The globalisation of ICT research and development: some implications for firms, public research institutions and governments

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Abstract

This paper argues that there is a new wave of globalisation, with international investment flows increasingly focussing on developing economies such as China and India, on services rather than manufacturing and, in particular, on a range of information and business services, including R&D, design and technical services. Examining some of the implications, this paper concludes that the challenge for local firms will be to participate in global production systems and take advantage of knowledge generated anywhere within the systems' value chains. The challenge for specialist research centres will be to engage the global architectural innovators and systems integrators from a distance. And the challenge for governments lies in enhancing underlying capabilities through investment in education and research, attention to the other critical factors in attracting foreign investment in domestic R&D activity, and creating the global linkages and domestic environment to support global discovery and domestic absorption.

Keywords

Globalisation, Information and Communication Technology (ICT), Innovation, Research and Development (R&D), Science and Technology Policy, Innovation Policy

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INTRODUCTION

The information and communication technology (ICT) industries are among the most highly globalised of industries and they are advanced users of information and communication technologies – technologies that are an important enabler of globalisation.[1] Consequently they are a lead indicator of future developments, with changes in the ICT industries spreading to other industries over time.

The recovery from the 2001 'Dot Com' crash brought a new wave of globalisation in the ICT industries, which features increasing specialisation along the value chain and fragmentation of production activities, together with the emergence of developing economies as both new production locations and new growth markets.[2] Increasingly since the crash, international investment flows have focused on developing economies, on services rather than manufacturing and, in particular, on a range of information and business services, including R&D, design and technical services.[3] As a result, there is a new international division of labour, with the globalisation of R&D now following a similar path to that previously seen in IT services and manufacturing.

This paper explores recent trends in the ICT industries and examines the implications of the globalisation of ICT related R&D for firms, universities and research centres, and for science and innovation policy.

GLOBALISATION OF ICT PRODUCTION, RESEARCH AND DEVELOPMENT

The Organisation for Economic Cooperation and Development (OECD) noted that:

> 'The globalisation of trade in goods and services is opening up new and increasingly large markets. …One consequence of these changes is the fragmentation of production processes, with different stages of production carried out in different countries… Thanks to ICTs, firms are organising themselves into transnational networks...'[4]

The internationalisation of production is not new. What is distinctive about recent developments is the intensity of integration on a global scale and the emphasis on the efficiency of the system as a whole,[5] with international investment now seeking efficiency through the rationalisation of production activities at a global level, rather than simply seeking access to markets and resources. This has led to the globalisation of ICT related manufacturing, and more recently to the emergence of offshoring (i.e. the globalisation of information services, research, design and technical services).

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1 OECD, Information Technology Outlook 2006 (Paris: OECD, 2006); and OECD, OECD Economic Globalisation Indicators 2005 (Paris: OECD, 2005).

2 OECD, Information Technology Outlook 2006 (Paris: OECD, 2006).

3 Houghton, J.W., Global Chains: Australia's challenge in the evolving world economy (Melbourne: Committee for the Economic Development of Australia, 2006).

4 OECD, OECD Handbook on Economic Globalisation Indicators (Paris: OECD, 2005), 16-17.

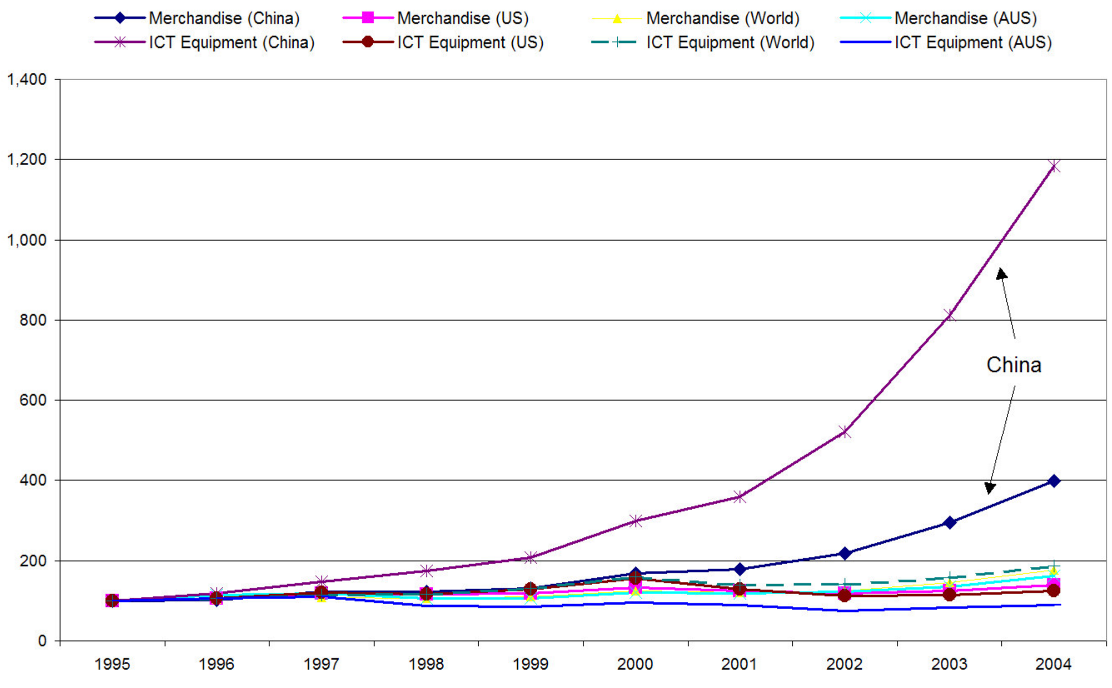
5 Kaplinsky, R., 'Spreading the gains from globalisation: what can be learned from value chain analysis?' Journal of Development Studies 37(2), (2000), 117-146.

A CHANGING CONTEXT

Between 2000 and 2004, the export volume of manufactures from Asia is estimated to have increased by 40 per cent, while that from Europe increased by 13 per cent, and North America's export volume only regained its previous 2000 peak level during 2004. International trade in office and telecommunication equipment rose 19 per cent to USD 1,134 billion during 2004 – with Asia's exports of ICT equipment rising by 25 per cent, twice as fast as the exports of all other regions combined.[6]

Within Asia, China stands out. Its exports of ICT equipment increased by 32 per cent per annum between 1995 and 2004, compared with 7 per cent per annum worldwide. As a result, China has become the world's largest importer of integrated circuits and its exports of computer and office equipment now exceed the combined exports of the United States and Japan.[7] What is notable is the contrasting performance of China and other 'new' suppliers, and that of traditional suppliers like the United States – with the post-'Dot Com' recovery featuring a marked global restructuring of ICT production (Figure 1).

Figure 1 Merchandise and ICT equipment exports, 1995-2004 (current prices, indexed 1995=100)



Source: WTO, Author's analysis.

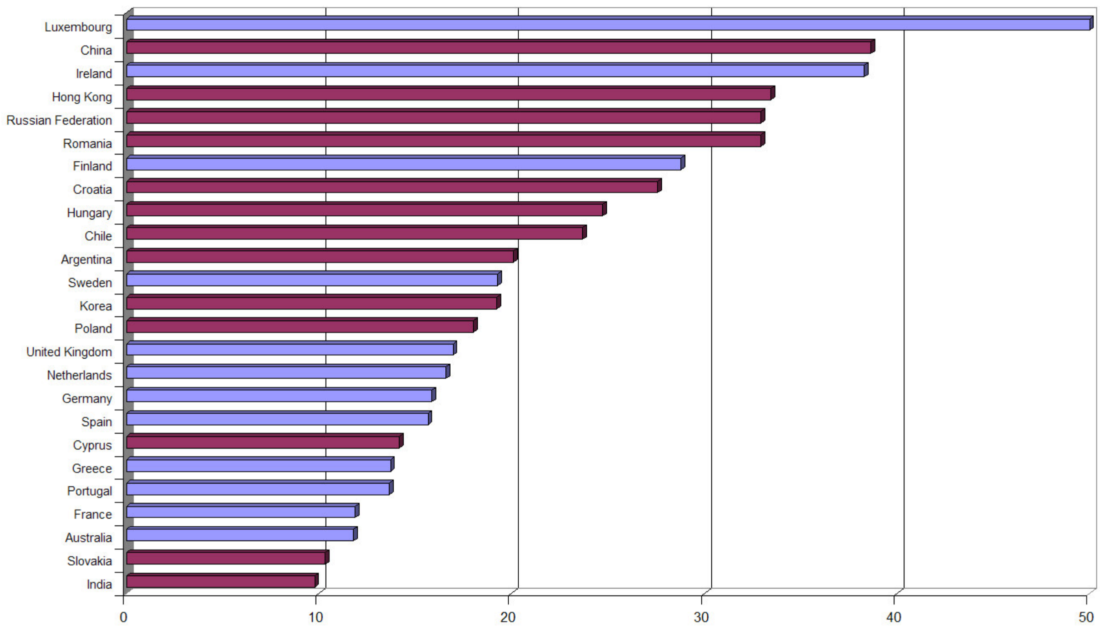
This global restructuring has also affected services, with the emergence of offshoring representing a new global rationalisation of services functions. World services exports

6 WTO, World Trade Report 2005: Exploring the links between trade, standards and the WTO (Geneva: World Trade Organisation, 2005).

7 Ibid.

increased by 9 per cent per annum between 2000 and 2004, with commercial services (excluding government, transport and travel) growing by 11 per cent per annum. In contrast to the deceleration of exports from North America and Europe, Asia's exports of other commercial services (including a range of information and business services) recorded growth of almost 25 per cent. India has emerged as Asia's second largest exporter of other commercial services, after Japan. In 2004, India ranked 9th among the world's leading exporters of commercial services, Hong Kong ranked 11th and China 15th.[8] India, China and the Russian Federation are also among those countries increasing their information and business services exports most rapidly – although India was severely affected by the 'Dot Com' downturn over the 2000 to 2003 period. Developing economies such as these are now emerging as services production locations (as well as manufacturing locations) as firms rationalise services activities (Figure 2).

Figure 2 Annual growth of combined IT and IT-enabled services exports, 2000-2003 (per cent)



Note: Includes those countries exporting more than USD 500m in combined IT and IT-enabled business services during 2003 and recording average growth of 10 per cent or more between 2000 and 2003, ranked by average annual growth rate.
Source: UNCTAD, Author's analysis.

A CHANGING FOCUS

Foreign Direct Investment (FDI) has been playing an increasing role in globalisation, and a major feature of recent FDI flows has been the shift to developing countries – with inflows to developing countries rising by more than 50 per cent during 2004, while inflows to developed countries fell by 14 per cent. During 2005, inflows to developing countries rose 22 per cent and reached a record USD 334 billion. The major recipient

8 Ibid.

regions were Asia and Oceania, wherein East Asia experienced a 46 per cent increase in FDI inflows during 2004. Combined, China and India accounted for 23 per cent of worldwide greenfield FDI investments during 2004, and 10 per cent of worldwide FDI inflows.[9]

The other significant trend in FDI flows has been a shift from manufacturing to services – including telecommunications, computer and information services, a range of IT-enabled business process services, and R&D, technical testing and design services with a strong emphasis on ICT (e.g. mobile communications related R&D and semiconductor 'chip' design).[10] Services accounted for more than 60 per cent of all cross-border mergers and acquisitions during 2004, and FDI flows to services were 2.4 times greater than those to manufacturing over the period 2002 through 2004. Moreover, these shifts to developing countries and to services have combined. In 1990, business services accounted for just 7 per cent of inward FDI stock in developing countries. By 2002, their share had risen to 38 per cent.[11]

GLOBALISATION OF R&D

Within these trends the growth of international investment in R&D has been particularly notable. Multinational firms are key players, accounting for close to half of all global R&D expenditures and at least two-thirds of business R&D expenditures (estimated at around USD 450 billion). Between 1993 and 2002, the R&D expenditure of foreign affiliates worldwide rose from an estimated USD 30 billion to USD 67 billion (or from 10 per cent to 16 per cent of global business R&D). What is most notable is that the rise was modest in developed host countries, but quite significant in developing countries – with the share of foreign affiliates in business R&D in the developing world increasing from 2 per cent to 18 per cent between 1996 and 2002.[12]

During 2005, 315 new FDI projects in R&D were recorded in South, East and South-East Asia, 80 per cent of which were in China and India – with the number of foreign invested R&D centres in China rising to 750 by the end of 2005.[13] In a survey of the largest R&D spending multinational corporations, UNCTAD found that China, India, Singapore and Brazil ranked highly as current foreign R&D locations (Figure 3), and

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[9] UNCTAD, World Investment Report 2005: Transnational Corporations and the Internationalisation of R&D (New York and Geneva: United Nations, 2005); and UNCTAD, World Investment Report 2006: FDI from Developing and Transition Economies – Implications for Development (New York and Geneva: United Nations, 2006).

[10] OECD, Information Technology Outlook 2006 (Paris: OECD, 2006).

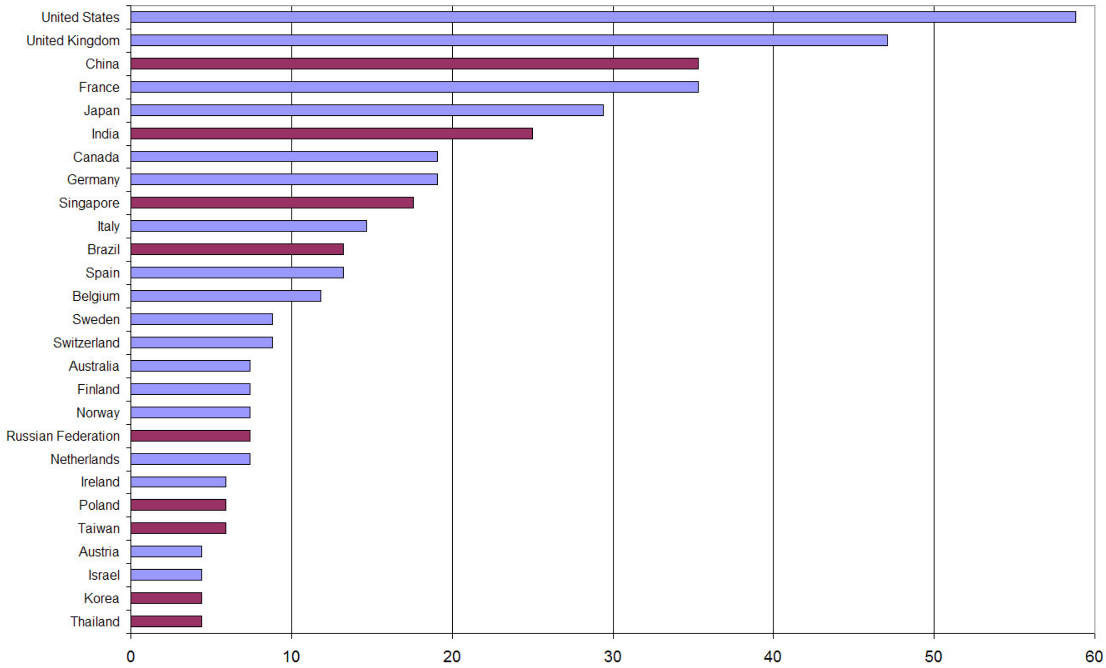
[11] UNCTAD, World Investment Report 2004: The Shift Towards Services (New York and Geneva: United Nations, 2004); and UNCTAD, World Investment Report 2006: FDI from Developing and Transition Economies – Implications for Development (New York and Geneva: United Nations, 2006).

[12] UNCTAD, World Investment Report 2005: Transnational Corporations and the Internationalisation of R&D (New York and Geneva: United Nations, 2005)

[13] UNCTAD, World Investment Report 2006: FDI from Developing and Transition Economies – Implications for Development (New York and Geneva: United Nations, 2006).

that developing countries such as China, India and the Russian Federation rated even more highly as prospective R&D locations (Figure 4).[14]

Figure 3 Current foreign locations of R&D, 2004 (UNCTAD Survey)



Note: Percentage of leading multinational corporate respondents citing locations by country.
Source: UNCTAD, *World Investment Report 2005: Transnational corporations and the internationalisation of R&D* (New York and Geneva: United Nations, 2005), 133.

Developing country governments are also investing in R&D. During 2002, Asia overtook Europe in R&D expenditure, with China accounting for 8.7 per cent of worldwide R&D expenditure in 2002, while already India accounted for 2.5 per cent in 2000. State-owned and private industry together account for around 60 per cent of R&D expenditure in China, while private industry accounts for around 23 per cent in India – with both the public and private sectors contributing to R&D expenditure increases.[15] The OECD predicted that China's R&D spending would surpass that of Japan during 2006, making it the second largest investor in R&D – with the United States spending USD 330 billion, China USD 136 billion and Japan USD 130 billion on R&D during 2006.[16]

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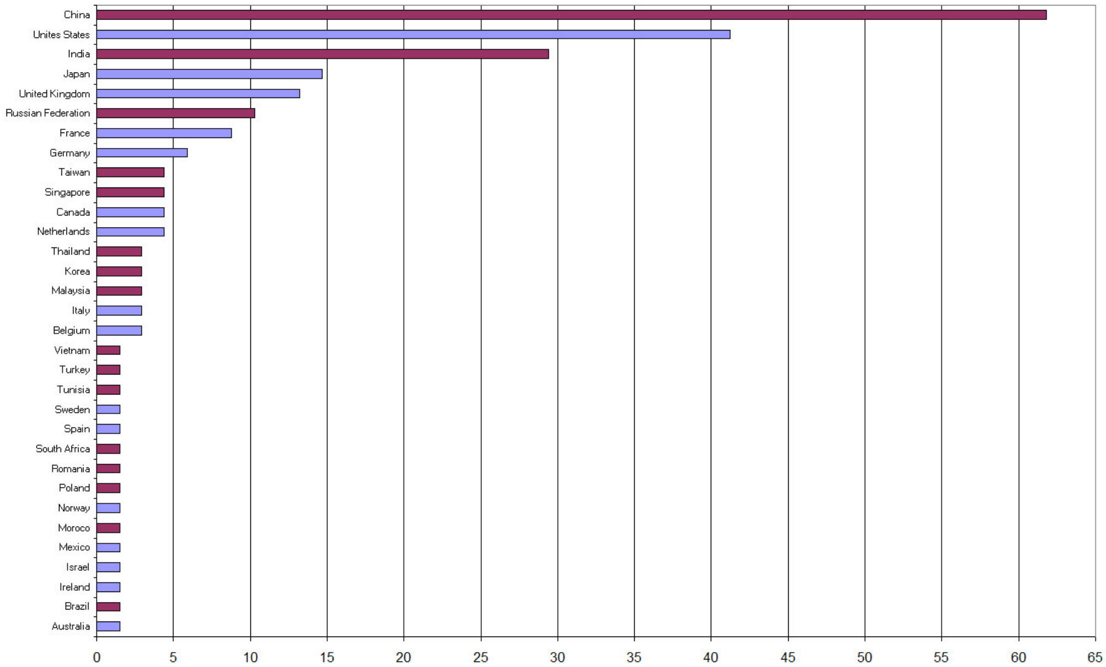
[14] UNCTAD, World Investment Report 2005: Transnational Corporations and the Internationalisation of R&D (New York and Geneva: United Nations, 2005).

[15] UNESCO, UNESCO Science Report 2005 (Paris: UNESCO, 2005).

[16] OECD, Science, Technology and Industry Outlook 2006 (Paris: OECD, 2006).

Figure 4 Prospective foreign locations of R&D, 2004 (UNCTAD Survey)



Note: Percentage of leading multinational corporate respondents citing locations by country.
Source: UNCTAD, *World Investment Report 2005: Transnational corporations and the internationalisation of R&D* (New York and Geneva: United Nations, 2005), 153.

These trends reveal a new wave of globalisation, with a rapid global restructuring of ICT and related manufacturing and services, including R&D, design and technical services. The scale and pace of these changes raise significant challenges for all participants as well as for national science and innovation policy.

UNDERSTANDING RECENT TRENDS IN RESEARCH AND INNOVATION

Various frameworks have been used in the analysis of recent trends in research and innovation. These include:

- The Systems of Innovation approach, which encompasses a wide range of work focusing on the systems within which knowledge is produced, communicated and applied;[17]
- The New Production of Knowledge approach, which is based on comparing and contrasting traditional disciplinary research with an emerging interdisciplinary, problem oriented mode of knowledge production;[18]

[17] Edquist, C. (ed.), Systems of Innovation: Technologies, Institutions and Organizations (London: Pinter, 1997).

[18] Gibbons, M., Nowotny, H., Limoges, C., Schwartzman, S., Scott, P. and Trow, M., The New Production of Knowledge: The dynamics of science and research in contemporary societies (London: Sage, 1994).

- Post-Academic Science, which seeks to describe the emerging era of science and contrast it with traditional 'academic science';[19]
- The Triple Helix, which seeks to describe the emerging inter-relationship between universities, industry and the state;[20] and
- Open Innovation, which seeks to explain the decline of major corporate research laboratories and emerging innovation and commercialisation practices.[21]

The Innovation Systems approach offers a broad perspective on the actors and activities involved in innovation. The New Production of Knowledge and Post Academic Science approaches focus their attention on specialist knowledge producers, such as universities and research institutions. The Triple Helix approach focuses on the changing sectoral relationships between universities, industry and the state. Each approach has its strengths and weaknesses, but what they have in common is a recognition of key trends – including: increasing diversity in the location of research activities, an increasing focus on interdisciplinary research, an increasing focus on problems rather than techniques, greater emphasis on collaborative work and more diverse modes of research communication and dissemination.[22] All point to an increased permeability of the traditional borders between 'science' and 'industry' and the rise of the, so-called, entrepreneurial university.[23]

The ICT industries are a particular focus of the Open Innovation approach and, leaving aside possible theoretical and methodological limitations, it appears to offer some insight into recent developments. The Open Innovation approach treats research and development as an open system. It assumes that useful knowledge is widely distributed, and that even the largest and most capable corporate laboratory could not possibly cover all the areas of knowledge and skills necessary to provide a firm with a single source for innovation. In defining Open Innovation, Chesbrough wrote:

> 'The open innovation paradigm can be understood as the antithesis of the traditional vertical integration model where internal R&D activities lead to internally developed products that are then distributed by the firm. …open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open Innovation is a paradigm that assumes that firms

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19 Ziman, J., Real Science (Cambridge: Cambridge University Press, 2000).

20 Etzkowitz, H. and Leydesdorff, L. (eds.), Universities and the global knowledge economy: a triple helix of university-industry-government relations (London: Pinter, 1997).

21 Chesbrough, H., Open Innovation: The new imperative for creating and profiting from technology (Boston MA: Harvard Business School Press, 2003); Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.), Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006).

22 Houghton, J.W., Steele, C. and Henty, M. Changing Research Practices in the Digital Information and Communication Environment (Canberra: Department of Education, Science and Training, 2003).

23 Van Looy, B., Callaert, J. and Debackere, K., 'Publication and patent behaviour of academic researchers: Conflicting, reinforcing or merely co-existing?' Research Policy 35(4) (2006), 596-608.

> can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology.'[24]

The key features of open innovation are the sourcing and use of external knowledge by firms in the development of new products and services, and the ability of firms to realise the value of internal knowledge by external means, such as licensing and spin-offs, as well as bringing it to market internally. Crucially open innovation depends on a 'market in knowledge' (a market in intellectual property and research services), with the use of markets, rather than internal firm hierarchies, to coordinate the flows of knowledge between firms and other entities.[25]

The emergence of open innovation is part and parcel of the wider changes affecting the ICT industries, with increasing specialisation along the value chain, vertical disintegration[26] and outsourcing. Like electronics manufacturing before it,[27] innovation itself has become modularised (taking place at the component level and the architectural or system level),[28] and specialised and increasingly outsourced (being conducted in specialist organisations such as universities and research centres).[29] Innovation is also increasingly globalised, with modularisation and specialisation in manufacturing, services and now R&D being organised at the global rather than national level.

As Cantwell put it:

> '…technology leaders have altered the nature of international technology creation by pioneering the international integration of MNC [multinational corporation] facilities into regional or global networks. Globalisation in this sense involves the establishment of new international structures for technology creation. In the past, foreign technological activity exploited domestic strengths abroad… By contrast, today for companies of the leading centres, foreign technological activity now increasingly aims to tap into local fields of expertise, and to provide a further source of new technology that can be utilised internationally in the other operations of the MNC. In this respect, innovation in

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24 Chesbrough, H., 'Open Innovation: A New Paradigm for Understanding Industrial Innovation,' in Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.), Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 2.

25 Ibid., 1-12.

26 Vertical integration refers to the situation in which production occurs within a single organisation. Vertical disintegration means that the production process has been split across separate companies, each performing a limited subset of the activities required to create a finished product (e.g. electronics or automobile production in which there is a chain of designers, various levels of components manufactures and final assemblers).

27 Houghton, J.W. with Thorburn, L., The Victorian Electronics Industry Cluster, Report prepared for the Victorian Department of Industry, Innovation & Regional Development on Behalf of the Australian Electrical and Electronic Manufacturers Association (Melbourne, 2004).

28 Architectural or system innovation refers to innovation on a higher system level technically and socially, while component innovation refers to innovation at a lower level that focuses on the system components (e.g. innovation relating to computers versus that relating to disc drives).

29 Christensen, J.F., 'Wither core competency for the large corporation in an open innovation world?' in Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.), Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 35-61.

> the leading MNCs is more genuinely international or, in the terminology used here, it has become 'globalised'.'[30]

From the perspective of senior management in the ICT industry, the new wave of globalisation and more open innovation practices have been characterised as the emergence of the 'Globally Integrated Enterprise' – focussed on the integration of production and value delivery worldwide in order to cut costs and tap into new sources of skills and knowledge.[31]

RECENT DEVELOPMENTS IN AUSTRALIAN ICT R&D

Recent developments in ICT related R&D in Australia reflect these trends, with a renewed focus on public sector ICT research through the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and National ICT Australia (NICTA), combined with a decline in the activities of Telstra's Research Laboratories (TRL), the closure of ICT related Cooperative Research Centres (CRCs) and withdrawal of a number of major multinational firms from R&D activities in Australia (e.g. Ericsson, Motorola and Nortel).

Telstra's Research Laboratories (TRL) had an 80-year tradition of providing internal research and leading Telstra's participation in research partnerships. Nevertheless, TRL's activities have now been cut back and the organisation absorbed into network and technology operations. Telstra has also withdrawn from participation in a number of Cooperative Research Centres (CRCs), including the Smart Internet Technology CRC and the Australian Photonics CRC – although in the former case Telstra has become a participant in the new Smart Services CRC.

Ericsson, Motorola and Nortel are among recent high profile corporate departures from ICT R&D in Australia. Ericsson announced the closure of its AsiaPacificLab in late 2002, with 400 engineers in Melbourne and another 50 in Sydney losing their jobs. Newspaper reporting of the closure noted that 'for Victoria the loss of the AsiaPacificLab is a bitter blow, snatching away nearly 20% of the state's research and development activity and, perhaps even more significantly, removing an important conduit to Europe and the US.'[32] Motorola closed its Sydney R&D centre the following year, and Nortel's R&D operation at the University of Wollongong faced closure until it was acquired by the Andrew Corporation.[33]

Meanwhile, public sector ICT related R&D activities have expanded. The CSIRO has increased its funding of ICT research, with the ICT and mathematical sciences division receiving an extra AUD 7.8 million in 2006-07 and the ICT Centre's budget increasing

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30 Cantwell, J., 'The Globalisation of Technology: What Remains of the Product Cycle Model?', in D. Archibugi and Michie, J. (eds.), Technology, Globalisation and Economic Performance, Cambridge: Cambridge University Press, 1997), 236.

31 Palmisano, S.J., 'The Globally Integrated Enterprise,' Foreign Affairs 85(3), (2006).

32 Barker, G., 'Victoria loses cutting-edge team,' The Age (4 October 2002).

33 Norington, B., 'Motorola axes research, jobs,' Sydney Morning Herald (26 November 2003); and Dinham, P., 'Andrew Corporation buys Nortel R&D arm,' ITWire (11 September 2005).

by 14% to AUD 48 million.[34] NICTA, established in 2002 as an independent non-profit company, received AUD 130 million from the Commonwealth Government over the first five years. Under a new funding agreement for the next 5 years, the Commonwealth Government has increased its contribution to AUD 250 million.[35] At the same time, however, most ICT related CRCs have failed to gain continued government support – with the operations of the CRC for Sensor Signal and Information Processing, the CRC for Enterprise Distributed Systems Technology, the CRC for Satellite Systems, the Australian Telecommunications CRC, and the Australian Photonics CRC all terminated.

IMPLICATIONS FOR FIRMS, PUBLIC RESEARCH INSTITUTIONS AND GOVERNMENTS

This rapid emergence of developing economies, the globally integrated enterprise, more open innovation and the new wave of globalisation of services, including R&D, design and technical services, have important implications for firms, public research institutions and governments in Australia and elsewhere.

> 'Until recently, R&D policy has largely been national in scope, often supporting the development of critical knowledge bases and technologies or particular national specialisations. The new forms of internationalisation of R&D, based on global sourcing and integration of complex knowledge bases, present challenges to national approaches. When innovation networks span national boundaries, how should national innovation systems relate to the global division of labour in knowledge production?'[36]

At the national level, attention to the critical factors in attracting foreign investment in domestic R&D activity, and creating the global linkages and domestic environment to support global discovery and domestic absorption are likely to be crucial.[37] The former will depend on developing and maintaining a public research infrastructure and skills base of world class and creating a suitable environment for investment in R&D, while the latter will depend on developing and maintaining both global and domestic networks and linkages and enhancing discoverability, appropriability and domestic absorptive capacity. Some key aspects and implications are discussed in the following sections.

A MARKET IN KNOWLEDGE?

Vertical disintegration and the demise of major corporate laboratories, combined with specialisation and the outsourcing of R&D depends on the development of functioning markets in knowledge (in research services and intellectual property). Establishing and managing that market, understanding its dynamics and understanding customer needs will be essential for successful participation.

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34 Hayes, S., 'More cash for CSIRO IT,' The Australian (2 February 2006).

35 Riley, J., 'NICTA gets $250m,' The Australian (22 May 2006).

36 OECD, Science, Technology and Industry Outlook 2006 (Paris: OECD, 2006).

37 Ibid.

Governments and public sector research organisations, such as universities and public research centres, play the role of 'innovation benefactor', providing basic knowledge and training.[38] They are subject to many and sometimes conflicting policy instruments, with incentive structures affected by a number of policies. One major influence in recent years has been the increasing focus on commercialisation, with governments following the logic, if not the lead, of the US Bayh-Dole Act.[39] As elsewhere, Australian universities and research centres have been encouraged to pay greater attention to the management of their intellectual property (IP), to patenting, and the use of IP as an additional and/or alternative source of funding. Patent counts have risen rapidly, but it is not clear that it has been an entirely successful mechanism for the promotion of technology transfer and commercialisation.

Commenting on the impact of the Bayh-Dole Act on commercialisation of university research in the US, Nelson noted that:

> 'My strong suspicion is that a good share of the technology transfer that has occurred would have proceeded as widely and as rapidly as it in fact did, even if there had been no claiming of intellectual property rights by the university. And in some cases, it would appear that such claiming probably has made technology transfer more costly and time consuming for the firms involved.'[40]

A number of authors have expressed similar concerns about the impacts of university patenting (i.e. the market in IP).[41] It is notable, however, that there is much less concern about the possible impacts of contract research (i.e. the market in research services).[42]

One concern is that patenting by universities may lead to there being less follow-on research and innovation than there might otherwise have been. For example, Stern and Murray found that following a grant of patent covering university research that was also contained in a publication, citations to the publication were lower than would otherwise be predicted;[43] and Fabrizio cited a number of examples of the slowing of innovation

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[38] Chesbrough, H., Open Innovation: The new imperative for creating and profiting from technology (Boston MA: Harvard Business School Press, 2003).

[39] The Bayh-Dole Act aimed to encourage commercialisation by providing a clear and uniform system for managing IP rights in publicly funded institutions that provided an incentive for technology transfer through granting rights of ownership subject to a number of obligations. See Christie, A.F., D'Aloisio, S., Gaita, K.L., Howlett, M.J. and Webster, E.M., Analysis of the Legal Framework for Patent Ownership in Publicly Funded Research Institutions (Canberra: Department of Education, Science and Training, 2003).

[40] Nelson, R.R., 'Observations on the Post-Bayh-Dole rise of patenting at American universities,' Journal of Technology Transfer 26, (2001), 16.

[41] Geuna, A. and Nesta, L.J.J., 'University patenting and its effects on academic research: The emerging European evidence,' Research Policy 35(6), (2006), 790-807; Dosi, G., Malerbra, F., Ramello, G.B. and Silva, F., 'Information, appropriability, and the generation of innovative knowledge four decades after Arrow and Nelson: An introduction,' Industrial and Corporate Change 15(6), (2006), 891-901; Eisenberg, R.S., 'Patents and data-sharing in public science**,**' Industrial and Corporate Change 15(6), (2006), 1013-1031.

[42] Van Looy, B., Callaert, J. and Debackere, K., 'Publication and patent bahvior of academic researchers: Conflicting, reinforcing or merely co-existing?' Research Policy 35(4), (2006), 596-608.

[43] Stern, S. and Murray, F., Do formal intellectual property rights hinder the free flow of scientific knowledge? An empirical test of the anti-commons hypothesis, NBER Working Paper No. 11465 (Cambridge MA: National Bureau of Economic Research, 2005).

resulting from increased protection and management of university IP.[44] Nelson concluded that the case for patenting by universities on the grounds that it facilitates technology transfer is no longer credible[45] – exclusive licensing creates barriers to downstream R&D and risks the under-utilisation of results (i.e. a tragedy of the anti-commons),[46] while non-exclusive licensing is really just a tax on knowledge.[47]

On the other hand, a number of studies have noted the importance of non-IP related knowledge transfer mechanisms between universities and firms, such as publications, conferences, consulting and contract research, collaborations and informal interactions.[48] In a survey exploring the influence of public research on industrial research, for example, an average of 41 per cent of industry respondents noted the importance of publications and reports, 32 per cent consulting, 21 per cent contract research and just 17.5 per cent suggested that patents were an important means of knowledge transfer.[49] Similar results were reported from the supply-side (i.e. from the perspective of university researchers) by Agrawal and Henderson.[50] Moreover, in a recent Australian survey, 73 per cent of innovating businesses reported having no formal IP protection mechanisms in place, just 7.3 per cent used patents, and just 2.0 per cent reported acquiring IP from universities and research centres in the form of patents, designs, etc.[51]

In the light of this, governments are now focusing attention on creating more open access to the results of publicly funded research (e.g. the OECD Declaration on Open Access to Scientific Data), and there is mounting evidence that open access to research findings may have a significant positive impact on social returns to R&D.[52] So,

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44 Fabrizio, K.R., 'The use of university research in firm innovation,' in Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.) Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 134-160.

45 Nelson, R.R., 'The market economy, and the scientific commons,' Research Policy 33(3), (2004), 470.

46 The 'tragedy of the anticommons' is where a resource is under-utilised because too many individuals have rights of exclusion. It is the opposite of the 'tragedy of the commons', where lack of individual property rights led to over-utilisation. See Heller, M.A. 'The Tragedy of the Anticommons: Property in the transition from Marx to Markets,' Working Paper No. 40, University of Michigan, (1997).

47 Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R.R., Rosenberg, N. and Sampat, B.N., 'How Do University Inventions Get Into Practice?' Management Science 48(1), (2002), 67.

48 Cohen, W.M., Nelson, R.R. and Walsh, J.P., 'Links and Impacts: The Influence of Public Research on Industrial R&D,' Management Science 48(1), (2002), 1-23; Agrawal, A. and Henderson, R., 'Putting Patents in Context: Exploring Knowledge Transfer from MIT,' Management Science 48(1), (2002), 44-60; Adams, J.D., Industrial R&D Laboratories: Windows on Black Boxes, Rensselaer Working Papers in Economics (New York: Rebsselaer, 2004); Fabrizio, K.R., 'The use of university research in firm innovation,' in Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.), Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 134-160.

49 Cohen, W.M., Nelson, R.R. and Walsh, J.P., 'Links and Impacts: The Influence of Public Research on Industrial R&D,' Management Science 48(1), (2002), 15.

50 Agrawal, A. and Henderson, R., 'Putting Patents in Context: Exploring Knowledge Transfer from MIT,' Management Science 48(1), (2002), 44-60.

51 ABS, Innovation in Australian Business (Canberra: Australian Bureau of Statistics, 2006).

52 A growing list of studies is reported by The Open Citation Project (http://opcit.eprints.org/oacitation-biblio.html). See also Houghton, J.W. and Sheehan, P.J., The Economic Impact of Enhanced Access

notwithstanding the need to support the market in knowledge, we may need to limit the tendency for universities and research centres to attempt to profit from their IP – thereby creating barriers to the flow of knowledge and potentially reducing returns to public investment in R&D and slowing the rate of diffusion, adoption and commercialisation.[53] We may also need to think more carefully about the conflicting incentives for research communication created in Australia by the proposed Research Quality Framework and commercialisation goals and possible moves towards Open Access policies – at a minimum ensuring that research evaluation does not run counter to research commercialisation and communication (e.g. is not biased against commercially oriented or open access research outputs and/or dependent on traditional metrics that cover only traditional outputs, such as a limited subset of the subscription journal literature).

The key challenge will be to simultaneously solve management of university and public sector research IP for appropriability and commercialisation on the one hand, and for discovery and diffusion on the other. Whether conflicting policies create a tension and thereby a balance, or a polarisation and a 'worst of both worlds' outcome will depend on a number of factors, not least of which being sensitive implementation. One crucial aspect will be to sensitively manage the different conditions and dynamics in different research fields and industries – with patenting, to date, apparently playing an enabling role in pharmaceuticals, while having little or no place in other fields. A 'one size fits all' solution to IP management, research evaluation or research communication is unlikely to succeed.

WHAT SORT OF KNOWLEDGE AND WHO FOR?

Even if we can successfully manage the market(s) in knowledge, the question remains what sort of knowledge and who for?

Major multinational firms are increasingly specialising in an 'integrative competence', while smaller firms and other agents specialise in innovation in specialised 'component' fields[54] – a division of labour that imperfectly parallels that between architectural innovation and component innovation.[55] This suggests that most commercially oriented research specialists will focus on component technologies and commercialisation through licensing, alliances and spin-offs, rather than on fundamental architectures. Such specialists will need to select a focus, or a small number of foci, in a specialised

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to Research Findings, CSES Working Paper No.23 (Melbourne: Victoria University, 2006); and Houghton, J.W. Steele, C. & Sheehan, P.J., Research Communication Costs in Australia, Emerging Opportunities and Benefits (Canberra: Department of Education, Science and Training, 2006).

53 Nelson, R.R., 'The market economy, and the scientific commons,' Research Policy 33(3), (2004), 455-471; and Dosi, G., Malerbra, F., Ramello, G.B. and Silva, F., 'Information, appropriability, and the generation of innovative knowledge four decades after Arrow and Nelson: An introduction,' Industrial and Corporate Change 15(6), (2006), 891-901.

54 Integrative competence refers to the ability to identify or develop and bring together a number of complex components, and integrate them into a new product or service, thereby innovating at the system or architectural, rather than the component level.

55 Christensen, J.F., 'Wither core competency for the large corporation in an open innovation world?' in Chesbrough, H., Vanhaverbeke, W. and West, J., (eds.) Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 35-61.

modular component based on an understanding of both the science and the architecture, business models and value systems in which it might be applied, and they will need to create and maintain sophisticated and flexible capabilities for managing the borders between their science and its potential developers and users. From the research perspective, the former implies a need for combinations of broad research, technology and industry skills, and the latter a need for broad research and IP management skills.

A minority of research specialists might focus on architectural innovation and issues relating to integrative competencies – operating, for example, as sources of knowledge, advisors and consultants (e.g. cutting-edge and theoretically grounded technology, business, economic and management research). Such specialists will need to maintain substantial global networks for both awareness and marketing purposes. Possible complementarities[56] between these specialisations suggest that close collaboration and, perhaps, integration might be beneficial (e.g., in the Australian context, incorporating economic and management research into NICTA, CRCs and the CSIRO).

National R&D statistics suggest that public sector ICT research in Australia is increasingly focused on services and on ICT use, rather than production.[57] Given the lack of a significant local ICT producing industry in Australia, this would seem to be an understandable strategy. However, there are likely to be significant differences between IP management and knowledge diffusion strategies for ICT producers and users, with a greater need to not only allow but to actively facilitate spillovers for the latter. If use is the focus, innovation partners will be more diverse, but their IP requirements may well be less demanding. As noted above, a number of studies have shown the importance of non-IP related knowledge transfer mechanisms, such as publications, conferences, consulting and contract research and collaboration, suggesting that these might be a primary focus for research communication when ICT users and applications are the target. Again, from the research perspective, the research skills required will be much broader, with multiple vertical market and application context knowledge required as well as technical expertise.

A major challenge for firms lies in the identification of useful external knowledge and its integration into the firm, so '[a] crucial part of the Open Innovation strategies of technology-component suppliers… is proactively building ecosystems to attract systems integrators and complementors.'[58] For research agencies and research firms, well-designed and targeted promotional activities and flexible but certain IP processes will be crucial.

It has been noted that de-regulation and privatisation of utilities in energy, water and telecommunications, together with government purchasing policies favouring larger projects, have created an environment wherein there is a lack of 'lead projects' (i.e.

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56 Complementarity is defined as the state or quality of being complementary. A complementary good is defined in economics as a good that should be consumed with another, such that if goods A and B were complements, more of good A being bought would result in more of good B also being bought.

57 Houghton, J.W., 'Innovation in ICT: a changing landscape,' Telecommunications Journal of Australia 56(3/4), (2006), 93-105.

58 West, J., 'Does appropriability enable or retard open innovation?,' in Chesbrough, H., Vanhaverbeke, W. and West, J., (eds.) Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 109-133.

projects in which solutions can be sought locally and developed into potential export products and services).[59] Such projects provided an important mechanism for commercialisation, being sufficiently patient and deep-pocketed to bring ideas through to commercialisation. Development and commercialisation grants are an alternative, but may not be sufficient. As the former Australian Commonwealth Chief Scientist recently put it: 'the only thing wrong with commercialisation of research in Australia is that there is no demand for it.'[60] The same problem has been noted elsewhere,[61] with the recent UK 'Lambert Review' reporting that: 'The main challenge… is not about how to increase the supply of commercial ideas from the universities into business. Instead, the question is about how to raise the overall level of demand by business for research from all sources.'[62]

It has long been understood that the 'D' in R&D is often much more expensive than the 'R', and some have likened the knowledge created through research to a commodity that is produced in raw form as research papers and reports. The value chain that takes this raw material and adds value by turning it into a new technology, a new drug, a creative work, a policy or management decision is often long and poorly structured.[63] Moreover, the knowledge value chain appears to work differently in different fields – with the emergence of specialist, commercial commercialisation agents in some fields (e.g. the early years of semiconductors, pharmaceutical biotechnology, and, perhaps, the Internet boom) but not in others.

What is less clear is the nature of agency. If firms are the commercial commercialisation agents, then it is apparent that they have often lost a good deal of money for their investors or been taken over by large firms as they succeed – a system of 'natural selection' in which neither successes nor failures survive. However, if people are the commercialisation agents, then it is apparent that they often develop a technology through a series of 'failed' firms, losing a lot of other people's money along the way, before successfully commercialising (e.g. semiconductors).[64] These differences may be the result of different commercialisation funding and IP regimes, or they may suggest what suitable funding and IP regimes should look like.

The decline of lead projects, the demise of large scale corporate laboratories and the emergence of more open innovation and a 'market in knowledge' imply the need for much greater understanding of the knowledge value chain and the nature and agency of commercialisation in different fields. Greater understanding of the knowledge value

59 Houghton, J.W. with Thorburn, L., The Victorian Electronics Industry Cluster, Report prepared for the Victorian Department of Industry, Innovation & Regional Development on Behalf of the Australian Electrical and Electronic Manufacturers Association (Melbourne, 2004).

60 Batterham, R., 'Some comments on Jeremy Howell's paper,' presentation at the Knowledge Intensive Services Conference (Sydney, 2006).

61 Howells, J., 'Where to from here for services innovation?' presentation at the Knowledge Intensive Services Conference (Sydney, 2006).

62 HM Treasury, Lambert Review of Business-University Collaboration (London: HM Treasury, 2003), 3.

63 Jones, G., 'Increasing the impact of research – making scientific knowledge more than just a commodity product,' paper presented at INORMS2006 (Brisbane: INORMS, 2006).

64 Braun, E. and MacDonald, S. Revolution in Miniature: The history and impact of semiconductor electronics (Cambridge: Cambridge University Press, 1982).

chain and greater attention to linking knowledge supply and demand, wherever it is around the world, are likely to be an increasingly important focus for innovation policy. So too will incentives and mechanisms that increase industry demand for research-based innovation.

For firms, developing absorptive capacity through internal R&D investments appears to be an important prerequisite for converting external knowledge into internal innovation.[65] This raises a number of questions. Is there enough internal business R&D in firms? Is there enough in their value chains? Is it located locally or overseas? And what do the answers to these questions tell us about the necessary linkages for success? Given limited local business R&D in Australia, targeting, in terms of both technologies and industries, and attention to global production systems, international value chains and international linkages are likely to be crucial for research agencies, firms and government policy.

Policies supporting and enabling wider access to publicly funded research may be more appropriate to the needs of many smaller firms, which typically have limited time and resources and are less able to engage in protracted IP licensing negotiations than are larger firms. More 'open access' policies would also enable smaller firms to engage more easily in internal R&D activities, thereby enhancing their absorptive capacity and fostering demand for research-based innovation.[66] Enhanced discoverability might also contribute to the formation of linkages and greater engagement with global architectural innovators and systems integrators.

SUMMARY

Significant changes are underway and there may be a need to re-examine research communication, commercialisation and innovation strategies, structures and policies. A new wave of globalisation has emerged in the recovery from the 'Dot Com' crash, which features the rise of emerging economies as new centres of manufacturing and services production, including high-technology manufacturing and research, design and technical services, and the emergence of globally integrated enterprises and more open corporate innovation models.

The challenge for local firms in countries like Australia will be to participate in global production systems and take advantage of knowledge generated anywhere within the systems' value chains. The challenge for specialist research centres will be to engage the global architectural innovators and systems integrators from a relatively small and isolated base. The challenge for governments lies in enhancing underlying capabilities through investment in education and research, attention to the other critical factors in

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65 Cohen, W.M. and Levinthal, D.A., 'Absorptive capacity: a new perspective on learning and innovation,' Administrative Science Quarterly 35(1), (1990), 128-152; West, J. and Gallagher, S., 'Patterns of open innovation in open source software,' in Chesbrough, H., Vanhaverbeke, W. and West, J., (eds.) Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006), 82-106.

66 Houghton, J.W. and Sheehan, P.J., The Economic Impact of Enhanced Access to Research Findings, CSES Working Paper No.23 (Melbourne: Victoria University, 2006); and Houghton, J.W. Steele, C. & Sheehan, P.J., Research Communication Costs in Australia, Emerging Opportunities and Benefits (Canberra: Department of Education, Science and Training, 2006).

attracting foreign investment in domestic R&D activity, and creating the global linkages and domestic environment to support global discovery and domestic absorption – with key elements of that environment being the creation of a supportive structure of incentives and sensitive regulation and management of IP which shift the emphasis from protecting IP to maximising its use.

As outlined above, inter alia, this will mean:

- Developing an understanding of the new global market in knowledge (in IP and research services);
- Adjusting IP management policies to take account of the emergence of more open corporate innovation practices, and striking an appropriate balance between appropriability and discovery by shifting the emphasis from protecting IP to maximising its use;
- Understanding the implications for IP management strategies of various choices and of targeting (e.g. production/use, architectural/component innovation, sector and/or value chain, systems integration/component innovation, etc.);
- Adjusting research education and management practices to take account of the increasing skills demanded of researchers and research managers (e.g. for broader understanding of the commercialisation and/or application context, and of IP and research management);
- Minimising the potentially negative consequences of conflicting policies and incentive structures by, for example, ensuring that research evaluation does not run counter to research commercialisation and communication, and sensitively managing the different conditions and dynamics of different research fields and industries;
- Paying greater attention in innovation policies to the knowledge value chain, to linking research supply and demand, to the demand-side and the incentives and mechanisms that might increase industry demand for research-based innovation; and
- Focusing on policies supporting and enabling wider access to publicly funded research to enable firms to engage more easily in internal R&D activities, thereby enhancing their absorptive capacity, and fostering demand for research-based innovation, and contributing to the formation of linkages and greater engagement with global architectural innovators and systems integrators.