What is going on in Queensland's universities?* – It seems odd that universities in Queensland report such low R&D investment in construction-related fields relative to other states, especially given the

high levels of construction-related R&D reported by Queensland businesses. Is this simply an artefact, caused by the way university researchers classify their work in Queensland? Does it reflect differences in the willingness of state governments to subcontract work to their local universities in this area? Have there been consequences for the construction firms active in R&D in Queensland? The difference between Queensland and other states provides a potential opportunity for a deeper comparative study.

- *Is the nature of civil engineering research or building research changing?* – The analysis in this paper has been constructed around statistical classifications of research fields. But of course fields themselves change, even though their labels may remain constant. A fuller analysis of the evolution of R&D within the construction industry would need to consider how key disciplines like civil engineering and building have changed over time. This could readily be explored through case studies, and would be a meaningful counterpoint to a research project that starts from the premise that everything that is new and exciting must have the label "sustainability" or "information technology" attached to it.

- *What is the most important role for public research organisations?* – Universities and government agencies can assist local industries both directly through the discovery of new knowledge, and indirectly by facilitating networks, disseminating knowledge and producing skilled graduates. A study of the history of the CRC for Construction Innovation may provide insights into which of these roles has proved most useful to the construction industry. Specifically, it would be useful to study: (a) the role of the CRC in establishing a national and international network for researchers in the construction industry; and (b) how the number of new employees with research degrees in fields relating to the built environment has grown in Australia over the past twenty years.

- *Has the construction industry's perception of public research changed over the past decade?* – Over the past decade, the construction industry's R&D budget has come to dwarf that of public sector organisations. Thus, even though funding to ARC Linkage Projects appears to have grown, this growth has been modest in the key field of 'civil engineering'; and while the external member contributions to, say, the CRC for Construction Innovation roughly doubled over the decade of its existence, they nonetheless shrank as a share of total business R&D outlays within the construction industry. This raises an interesting question. Has the construction industry grown its own R&D capacity beyond the point where it cares much about what happens in the public sector?

Answering these questions would provide useful insights into what has happened in this sector of Australia's economy of ideas over the past two decades. But answering these questions would also provide insights of value to policymakers with more generic interests. Many of the trends we have identified for the construction industry have analogies across other areas of the Australian

economy. Understanding in a deep sense what has driven R&D investment relating to the built environment over the past two decades can be expected to yield new ideas with strong potential to improve the effectiveness of a range of Australian innovation policies.

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