



# NO SIMPLE SOLUTIONS

HOW SECTORAL INNOVATION SYSTEMS CAN BE TRANSFORMED

DON SCOTT-KEMMIS, MAGNUS HOLMÉN, ANTONIO BALAGUER,  
ROBERT DALITZ, KEVIN BRYANT, ALAN J. JONES, AND JUDY MATTHEWS

---

KEY FINDINGS FROM THE AUSTRALIAN INNOVATION SYSTEMS (AUSIS) PROJECT



# NO SIMPLE SOLUTIONS

HOW SECTORAL INNOVATION SYSTEMS CAN BE TRANSFORMED

DON SCOTT-KEMMIS, MAGNUS HOLMÉN, ANTONIO BALAGUER,  
ROBERT DALITZ, KEVIN BRYANT, ALAN J. JONES, AND JUDY MATTHEWS

---

KEY FINDINGS FROM THE AUSTRALIAN INNOVATION SYSTEMS (AUSIS) PROJECT

© D. Scott-Kemmis, M. Holmén, A. Balaguer, R.P. Dalitz, K.H.J. Bryant, A.J. Jones, and J.H. Matthews, 2005

This work is copyright. Apart from any use as permitted under the *Copyright Act 1968*, no part may be reproduced by any process without prior permission.

Requests and enquiries should be addressed to Associate Professor D. Scott-Kemmis, Innovation Management and Policy Program, National Graduate School of Management, The Australian National University, Canberra ACT 0200, Australia. Alternatively, email [don.scott-kemmis@anu.edu.au](mailto:don.scott-kemmis@anu.edu.au)

ISBN: 0 646 4487 0

#### Acknowledgements

It should be noted that the work on which this report has been based was undertaken under the terms of a Linkage Grant from the Australian Research Council. The authors are grateful for generous additional support (under the terms of that grant) from the Australian Business Foundation, and the Australian Government departments of Industry Tourism and Resources and Agriculture, Fisheries and Forestry. They are also grateful for subsequent support generously provided by CSIRO and the Department of Communications, IT and the Arts. It should be stressed that the views expressed in this report are strictly those of the authors and do not necessarily reflect the views of any of these organisations.

The authors are grateful to Clarity Communications Australia for their assistance in the editing and presentation of this report.

# Table of Contents

<b>Executive Summary</b>	<b>v</b>
<b>1. Introduction</b>	<b>1</b>
1.1 Approaching the study of innovation	1
1.2 Contrasting views on Australia's economy	3
1.3 Why take a sectoral focus?	4
<b>2. Sectoral transformation and patterns of innovation</b>	<b>5</b>
2.1 The advantage of a sector-based focus	5
2.2 Specialisation in sectors	5
2.3 Competition and sectoral transformation	7
2.4 Renewal and evolution of sectors	10
2.5 The pursuit of opportunities as the driver of sectoral transformation	10
2.6 A basis for understanding innovation in industry	11
<b>3. Sectoral transformation and innovation in selected Australian cases</b>	<b>13</b>
3.1 Introduction	13
3.2 Sectoral transformation in Australia	13
3.3 Competition and sectoral transformation in Australia	13
3.4 Opportunities, transformation, and prospects for the renewal of sectors	18
3.5 The roles of Australian players in relation to international counterparts	21
3.6 Sectoral systems of innovation	22
<b>4. Conclusion and discussion</b>	<b>25</b>
4.1 A new approach to the analysis of innovation in industry	25
4.2 General lessons from our case studies	25
4.3 Implications	27
<b>Appendix: Case study summaries</b>	<b>29</b>
<b>Appendix 1 Computer games</b>	<b>29</b>
<b>Appendix 2 Dairy products</b>	<b>32</b>
<b>Appendix 3 Mineral exploration</b>	<b>34</b>
<b>Appendix 4 Motor vehicles sector</b>	<b>37</b>
<b>Appendix 5 Oil and gas engineering</b>	<b>39</b>
<b>Appendix 6 Photovoltaics</b>	<b>41</b>
<b>Appendix 7 The wine sector</b>	<b>43</b>
<b>Endnotes</b>	<b>45</b>
<b>References</b>	<b>51</b>



## Executive summary

This study is concerned with change in the factors that drive and support innovation, focusing on the influences of business behaviour and industrial dynamics. The study draws on seven sectoral case studies: computer games, dairy products, mineral exploration, motor vehicles, oil and gas engineering services, photovoltaics, and wine. It develops a framework that recognises both the strongly systemic nature of innovation and the inexorable processes of transformation in an increasingly international competitive context. It brings together sectoral innovation system approaches and frameworks for analysing industrial dynamics and sectoral transformation.

All the sectors investigated have become more complex over time. And this is most relevant to innovation systems study. There are now larger markets, more types of organisations, a broader and deeper knowledge-base, and more technologies. Consequently, specialisation and the division of labour have increased in all seven sectors studied. These changes in turn provide new business opportunities.

To illustrate some of the findings, successful firms in our world-leading mineral exploration and wine sectors have become internationally competitive through changes in product innovations and process innovations. New patterns of innovation emerged through the development of good interactions between several types of organisations. The size and nature of demand has also been influenced by Australian firms in these successful sectors. It is also notable that changes in activities, start-up of new organisations and changes in the relationships between others (such as firms and research organisations) have transformed these sectors, not just in Australia, but worldwide.

Continuing globalisation will increase the pressure to specialise, forcing the need to increase the depth of knowledge and producing closer interaction and collaboration across sectors.

The process of increasing specialisation also provides opportunities for entrepreneurs and opportunities to create and grow new sectors. The ongoing pressure to innovate and specialise means innovation policy is increasingly important for the future economic wellbeing of a nation. Important too, is that the relative ease of the emergence and growth of new sectors can be considerably affected by public policy, and thus growth and the future economic structure of the nation is significantly influenced by innovation policy and other related policies.

The framework and the sector studies show a close interaction between innovation, competition and how the benefits from innovation are captured as firms respond to the sequences of opportunities and problems they face. The study shows two main ways in which firms benefit from innovation. The first applies in sectors dominated by mass production, while the second is associated with sectors dominated by 'blockbusters'—where a single business controls a product, production facility or service that enables it to hold a substantial share of the overall market. Each of these ways (which are not necessarily mutually exclusive) are associated with particular patterns of innovation.

Innovation changes societies and economies—over time the cumulative effect of many changes results in radical transformation. But innovation remains a complex and elusive phenomenon. The study argues for ongoing investigation of its relationship to the dynamics of industry. Innovation presents both opportunities and problems—but no simple solutions.



# 1

## INTRODUCTION

### 1.1 Approaching the study of innovation

Are Australia's innovation systems sick, healthy or irrelevant? On the one hand, we are told we lag well behind comparable countries and need to lift our game, both in private industry and in public policy. On the other hand, we are presented with good news stories showing that innovation in Australia is world-class, that in many respects we are a leader, and that our innovation policies have us on the right track for long-term economic growth.

Both views are over-simplified. They manifest differences in approach and perceptions on how we should measure and assess innovation, and—more fundamentally—define what 'innovation' is.

This report derives from a larger project on innovation.<sup>1</sup> It takes a new perspective—a different approach from many other innovation studies undertaken in Australia.

Our work takes the relatively new and developing *innovation systems* approach (Box 1) and applies it to the study of some diverse *industry sectors*. We aim to investigate the dynamics of industry and how these relate to innovation—studying sectors is a means to this end.

Globalisation—particularly the lowering of trade barriers—has removed the isolation of national industries. Consequently, we began each sectoral study from a global perspective, analysing Australian sectors against their international environments.

Earlier research into innovation in Australia focused on aggregate indicators,<sup>2</sup> such as R&D, patenting, and venture capital investment. In developing our approach we have, instead, drawn on the growing understanding of innovation<sup>3</sup> and its important role in economic development.<sup>4</sup> We take a systemic view of innovation, recognising that it is primarily centred within organisations that interact with one another. At the same time, these organisations are strongly influenced by the incentives provided by demand in the market as well as the 'rules of the game' set by legal, policy or social institutions. Over time, many frequent interactions transform the innovation system itself, as well as the internal processes of its component organisations.

Much recent international work aims to develop a more realistic and useful framework for the role analysis and policy development play in the innovation system. Our approach builds on this work.<sup>5</sup> Our study concludes that patterns of innovation, specialisation and transformation are shaped by dominant characteristics of industry sectors.<sup>6</sup> By building in international considerations, we have gone a long way toward addressing some of the difficulties faced by studies that confine themselves only to *national* innovation systems.<sup>7</sup> While national innovation systems deal well with national and local factors, such as legal, policy and social institutions, they tend to downplay the influence of powerful international factors, such as foreign competition and foreign demand.

Our study is based on an in-depth look at seven sectors (based on case studies for each). Our choice of sectors is outlined in Section 2.

This report takes a new perspective—a different approach from other innovation studies undertaken in Australia.

## Box 1: Innovation systems—a summary of core concepts<sup>8</sup>

Systems approaches to innovation recognise the complexity of the processes involved in innovation.

Systems involve elements\* that interact with and influence each other. The systems approach to innovation views economies principally as interacting organisations (mostly business enterprises or firms)\* that to a greater or lesser degree respond to demand by engaging in innovative activities, strategically marketing products or services, and influencing each other's behaviour. Firms prosper when they continually innovate and develop successful strategies. Those that do not eventually go out of business.

An innovation system also includes non-business organisations (for example, universities, government agencies, or regulatory authorities) providing direct or indirect services to innovative firms. Some non-business organisations therefore form a support base for fresh ideas and new opportunities. Others necessarily constrain what can be done.

Within a broader context (geography, climatic and environmental conditions, natural resources, and the state of physical infrastructure), the key factors to take into account in innovation systems include:

- *The legal, policy, financial and social institutions* (including administrative practices) that set the rules for competition, cooperation and innovation among the key organisations in the innovation system. Literature on the innovation system generally uses 'institution' to describe the business environment in which firms (and other types of organisations) operate—institutions are not, therefore, considered to be organisations. Rather, they are the formal legislative, regulatory and policy rules established by governments, combined with the less formal range of common social behaviours and instituted administrative practices that affect practical business operations. The boundaries of accepted business and social behaviour and the forms of instituted practices may vary substantially between countries and even locally within a country.
- *The division of labour or types of specialisation* that apply to the key organisations within each system.
- *The nature of interactions between organisations comprising the system*, such as their frequency and persistence over time, whether they are governed by informal or formal arrangements, the strength of their influence, and whether they are self-reinforcing.
- *Stages of evolution within sectors*—the broad paths followed by organisations between the problems, opportunities and critical events that are commonly faced over time.
- *The knowledge base drawn on by organisations* and the broad patterns of innovation that proves important in certain sectors.
- *Major skills and competencies important for innovation within the key organisations*, together with the means used to build these skills and competencies in key organisations and across the sector overall.
- *The means that organisations use to appropriate economic value* from innovation.
- *Demand-side influences* on innovation, as exerted by the market and its changing nature over time.
- *The ecology*—how competing organisations enter and leave the innovation system (business churn, birth and death of firms) and how these influence and interact with each other and with the public sector.

---

\* In the broad sense, the component elements of a system are held together by interactions that are strong enough and sufficiently persistent to prevent them from dispersing rapidly. In an economic or innovation system, the elements are individuals or organisations (often referred to in the literature as 'agents', 'actors', or 'players'). In an innovation system, the key elements are mainly organisations—of which there are two main types: business enterprises—called 'firms' in this report—and non-business organisations that are mostly non-profit and established (most often by governments) to undertake a specific function such as research, policy formulation or the administration of regulations. Throughout this report we use 'organisation' to refer to all types, and 'firm' to refer to business enterprise.

## 1.2 Contrasting views on Australia's economy

Has Australia developed a dynamic economy that forms the basis for sustained growth, or have we failed to build new strengths to increase our options for the future? If our economy is successful, then questions of innovation may be primarily matters of fine tuning. If not, they are more far-reaching and urgent.

Among a range of views expressed on Australia's economy, two sharply contrasting positions have recurred persistently over many years. These views can be roughly divided between those who are positive and see Australia as performing well and those who are negative and see Australia as at risk.<sup>9</sup>

### Positive view of Australia's economy

For the most part, the positive view believes that the growth in Australia's economy in recent years results from increases in productivity arising from deregulation and other microeconomic changes made over the 1970s, 1980s and early 1990s. These changes were driven by the need for Australia to be more internationally competitive, by increasing demand from Asia, and by the positive effects of rising international competition. In addition, Australia has several emerging specialisations in, for example, industrial applications of new materials, biotechnology, and pharmaceuticals. Also notable is the high growth of Australia's commercial and financial service sectors which are taken to be a result of the growth of outsourcing and the uptake of information and communications technology (ICT) in the drive for improved productivity.

### Negative view of Australia's economy

The negative view typically believes that deregulation and other microeconomic changes have reached the point of diminishing returns—with little prospect of further productivity from more change. In addition, this view is concerned that Australia increasingly relies on commodity trade when the country's resources may face severe competition from foreign sources with a lower cost-base. At the same time, Australian manufacturing continues to decline in world terms, and fails to offer high value-added products in high volume to potential foreign customers. Further, no major new sectors have emerged in Australia during recent decades. This is in striking contrast to some other parts of the world (the growth in telecommunications in Scandinavia, for example, or semiconductors in South Korea and Taiwan).

### Balancing the positives and negatives

The rapid growth of industrial production in Asia continues to change the landscape for Australia. While in many ways the competitiveness of manufactured goods produced in Asia has greatly benefited growth in the Australian resource sector, the growth of Asian manufactured exports adds pressure on Australian manufacturing to increase its competitiveness and specialisation. Those holding a positive view are sanguine about these changes—they are relatively confident Australian firms are leading and will adjust well in response to the challenge. However, the negative argument is that the resource sector is an uncertain base for assured profits and jobs, and may not be competitive if and when large foreign suppliers come on-stream. It sees resources as largely a 'price taking' industry that is inherently limited in its ability to adapt its products so it can claim a premium price for any significant period of time.

Our aim is to draw lessons from both positive and negative stories, focusing on innovation's potential benefits.

What assumptions on innovation underlie the positive and negative views?

When innovation is brought into the debate, the major emphases of the two views differ again. In the positive view, the prime focus is on the benefits from institutional innovation (in this case, regulatory change) and the flow-on cost-saving innovations in organisational structures and work practices, as well as on technological process innovations that reduce costs. The negative view draws attention to Australia's relative lack of success in product innovation—especially, our seeming inability to develop or capitalise on technological innovations that might provide 'first mover' or premium price advantages.<sup>10,11</sup>

In this report, we aim to develop a more discriminating perspective than the two viewpoints discussed above. While we have described strongly positive and negative perceptions of Australia's prospects, other voices in the

discussion point to a mixture of success and failure. Our goal is to draw lessons from both. Our approach is to focus on the part played by innovation of all kinds—and examine the dynamic interplay of factors that produce benefits or disadvantages for Australian firms, and therefore to our economy overall.

### 1.3 Why take a sectoral focus?

The literature on innovation research makes it clear that the characteristics of innovation vary substantially from one industry sector to another—thus, aggregate analysis is unlikely to take us far.

Australia has a strong technological specialisation towards the resource base in agriculture, mining and primary metals. Many countries have pursued industry development policies aimed at increasing specialisation in sectors where demand increases as consumer affluence improves. Among OECD countries Australia has had one of the lowest levels of change in technological specialisation over the past 20 years.<sup>12</sup> Nevertheless, it would be misleading to conclude there has been little structural change in Australia. In reality, there has been substantial change at the broad sectoral level (services account for an ever-growing share of output) and at the sub-sector level (for example, we export components as well as motor vehicles). It would also be misleading to suggest that Australia is not a 'knowledge economy'. In reality, our relatively high specialisation in resource-based industries has arisen only because we are.

The mining and agricultural industries were initially resource-enabled but have become increasingly knowledge-based. Thus while the productivity performance of the mining and agricultural sectors is world-leading and dependent on innovation, they are in turn based on high-level capabilities incorporating complex and new technologies. Furthermore, substantial specialist Australian providers of equipment have emerged, backed by high value-added engineering services. This is despite the need to import the core capital goods incorporated in such equipment.<sup>13</sup> Thus, a leading contribution to Australia's economic performance has arisen from implementing knowledge, and adopting and adapting technology, largely in resource-based, service and low technology industries where innovation is focused on changing processes rather than on major products. In several areas, Australia's knowledge base has also assisted with the rapid uptake and integration of technologies to a broad range of applications with positive outcomes for the economy. In our earlier work,<sup>14</sup> we labelled this use and adaptation of core technologies as *Systems Integration*.<sup>15</sup> In this report, we argue that changes in specialisation are systemic and that the evolution of specialisations produces radical transformation in industry. Firms do not innovate or make money in isolation; instead innovation and the means through which benefit is gained from it are shaped and altered through interactions and interdependencies among organisations—including firms, government organisations, industry alliances, networks, regulation-setting agencies, and especially by the extent and nature of demand.

The evolution and transformation of sectors (and economies) is irreversible. We argue in Sections 2 and 3 that sectors evolve continuously by addressing problems and pursuing opportunities. As a result, organisations, technologies, relationships, and legal and social institutions particular to sectors all co-evolve. The capacity of organisations to address problems and pursue opportunities effectively—and indeed the nature of these problems and opportunities—is shaped both by the wider national context that is common to all sectors *and* the specific sectoral context overseas. This comes about as firms increasingly interact with suppliers, customers and competitors beyond their local region and nation.

Similar sectors in different countries are likely to have more in common than different sectors in the same country. This is particularly true with the patterns of innovation and the role institutions play. In this context, the ongoing globalisation of markets, production, and development—which proceeds faster in some sectors than in others—supports our view that *taking a sectoral and dynamic approach to innovation systems sets a valuable path towards understanding the structural transformation of industry*. Neither a purely national focus on innovation systems,<sup>16</sup> nor a focus on technologies, nor the use of statistics alone, is sufficient by itself for developing an adequate understanding of the evolution of industry.

Globalisation supports our view that a sectoral approach to innovation systems is valuable in understanding industrial transformation.

# 2

## SECTORAL TRANSFORMATION AND PATTERNS OF INNOVATION

### 2.1 The advantage of a sector-based focus

This section outlines the conceptual and analytical framework used in our study. The focus of the framework is on transforming the economy and how this transformation is driven by dynamic behaviours in industry that are closely associated with innovation. The detail of such transformation is more clearly seen through studying individual sectors—as a major force, creating and distributing economic prosperity and growth between firms, consumers and nations.

The new focus of this report shows how sectoral transformation is driven by competition, which is itself driven by innovation, particularly the benefits of innovation.<sup>1</sup> Globalisation means sectoral transformation in Australia is increasingly determined by international events and not just events within this country. Hence, while this study concentrates on transformation in sectors in Australia our approach can be used to characterise competition and transformation internationally.<sup>2</sup>

In the rest of Section 2 we define sectors and show how changes in demand and consumption affect their degree of specialisation and transformation. Section 2.3 explains how competition through innovation, and its resulting benefits (appropriation), drives sectoral transformation. In Section 2.4 we describe how firms identify, generate and exploit business opportunities and in Section 2.5 we explain how the pursuit of opportunities also drives sectoral transformation. Section 2.6 discusses some difficulties in applying mainstream economic analysis to innovation and outlines why we prefer this study's new approach.

### 2.2 Specialisation in sectors

#### 2.2.1 What is a sector?

In this study, we define a sector as a bundle of organisations that carry out market and non-market functions and which interact to create, produce, disseminate, and sell related products and services. We also report on how organisations, interactions, products, and services co-evolve.<sup>3</sup> This broad definition highlights the fact that behaviours within sectors change over time. Organisations change how they operate and how they compete and collaborate with one another.<sup>4</sup>

Generally, firms in a sector specialise in, and perform some but not all, of the activities needed to deliver end products or services to consumers. The activities of organisations in a sector are connected and coordinated through market transactions and other types of relationships, including networks.<sup>5</sup> Thus, organisations become specialised and their actions become coordinated. This is often referred to as a division and integration of labour.<sup>6</sup>

Over time, sectors also change—through transforming relationships between organisations; through organisations entering and leaving a sector; through the skills and knowledge-base developed within organisations; and through changes in an organisation's activities. While organisational activities most directly determines the overall nature of sectoral transformation (one example is product diversification), other influences outside their immediate control also impact. Policy makers and political players, for example, can change the legislation that governs an organisation, or alter public procurement policies that affect the demand for goods and services. They may also influence whether new firms or other organisations enter a sector.

This report defines these influences as sectoral transformation.

In summary, we believe sectoral transformation involves changes in the number, type and activities of organisations, as well as changes in inter-organisational relationships and how these relationships are shaped.<sup>7</sup>

### 2.2.2 Markets, specialisation and the division of labour

A major driver of economic progress is the size and nature of market transactions. As Adam Smith states,<sup>8</sup> the specialisation and division of labour depends on the size of the market. The opposite is also true, however: the size of the market depends upon the division of labour.<sup>9</sup> The greater the size of the market<sup>10</sup> the more sectors, organisations and employees specialise in tasks and skills. At the same time, specialisation and changes in activities affect the size and nature of the market through, for example, reducing costs or widening product appeal. Thus, changes in the structure of markets—such as the relative importance of different market segments, or alterations in consumption patterns—drive sector transformation.

Changes in the division of labour are a crucial aspect of sectoral transformation. For example, sectors tend to mature by increasing their internal division of labour.<sup>11</sup> Division of labour tends to increase when new types of activities, professions or specialised firms and other organisations enter a sector. This illustrates how the means of production and consumption can change over time, especially when a growing market accompanies (and stimulates) the growing maturity of a sector.

In particular, transformation is driven by indirect means of production. In this context, indirect<sup>12</sup> means activities and problem-solving not necessarily directly linked to the original problem identified (or perception of that problem). Instead, they are linked to issues or opportunities surrounding, or connected to, the original problem. This creates more opportunities to develop a richer suite of solutions. As a consequence, the range of tools and technologies required to innovate increases in size and forms a greater interdependence. Such indirect means of production are driven by evolving specialisations in a work force that generally needs to change its knowledge and skills base to enable workers to handle increasingly more difficult tasks.

Over time, changes in production may in turn change an organisation's activities, knowledge, skills base, and technologies.

To summarise, changes in the means of production arise from the need to solve complex problems. This involves splitting complex tasks into simpler sub-tasks, and supporting (or substituting) some sub-tasks with new types of technologies. Over time, changes in production may in turn change an organisation's activities, knowledge, skills base, and technologies. An example of this indirect means of production may be the innovative work required to develop new technologies for instrumentation or software.<sup>13</sup> These new technologies can support R&D in ways previously too costly or impossible to consider. Transformation, in other words, creates substantial opportunities for new organisations to enter a sector as well as promote change in organisations to enable them to respond in new and effective ways.

### 2.2.3 Throughput and the international division of labour

To different degrees, sectors may be characterised by economies of scale. For firms, the level of 'throughput' is essential to achieve increasing returns. Throughput is the amount of materials or data processed in a production facility or project during a specified period of time.<sup>14</sup> If the throughput is highly sensitive to the scale or scope of production, successful investments to increase scale or broaden scope are likely to lead to a skewed distribution of, for example, the size, market share or turnover of companies.<sup>15</sup>

Shifts in the throughput of one firm in a sector may have consequences for others in the sector—both for suppliers and customers, for example, and/or supplier and customer firms in related sectors. Another example is how changing the scale of operations of retail firms affects the patterns of innovation and appropriation of suppliers. To ensure high and consistent throughput, and therefore better profits, retailers will often standardise goods so they have mass appeal, using a short 'test time' to ensure new products are as attractive to customers as possible. The growth of large markets for standardised inexpensive goods can also have side effects—for example, it can lead to the creation of niche markets for expensive high-quality goods.

The division of labour is affected by appropriation since changes in throughput may change opportunities.<sup>16</sup> Investments to increase the scale of operations in chemical plants, or increase the throughput of data in pharmaceutical R&D or in packaged software, for example, all have strong, in-built mechanisms for reaping increasing returns. The first organisations to master increases in throughput often become efficient, prime

movers which alter the nature of competition in a sector. In this scenario, large national firms may sometimes emerge well placed to become multinational corporations.

The nature of throughput also impacts on the international division of labour. For example, countries without organisations operating on a large scale cannot sustain certain sectoral activities. This does not imply that these countries have lost the ability to participate—they may complement or supplement the activities of others in the sector. They may also pursue new economic opportunities directly related to the activities of large, multinationals, becoming specialised suppliers or occupying niche markets that the large firms decide not to cater for or, indeed, overlook.<sup>17</sup>

## 2.3 Competition and sectoral transformation

### 2.3.1 Innovation and competition

Competition is a major driver of sectoral transformation. There are different types of competition, some more significant than others. The almost exclusive focus of many economists on competition based on changes in costs and prices, leads to oversights. The reality is that *the forms of competition most critical for transforming and sustaining industry over the long term are driven by innovation, imitation and appropriation*. Competition among firms (and sometimes other types of organisations) determines how innovation is generated, who the innovators are, and how the economic value generated through innovation is distributed and appropriated by different firms.<sup>18</sup>

Although competition drives innovation, individual innovations also change the competitive landscape and frequently establish a clear direction both for future innovations and further competition. Notably, most innovations complement earlier ones—a new product or service is therefore often made up of a package of innovations that complement one another or reinforce each other's competitive value.<sup>19</sup>

Innovation relevant to a particular sector tends to be carried out by firms already active in that sector, or a closely related one. There are countless examples of innovations that have rendered earlier products or services economically obsolete. Emerging innovations can put some organisations out of business. Over time, patterns of innovation can recast the technological and economic underpinnings of sectors. Nevertheless, most innovation and change tends to be modest or irrelevant to how a sector operates. In fact, most innovation is incremental and reinforces established paths of development. Consequently, patterns of innovation can persist for a long period after their first emergence at a sectoral or nation-wide level.

The forms of competition most critical for transforming and sustaining industry over the long term are driven by innovation, imitation and appropriation.

### 2.3.2 Patterns of appropriation

Questions of who captures the economic benefit from an innovation (*who appropriates*), and *how* value is captured,<sup>20</sup> are as important to understanding how sectors work and change, as are questions about the drivers of the underlying innovation process.<sup>21</sup>

There are many mechanisms that affect patterns of appropriation. These mechanisms include an organisation's strategy, the structure of the sector, access to complementary assets, and legal issues.<sup>22</sup> At any time, patterns of appropriation are affected by legal, policy and social institutions, and instituted practices.<sup>23</sup> Over time, patterns of appropriation are shaped by changes in increasing returns and the factors that underpin these returns.

Appropriation is affected by legally or socially enforced arrangements or firmly established practices governing how organisations interact (for example, through a 'gentlemen's agreement', a legally binding agreement, or through guile).<sup>24</sup> Innovation patterns are primarily shaped by the nature and distribution of property rights. These influence players to change strategies and behaviours to improve their chances of gaining benefit.

Who captures the economic benefit from an innovation and how value is captured are important to understanding how sectors work and change...

### 2.3.3 Modes of appropriation—blockbusters and mass production

Some sectors have strikingly different patterns of innovation.<sup>25</sup> And since these patterns are substantially related to the dominant means of appropriation, it is pertinent to ask what some important modes of appropriation look like and what characteristic patterns of innovation correspond to these modes.

There are two modes of appropriation—blockbusters and mass production.

This report concludes that there are two modes of appropriation—blockbusters<sup>26</sup> and mass production.<sup>27</sup>

#### *Blockbuster modes of appropriation*

Blockbusters are when the main business opportunities in a sector are taken by only a few firms.<sup>28</sup> It is when ‘the winner takes all’, or at least a sizeable market share.

These sectors are often characterised by firms with very high turnovers and market shares—organisations co-exist with a much greater number of small organisations with small turnovers and market shares. This arises because the leading firms’ products pre-empt much of the market over a considerable period and their products are difficult to imitate.

Blockbusters suit large markets and drive out the bulk of competition. While other organisations in the same sector may attempt to create the next blockbuster, few will succeed. The film and pharmaceutical industries have traditionally been dominated by the creation of blockbusters.<sup>29</sup> In this mode of appropriation, patterns of innovation and organisations’ operating routines focus on generating or finding new blockbusters, or sustaining and exploiting established ones. With blockbusters, successful radical innovation can result in a rapid increase in appropriation by new (or previously insignificant) organisations—sometimes accompanied by the rapid decline or extinction of others.<sup>30</sup> With other blockbusters, the degree of turmoil may be less dramatic, with the focus of innovation being on sustaining established blockbusters (large mine sites, for example) or developing a series of products or services that are sequels, and thus renew existing blockbusters (in the film industry, for example). These, however, can only be exploited by the organisation that holds the existing blockbuster.

#### *Mass production modes of appropriation*

Large organisations usually dominate a sector when the mass production mode of appropriation is at play, since only large organisations can afford the high up-front capital costs of the large, complex processing systems usually needed for mass production.

A plant has a large range of specialised operations—perhaps partly automated—which often require specialised workforce skills. Once a plant is established, the scale or scope of throughput per unit of time is a major determinant of efficiency, productivity and the level of appropriation of benefit gained. Since the complex processing systems usually required in mass production carry very high establishment and replacement costs, incremental innovation (often of a cost-cutting type) is favoured. This enables organisations to increase profits without major expense. This approach also enables organisations to build and maintain a large market share in their sector—and therefore maintain a high level of appropriation. Radical innovation is still possible but when it occurs it may cause turmoil because of the very high costs normally required.

Blockbusters and mass production modes of appropriation are more different in degree than in kind. They are not necessarily mutually exclusive and both can occur in one sector at the same time.

### 2.3.4 The effects of globalisation — from a national to an international focus

Globalisation of the modes of appropriation and patterns of innovation of sectors has caused a shift from a purely national to an international focus.

Traditionally, many large organisations emerged and prospered under the protection of national legislation (for example, tariffs on trade) which gave them advantages over foreign competitors. Over recent decades, however, deregulation across many countries—particularly the removal or reduction of trade barriers—has

radically changed this. Once previously regulated markets opened to competition, many already-large organisations increased their scale of operations further through acquisitions or organic expansion into foreign markets. As a result, in many countries, and across many sectors, the number of significant nation-specific players was replaced by a small number of larger organisations—usually multinationals.

In today's global environment, the opportunities for nation-specific firms to profit and survive differ substantially from those of the past. Nation-specific firms have had to change focus by entering niche markets or selling specialised support products or services to dominant international players. Thus, the sectoral shifts in scale and scope internationally may also create opportunities for organisations to become niche players. In addition, the range of sectoral activities across nations is likely to become more specialised over time.

### 2.3.5 Patterns of innovation and increasing returns

To generate increasing returns, there is a strong tendency for sectors to innovate around improved productivity. Large organisations within sectors tend to create and produce products that appeal to the masses, while at the same time seeking to improve processes and gain greater efficiencies. As a result, these organisations tend to pursue both product and process innovation.

Innovations that satisfy many buyers with differing demands may lead to increasing returns—thus appropriating the benefits of innovation. For example, spreading overhead costs (such as internal administrative services and rental of premises) across a number of products leads to economies of scale.

One important way to increase the value of economies of scale is to increase the throughput while *simultaneously* catering for the needs of many different users or consumers.<sup>31</sup> This can take place in three ways. One way involves building in a broader range of applications in the products being offered. A second way is to raise the quality of the product to satisfy the expectations of more people. Examples include establishing respected brand names, providing more functions, and standardising and quality-assuring offerings. A third way is indirect because it affects the demand side. Differences in demand are overcome, for example, by allowing users to create variety, by legislating a level of purchase, by inducing changes in buyers' perceived requirements, and sometimes by increasingly standardising taste.<sup>32</sup>

The source of increasing returns stems from the re-use of knowledge or from a larger number of organisations re-using well-established (but not necessarily well-known) knowledge. This may take place through imitation, through sharing information or more indirectly through mobility in the labour market.

This means that sectors sometimes change through diffusion and dissemination of knowledge, rather than just through individual inventions. Another example relates to the sale of a technical platform, which means that other developers or producers can focus on making applications based on that platform. A third example may involve creating or gradually developing intermediate product markets which in turn reduce the need for certain types of expertise and increase the need for other types of specialist skills.

...sectors sometimes shift through diffusion and dissemination of knowledge, rather than just through individual inventions.

These types of changes lower the amount of knowledge required by organisations to enter a sector. It may also bring about a higher level of specialisation as more organisations enter a sector. This in turn, can change the type of, or increase the amount, a sector experiments. This means that an opportunity acted upon by some organisations may generate business opportunities for others. Over time, this leads to more diverse organisations with an expanded knowledge base in a sector. For example, some organisations specialise in manufacturing while others move forward by identifying and acting on new opportunities to become service providers. Over recent years, some sectors have seen definite trends whereby organisations move from being product manufacturers towards serving customers through setting up, operating or maintaining technical systems.<sup>33</sup>

## 2.4 Renewal and evolution of sectors

Renewing the pool of opportunities in a sector is fundamental to its survival. Opportunities are the likelihood of innovating for a given investment. The means of renewing the pool of opportunities depends on knowledge accumulation and the ability to learn within a sector, as well as advances in other industries being transferred ('spillovers'), and fundamental advances in scientific or technological knowledge that can be applied to a sector.<sup>34</sup>

Renewing the pool of opportunities in a sector is fundamental to its survival.

When a sector emerges, or during periods of dramatic transformation, it is characterised by discontinuous change or turbulence in market demand which causes high levels of churn among organisations in the sector.

Some fail or seriously decline because their technological base suddenly becomes obsolete. Others with more appropriate skills grow rapidly by grasping technological opportunities and innovating in ways new to the sector (entrepreneurial individuals often play key roles in these successes). When a sector is well-established or mature, it is characterised by the dominance of a few large organisations which maintain their position by mastering a substantial base of sector-specific skills and by accumulating knowledge over a long period of time. In this case technological opportunities are closed to new entrants while established players often tread a narrow pathway of opportunity and incremental innovation.<sup>35</sup> Indeed, sectors can change from one state to another and back again over time.

## 2.5 The pursuit of opportunities as the driver of sectoral transformation

Direct transformation in sectors is driven by organisations, especially those identifying and acting on commercial opportunities or problems and purely technological ones.<sup>36</sup> These are opportunity-driven transformations. Some opportunities are based on price differentials, where a product can be bought or sold at lower or higher prices elsewhere and/or at some other time. These types of opportunities take place every day in the market place and, in time, can drastically change competition within a sector. They do this by triggering a change in behaviour which can affect profit levels. In this way, price differentials are a major factor in competition. Over time, opportunity-seeking behaviours redistribute wealth between organisations and also among consumers.

However, price differential is only one type of opportunity. Another common and important type comes from major bottleneck problems, for example, in a production process. While the problem may be well known it can be hard to solve. Since it may require a different knowledge or skill set, it is common for outside organisations to 'come-to-the-rescue' to solve the problem.<sup>37</sup>

Other opportunities occur when different organisations identify and generate a technological or organisational novelty perceived to hold economic value. This type of innovation alters how sectors work. Most of these build on existing knowledge and the habits, routines and physical artefacts in use.

When an innovation involves a technological artefact, its usefulness and value is largely set by what is already on the market and whether the new artefact complements an existing product or improves on a product that already exists on the market.

Opportunity-generating activities can take place in many ways. Organisations that observe opportunities may be from outside a sector, but for one reason or another have the skill-sets, resources and/or perception to move ahead of those well-established within the sector. Another common occurrence is when a competing organisation observes the initial action and imitates it, by copying it or diversifying from it.

Regardless of their nature, repeated activities like this mean that opportunities fuel opportunities—the economy is never 'at rest'. In this way, sectors evolve through *sequences of opportunities* some of which arise from challenges faced generally by established players in the sector—such as those arising from changes in the nature of consumer demand, or from new organisations entering into a sector and basing their processes or products on radically new technology or new approaches.

Sectors evolve through sequences of opportunities...

New problems and opportunities may also arise as a consequence of changes in legal or policy institutions. By altering legislation, regulatory requirements, policy, administrative settings, or standards, governments may induce indirect transformation of sectors by forcing affected organisations to alter their behaviours. For good or bad,<sup>38</sup> these alterations in behaviour are at times driven by areas of government that have no direct interest in a sector and no awareness that their actions will affect a sector. Changes in environmental regulations, for example, may unexpectedly lead to innovation.

Sectoral transformation itself affects the nature of opportunities—for example, when the size of the end-market and economies of scale in production increase simultaneously. This can bring about new opportunities for specialisation, either to serve dominant firms or to acquire products and provide added value. In the former example, small firms become upstream suppliers to large firms. In the latter example, small firms work downstream to, or horizontally with, large firms.

Once a problem is solved, future opportunities must be seized if an organisation is to maintain an adequate share of market demand, or better still, capture new demand. Over time, firms learn through the knowledge and experience gained by implementing a solution—the resulting increase in knowledge and skills in turn provides opportunities to solve new problems.

As discussed earlier in this section, innovation in industry is driven by consideration of appropriation—*how* economic value can be captured and *who* can gain financial benefit. The evolutionary path of sectoral transformation is then driven by organisational perceptions of how possible approaches to successive problems and opportunities affect maintenance of value and continued financial gain. In analysing these approaches in selected sectors in Section 3, we focus on:<sup>39</sup>

- creating economic value by adapting new activities
- mobilising resources—including finance, technology, skills
- establishing conditions of appropriation at various stages in sectoral evolution.

## 2.6 A basis for understanding innovation in industry

The concept of sectoral transformation we have provided in this report goes far beyond the ‘mainstream’ economist (neo-classical<sup>40</sup>) view which focuses on markets that change primarily in response to prices, supply and demand.

Within the literature, mainstream economics has been severely criticised because it relies on a standard mathematical model which can only be constructed on a set of highly idealised assumptions about market behaviour.<sup>41</sup> The assumptions sit uneasily with the realities of industry. In particular, blockbuster-dominated industry sectors (which are far from uncommon) appear to be so far removed from the standard industry model that a fundamental re-think seems required.

Furthermore, in decision-making, mainstream economic theory supports actions attempting to make the real world conform to a simple model, rather than seeking a model that conforms to the real world. In addition, a major difficulty with the standard mathematical model approach is that the key innovations which determine the sharpest changes in sectoral transformation are normally applied by only a few individual or maverick firms in a sector, whereas the model can only cope with a single *average* firm.<sup>42,43</sup>

Deriving from a range of empirical research on innovation and business behaviour, historical studies of economic and industrial change, and institutional and evolutionary approaches to economic analysis over the past 10 to 15 years, some economists have introduced the systems approach to innovation, partly in reaction to dissatisfaction with mainstream economics.<sup>44</sup> However, the innovation systems approach has been mainly developed in relation to *national* systems of innovation.

While our work falls within the innovation systems tradition (and we draw substantially on other work relating to sectoral innovation systems<sup>45</sup>), in our view increasing globalisation invalidates a purely national approach. It is essential to take into account national, regional and local specificities, such as legal and social institutions, local infrastructure, and geography. However, key commercial aspects of the industry rules of the game, while increasingly set at a global level, vary substantially on a practical level from sector to sector. We therefore contend that international system considerations are equally important to the national, although these too should be taken into account on a sector-by-sector basis. While this is complex, taking the simple route is misguided.



# 3

## SECTORAL TRANSFORMATION AND INNOVATION IN SELECTED AUSTRALIAN CASES

### 3.1 Introduction

This section deals with economic transformation and patterns of innovation in seven sectors of Australian industry (motor vehicles, computer games, dairy, mineral exploration, oil and gas engineering, photovoltaics, and wine).<sup>1</sup> It draws on the detailed case studies summarised in the Appendix.

Technological opportunities and how Australian sectors have evolved in response are analysed through comparing different sectors. This section also presents the findings of our cross-sectoral analysis, focusing on the role of competition, patterns of innovation, modes of appropriation, and sectoral transformation. Finally, Section 3.5 examines sectoral innovation systems and compares the roles of the Australian players, their interactions, the roles of legal and social institutions, and patterns of demand.

### 3.2 Sectoral transformation in Australia

In Australia (and internationally), major changes over the past 20 to 30 years have reshaped most sectors. Changes include:

- growth in the size of markets
- greater specialisation among players and (often) between countries
- maturation of individual sectors (including greater specialisation)
- growth in the size, breadth and depth of underlying knowledge bases.

This report makes three main observations on sectoral change:

1. As a general rule, the roles of Australian sectoral players have become more specialised<sup>2</sup> when compared to the full range of roles seen across the world. At the same time, the scale of operations of Australian players within a sector has decreased in relative terms due to new organisations entering into a sector.
2. Major exceptions to the general rule occur when Australian organisations play a major role in transforming a sector.<sup>3</sup>
3. Even when Australian players are not major drivers of sectoral transformation, such transformation can create conditions for new types of economic activity in the country.

### 3.3 Competition and sectoral transformation in Australia

Competition among firms must be examined to determine how innovation occurs, who innovates, and how the economic value generated through innovation is appropriated by different players.

#### 3.3.1 Forms of appropriation deriving from mass production and blockbusters

A number of factors shape the appropriation of the economic value of an innovation. These include antecedent and subsequent innovations, the means of protection (for example, property rights or secrecy), a firm's strategy and the structure of the sector, access to complementary assets, legal issues, and patterns of consumption.

The two main findings arising from our new analysis of sectoral transformation are:

1. there is a distinction between two key modes of appropriation (blockbuster and mass production)
2. patterns of innovation primarily (but not entirely) reinforce these modes of appropriation.

Four sectors studied (motor vehicles, photovoltaics, wine, and dairy) adopt the mass-production mode of appropriation and three (computer games, mineral exploration, and oil and gas engineering) adopt the blockbuster mode.

One means of ensuring that firms generate increasing returns is that firms, alone or in collaboration with others, need to ensure a product has mass appeal. Mass appeal may arise as a result of product innovation—including standardised quality assurance, branding and cost lowering mechanisms, complementary or supplementary marketing, or service provision. Consequently, the transformation of sectors in the mass production mode includes sequential or parallel changes in products, production, marketing, and financing. In many cases, the firms first to invest and master complementary capabilities (the ‘first movers’) enjoy increasing returns.

There is a distinction between blockbuster and mass production modes of appropriation; and patterns of innovation primarily reinforce these.

In recent years we have seen a trend towards mass production as the principal means of securing appropriation, even in photovoltaics and wine.<sup>4</sup> Photovoltaics are increasingly dominated by large firms with major interests in electronics (Japanese) and materials (German). In wine, international acquisitions have been the dominant means of growth and of creating a focus on the mass market. This is also the case in dairy products.

As might be expected, market demand is a major driver shaping the evolution of sectors. In the wine sector, the dominant demand is for higher and consistent quality. Behind this is an increased prestige associated with drinking wine, increased advertising and publicity of the sector in mass media, and greater accessibility to wine and wine tastings by the mass market. With photovoltaics, environmental energy concerns have led to subsidised programs supporting the uptake by the construction industry of new photovoltaic products.

Blockbuster-dominated modes of appropriation are characterised by a high level of up-front financial investment, a range of skills employed in bringing a product to the market, and the time required to generate positive returns. New opportunities provide avenues for market entry for many new players, but this is not without risk. Indeed, many potential blockbusters face decreasing returns and failure in their early stages of development. However, when they succeed, they generate high returns—as exemplified by the international pharmaceuticals sector.

In addition to effort expended on the search for new blockbusters, a great deal of activity within a blockbuster-dominated sector is often devoted to sustaining an existing lead product. Methods for sustaining established blockbusters take place by improving original products, extending the life of a blockbuster,<sup>5</sup> branding, or creating sequels to the original product. Patterns of innovation are consequently dominated by exploiting property rights relating to an initial innovation or set of innovations.

For example, the Australian mineral exploration and oil and gas engineering sectors have evolved into service industries with a high proportion of international clients. In these sectors, large multinational operators own the rights to particular ground or off-shore sites for ore, oil or gas. It is not in their interest to diversify into equipment and site maintenance, which creates opportunities for smaller specialist organisations to step in. This trend has strengthened over the past few decades with the international shift to take fuller advantage of existing assets rather than searching for new ones. Opportunities for specialist companies to provide services in this context have been taken up by a substantial number of highly effective and growing Australian organisations, which contribute to these sectors internationally and domestically.

In the computer games sector, appropriation is largely determined by the relationship between retailers and suppliers. Large retailers in the United States, for example, focus on selling a small range of games with high turnover. They remove poor sellers from their inventories within a few weeks. This has produced a trend towards larger game platforms (for example, consoles and games custom-designed for each other, as opposed to games designed for a generic personal computer).

Another trend is that games publishers increasingly spend large budgets on sequels to existing rather than new games. By appropriating older blockbuster brands (albeit through sequels that modify the original product), these publishers effectively squeeze some new games out of the market.

### 3.3.2 Current innovation patterns in sectors: globally and in Australia

The two modes of appropriation are significantly diverse. Success in mass production requires ongoing improvement of operations and products. Success with blockbusters requires continually creating new products or extending or building on existing ones.

Success in mass production requires ongoing improvement of operations and products. Success with blockbusters requires continually creating new products or extending or building on existing ones.

In mass production, for example, the wine sector's innovative efforts focus on large-scale production of consistent quality wine and complementary assets such as brand names and agreements to distribute and market. Very effective sector-wide research and knowledge diffusion mechanisms have been developed through formal and informal means, especially strong networks. The Australian wine industry now leads the world in product, process and organisational innovation. Innovation in larger Australian organisations has taken place at different stages of the value chain. Notwithstanding the increasing presence of small- and medium-sized wineries focused on boutique wine production, the sectoral innovation system in Australian wine demonstrates it is well equipped for mass production competition.

The photovoltaics sector presents a sharp contrast. Internationally, some countries (particularly in Europe) have established regulatory institutions that promote a strong growth in demand for photovoltaics suitable for in-grid-connected markets. This provides major incentives for firms to move towards mass production and has resulted in some growing significantly and becoming world leading photovoltaic producers. These leading international players focus their innovation on reducing costs and implementing efficiencies in production. In Australia, on the other hand, while there have been a few recent institutional changes along the lines of those pioneered in Europe, their impact is weak. In the absence of grid-connected demand, Australian organisations have, over a long period, had to focus on fundamental research (including enhanced cell efficiency) or market niches providing enabling technology and services for small scale and off-grid applications of photovoltaics in remote areas. Since the early 1990s, changes in international competition in photovoltaics—from niche to mass production—have eroded Australia's overall competitive position. The absence of strong local demand for grid-connected applications means Australian firms have not been able to match world trends towards mass production and cost reduction.

The Australian dairy sector is a rapid user of new technology and knowledge that is sourced both nationally and internationally. Larger and more export-oriented dairy firms are now emerging following a long process of deregulation. Compared with the past, these firms now have a stronger capacity to develop, implement and appropriate the benefits of diverse areas of innovation—including product, process, supply chain, and marketing innovation. Smaller scale specialised product firms have also developed, serving niche national and international markets and regional tourist markets.

In the motor vehicles sector, Australian industry has remained competitive by successfully dominating local markets, extending reach to export and niche markets, and improving quality and productivity. This has been achieved by capitalising on a high level of expertise in design and flexible low volume production. Innovation in this sector focuses on three areas: (i) cost reduction; (ii) increasing performance; and (iii) specialisation. To succeed, Australia has adopted organisational innovations similar to those found internationally. As a result, outsourcing and adopting proven technology are key to surviving in this increasingly competitive and globalised mass production sector, where the core firms are among the largest in the world.

Responding to blockbuster modes of appropriation is different in kind and nature.

The mineral exploration sector, for example, has moved from searching for minerals by methods that rely solely on the skills of independent explorers or prospectors to searching for minerals through multi-faceted and systematic processes—often using highly sophisticated technology—that rely on a range of specialised skills and knowledge. With easy-to-find mineral deposits fast disappearing, the blockbuster logic of appropriation now applies to mineral exploration in the sense that firms need increasingly sophisticated methods both to locate new prospects and to extend the life of large, existing fields.

Critical for these firms is the ability to hold property rights and control interests in mine ownership for new and existing deposits. Innovative efforts on extending the life of blockbuster deposits focus on developing new ways of understanding where and how to explore—improved down-hole drilling surveys are an example.

In the oil and gas engineering sector, engineering firms primarily seek long-term contracts. In Australia, many of these contracts are for the North West Shelf gas development project, especially in servicing the repair and maintenance of high capital cost equipment. Australian oil and gas engineering firms are also heavily involved in international projects, including the recovery of the oil and gas industry in Iraq. This sector is experiencing an increasing number of innovative activities, including the development of specialised services for platform design and mooring systems.

In the computer games sector, appropriation is shaped by sales volume, ownership of intellectual property and the nature of agreed contracts between retailers, publishers and developers. To survive, Australian computer games developers must move quickly from one project to another and gain market access through existing distributor networks. Because Australian games developers rarely own the intellectual property, the Australian computer games sector exports services, not products. There are no local blockbusters in this sector so local developers are forced into a reactive relationship with international players. Australia's future growth in this sector is likely to be limited.

Tables 3.1 and 3.2 characterise both modes of appropriation and describe the differences between international and Australian patterns of innovation in the seven sectors we studied.

**Table 3.1 Sectoral transformation in mass production-dominated sectors**

Sector	Means of appropriation	International innovation patterns	Australian innovation patterns
MASS PRODUCTION			
Wine	<ul style="list-style-type: none"> <li>economies of scale in production</li> <li>marketing and distribution</li> <li>growth of mass production</li> <li>increased emphasis on property rights (brand names) and large contracts (retailers)</li> </ul>	<ul style="list-style-type: none"> <li>quality</li> <li>branding (year, district, genre, producer)</li> <li>increasing marketing and distribution competence</li> </ul>	<ul style="list-style-type: none"> <li>consistent quality products</li> <li>large-scale production</li> <li>research along the value-chain</li> <li>diffusion of management practices</li> <li>branding</li> <li>marketing and distribution</li> </ul>
Photovoltaics	<ul style="list-style-type: none"> <li>mass production and economies of scale in manufacturing</li> <li>protected markets (on-grid) or local niche markets</li> <li>downstream vertical moves</li> <li>service provision</li> <li>patents and licensing</li> </ul>	<ul style="list-style-type: none"> <li>processes innovation</li> <li>overall module performance</li> <li>cost reduction</li> <li>grid connected systems</li> <li>applied research</li> </ul>	<ul style="list-style-type: none"> <li>niche applications (off-grid)</li> <li>cell performance (efficiency)</li> <li>fundamental research</li> <li>services provision</li> </ul>

Sector	Means of appropriation	International innovation patterns	Australian innovation patterns
Motor vehicles	<ul style="list-style-type: none"> <li>property rights (brand name)</li> <li>mass production and economies of scale in production, marketing, financing</li> <li>continuous improvement (for example, JIT or TQM)</li> <li>design of vehicles</li> </ul>	<ul style="list-style-type: none"> <li>sequels (often annually) and imitation</li> <li>new products, features or genres, and cost reduction</li> <li>organisational innovations (just-in-time, TQM or TCM) to cut costs and reduce number of failed products</li> </ul>	<ul style="list-style-type: none"> <li>imitation</li> <li>reuse of proven solutions</li> <li>design (niche)</li> <li>follow world best-practice</li> <li>flexible low-volume production</li> </ul>
Dairy products	<ul style="list-style-type: none"> <li>economies of scale in production, distribution and marketing</li> <li>development of relationships with major customers</li> </ul>	<ul style="list-style-type: none"> <li>incremental innovation across a wide frontier</li> <li>cost reduction</li> <li>quality and product innovation in response to customer demand</li> </ul>	<ul style="list-style-type: none"> <li>product diversification, quality consistency, large scale production</li> </ul>

**Table 3.2 Sectoral transformation in blockbuster-dominated sectors**

Sector	Means of appropriation	International innovation patterns	Australian innovation patterns
<b>BLOCKBUSTERS</b>			
Mineral exploration	<ul style="list-style-type: none"> <li>deregulation and internationalisation of exploration</li> <li>increased difficulty in mature nations to acquire property rights</li> <li>contracts (mining companies, governments, stock exchanges)</li> <li>increasing focus on blockbusters</li> </ul>	<ul style="list-style-type: none"> <li>optimisation and life extension of existing mining operations</li> <li>search for ore formation regularities</li> <li>new or improved supporting technologies, concepts and standards to deal with more complex problems</li> </ul>	<ul style="list-style-type: none"> <li>optimisation and life extension of existing mining operations</li> <li>search for ore formation regularities</li> <li>new or improved supporting technologies, concepts and standards to deal with more complex problems</li> </ul>
Oil and gas engineering	<ul style="list-style-type: none"> <li>property rights (production title)</li> <li>networks in project bidding</li> <li>increased blockbuster focus</li> </ul>	<ul style="list-style-type: none"> <li>production optimisation</li> <li>systems integration and project management</li> <li>new supporting technologies to deal with more complex problems (off-shore)</li> </ul>	<ul style="list-style-type: none"> <li>preservation of blockbusters</li> <li>organisational innovation (system integration)</li> <li>following world best-practice</li> <li>specialisation in core technologies (upstream)</li> </ul>

Sector	Means of appropriation	International innovation patterns	Australian innovation patterns
Computer games	<ul style="list-style-type: none"> <li>property rights (brand names) and contracts (retailers, celebrities)</li> <li>increasing importance of blockbusters (brand names) and economies of scale</li> </ul>	<ul style="list-style-type: none"> <li>sequels, imitation, multiplatform, and convergence with film industry</li> <li>new game-play (online and mobile)</li> <li>increased scale and scope of games</li> <li>rapid endogenous and exogenous technological development (hardware)</li> </ul>	<ul style="list-style-type: none"> <li>contract work (fee for service) for existing titles</li> <li>follow international trends</li> </ul>

### 3.4 Opportunities, transformation, and prospects for the renewal of sectors

This report concludes that four sectors—motor vehicles, mineral exploration, oil and gas engineering, and dairy—are characterised by only low or moderate technological opportunities in core activities (for example, in car production or further development of mineral exploration methods). In the other three sectors examined—computer games, photovoltaics and wine—there are high *and* low technological opportunities, depending on the role organisations have adopted. For example, opportunities for developers in the computer games sector focused only on console games are rapidly decreasing. This is because games are becoming more complex, which means the innovation effort requires more highly specialised knowledge. This contrasts with the technological opportunities available to developers working on games for generic hardware platforms such as personal computers. For these developers, two to three months of work may suffice, given that the hardware involved is less complex than in specialist consoles.

This report identifies two patterns for the renewal of sectors.

The first pattern (which applies to computer games, photovoltaics, wine, and dairy) sees craft-based activities transform to industrial-style production. Once this pattern of production is introduced and adopted—providing a high level of technological opportunity with many possible sequence-paths to follow—firms are well positioned to gain a competitive edge through economies of scale and mass production. The form of competitive advantage can be supported by complementary players, such as government agencies, universities or research organisations. In other words, the means of competition (pattern of innovation and mode of appropriation) have caused these sectors to shift their approach from high levels of technological opportunities to low levels. During these major processes of transformation, the organisations closest to the leading edge of innovation drive change, grow and prosper.

The second pattern (which applies to the motor vehicles, oil and gas engineering, and photovoltaic sectors—and, to an extent, computer games), sees Australian firms facing stronger competition from major global players (in part due to falling trade barriers) and thus being forced to rise to international standards. To compete, these firms must usually take up specialist or niche roles in support of global players.

The nature and means of renewing opportunities in sectors is summarised in Table 3.3.

**Table 3.3 Opportunities, renewal and specialisation in seven Australian sectors**

Sectors	Nature of opportunities	Means of renewing opportunities in the sector	Australia's specialisation	Major Australian activities
Motor vehicles	<ul style="list-style-type: none"> <li>• incremental technological opportunities focused on enhancing product features and product innovation</li> <li>• process innovation to increase quality, lower costs and increase flexibility</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through imitation and high levels of R&amp;D</li> <li>• exogenous through spillover from other sectors (for example, electronics)</li> <li>• R&amp;D in applied engineering and technology development</li> </ul>	<ul style="list-style-type: none"> <li>• increased product specialisation towards low volume and flexibility</li> <li>• focus on imitation and late entry in product life cycle</li> <li>• reuse of knowledge and labour through networks and markets</li> </ul>	<ul style="list-style-type: none"> <li>• design and systems integration</li> <li>• imitation and technological reuse</li> <li>• flexible low-volume production of components and vehicles</li> <li>• support services to facilitate the industry</li> </ul>
Computer games	<ul style="list-style-type: none"> <li>• high technological opportunities but rapidly decreasing on powerful hardware (especially consoles)</li> <li>• new and high technological opportunities through emergence of new games platforms, game plays, and convergence with other forms of entertainment</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through imitation and rapid experimentation</li> <li>• exogenous through improvised hardware and software improvements</li> <li>• broader knowledge base and expansion of content (for example, animation or user creations)</li> </ul>	<ul style="list-style-type: none"> <li>• games development through fee-for-service</li> <li>• renewed strength on all platforms</li> <li>• early, small-scale experimentation in financial models and online games</li> </ul>	<ul style="list-style-type: none"> <li>• games development, software,</li> <li>• education</li> </ul>
Mineral exploration	<ul style="list-style-type: none"> <li>• low and decreasing returns to local superficial search</li> <li>• increased access to markets (deregulation)</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through increased scale and scope of search</li> <li>• institutionalised reuse of labour and knowledge (especially data sharing), and new technologies</li> <li>• more fundamental knowledge on the sectoral level (for example, new concepts)</li> <li>• spillover of knowledge and technology, especially</li> </ul>	<ul style="list-style-type: none"> <li>• increased level of systems integration of new technologies and maintained level of service provision (exploration) to see deeper and broader</li> <li>• service provision exports (exploration)</li> </ul>	<ul style="list-style-type: none"> <li>• geological, geochemical, geophysical exploration</li> <li>• education (including exports) and research (all types of knowledge bases and technologies)</li> <li>• systems integration and testing</li> <li>• financing</li> </ul>

Sectors	Nature of opportunities	Means of renewing opportunities in the sector	Australia's specialisation	Major Australian activities
Oil and gas engineering	<ul style="list-style-type: none"> <li>• low technological opportunities on the level of plant engineering</li> <li>• moderate for supporting technologies</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous focus on incremental innovation, reuse old and proven technologies</li> <li>• in situ problem-solving innovation</li> <li>• exogenous drawing on a range of sectors 'as needed' (for example, level of project)</li> <li>• some fundamental new knowledge (e.g. sediments)</li> </ul>	<ul style="list-style-type: none"> <li>• increasingly specialised in systems integration and off-shore engineering services.</li> <li>• decreasing Australian manufacturing content</li> <li>• Australian players have specialised in fast growing commodities (especially offshore LNG)</li> </ul>	<ul style="list-style-type: none"> <li>• systems integration</li> <li>• operations</li> <li>• increasingly upstream conceptual engineering and design</li> <li>• platform design</li> <li>• sub-sea mooring</li> </ul>
Photo-voltaics	<ul style="list-style-type: none"> <li>• moderate (decreasing) in on-grid markets</li> <li>• high in off-grid markets</li> <li>• unknown technological opportunities in new PV paradigms</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through R&amp;D and imitation (for example, design and materials)</li> <li>• exogenous in (for example, building materials, building design, maintenance)</li> <li>• research in materials (performance), production (quality, cost)</li> </ul>	<ul style="list-style-type: none"> <li>• increased specialisation niche applications (off-grid) and services provision in enabling technologies</li> <li>• decreasing specialisation in mass manufacturing</li> <li>• lost activities in mass-markets</li> </ul>	<ul style="list-style-type: none"> <li>• systems integration</li> <li>• service provision for niche markets</li> <li>• cutting edge fundamental research in PV cells</li> <li>• large-scale training PV engineers</li> </ul>
Wine	<ul style="list-style-type: none"> <li>• high-moderate technological opportunities for most wines (branding)</li> <li>• economic value of economies of scale through new products and markets (branded wines)</li> <li>• new varieties of grapes and styles of wine</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through experimentation with grapes and winemaking</li> <li>• exogenous, draw on processes and standards</li> <li>• broadened knowledge base and more specific knowledge (for example, salinity)</li> <li>• networks for sharing information and diffusing technologies and managerial practices</li> </ul>	<ul style="list-style-type: none"> <li>• Increased representation in grape growing, wine production, and wine research</li> <li>• public-private (formal and informal) networks</li> </ul>	<ul style="list-style-type: none"> <li>• grape growing</li> <li>• winemaking</li> <li>• tourism</li> <li>• education</li> <li>• R&amp;D</li> </ul>

Sectors	Nature of opportunities	Means of renewing opportunities in the sector	Australia's specialisation	Major Australian activities
Dairy products	<ul style="list-style-type: none"> <li>• low-medium technological opportunities based on meeting customer requirements through product and process innovation, while ensuring overall supply chain quality and efficiency</li> <li>• market growth in Asia</li> </ul>	<ul style="list-style-type: none"> <li>• endogenous through imitation and R&amp;D</li> <li>• exogenous through spillover from other sectors (for example, nutrition, biotech)</li> <li>• research in many aspects of production, and use, and in health and sustainability issues</li> </ul>	<ul style="list-style-type: none"> <li>• high volume, reliable, low-cost, high-quality customised commodities</li> </ul>	<ul style="list-style-type: none"> <li>• knowledge intensive primary production, systems integration, problem solving</li> </ul>

### 3.5 The roles of Australian players in relation to international counterparts

Because of their relatively small scale in global terms and relative ability to access resources (motor vehicles and photovoltaics), or because of late entry (oil and gas engineering), Australian firms have little influence on sectoral transformation world-wide. For the most part, our firms have become niche players relying on international resources and new developments. The Australian wine sector is an exception. It is understood to have been the first within the sector globally to move away from a craft-based tradition.<sup>6</sup> Later, a range of government- and industry-sponsored arrangements—supported by strong public research and intra-industry cooperation—stimulated important technological advances and the production of exceptional quality wine.

Without a lead role, most Australian firms look to increasing specialisation as a way to compete in the global arena. Indeed, in some sectors, specialisation is the *only* way Australian organisations can improve or sustain competitiveness. The motor vehicles sector is an example of this.

In photovoltaics, Australia also specialises in providing research, training and other services. Technological opportunities for new entrants in mass manufacturing of photovoltaic cells and modules are steadily decreasing as this sector becomes increasingly dominated by large organisations that mobilise substantial resources and invest in upgrading and scaling up for large-scale manufacture. Australian firms, in sharp contrast, are small in number and size and increasingly focus on specialising in the opportunities presented by off-grid systems.

Wine and mineral exploration are different. These sectors have strengthened or renewed their positions relative to international competitors.

The wine industry has achieved this through increasing economies of scale. The development of large Australian firms has played a key role in transforming the global sector through changing the nature of the product (branded wine) and the nature of the value chain (grape growing, supporting activities, research, and production). At the same time, there has been a surge in the number of specialist, boutique firms.

In mineral exploration, players have diversified technological innovation activities, conceptual development and standards. However, these changes have not fundamentally changed the technological opportunities for exploration because they are characterised by strongly decreasing returns in areas that have been repeatedly surveyed as technology has been improved.

Australian firms have little influence on sectoral transformation world-wide...our firms have become niche players relying on international resources and new developments.

In dairy, product manufacturers have not played any role in transforming the sector globally. In this sector, most national markets remain heavily regulated through production and trade controls. The dominant patterns of innovation and competition have driven many small Australian players to consolidate into larger organisations which base their operations on economies of scale. With deregulation of national trade and partial deregulation of international trade, a few organisations have developed into large, capable and strongly market-oriented ones which can compete internationally. These capture opportunities for growth and increasing returns based on relationships with customers and suppliers, economies of scale and competence in product design and production.

New activities and opportunities along the value-chain have emerged for Australian companies in all sectors studied. In manufacturing sectors characterised by relatively high technological complexity or high R&D intensity, and where mass production is the dominant form of appropriation, opportunities have increased for providing services in Australian markets and in exports to niche markets. The motor vehicles and photovoltaic sectors are examples. The difference between these is that while the motor vehicles sector has survived through the capacity of firms to adapt and reuse proven technologies developed elsewhere, the dominant form of Australian specialisation in photovoltaics is in ancillary services and research. This suggests that this sector is likely to decrease in size here and that Australian players will likely miss out on market segments of higher profitability and growth.

New activities and opportunities along the value-chain have emerged for Australian companies in all sectors studied.

On the other hand, in resource-based sectors like wine and dairy products, opportunities continue to emerge for Australia through the exploitation of economies of scale in mass production manufacturing and large investments in technologies and capabilities. This is related to the nature of Australia's key sectoral organisations, the connection between them and the institutions that have been established to support them.

### 3.6 Sectoral systems of innovation

As outlined in Section 2.5, we believe sectoral evolution is largely shaped by sequences of problems and opportunities organisations face in any competitive situation. Thus from our sectoral case studies we draw three generalisations:

We believe sectoral evolution is largely shaped by sequences of problems and opportunities players face in any competitive situation.

#### A Australian sectors that are growing *and* are internationally competitive

*The wine, dairy product and oil and gas engineering sectors*

These three sectors are all growing and competitive internationally. We found that opportunities for the wine, dairy, and oil and gas engineering sectors are generated by positively aligning both institutions and firms to take advantage of large and fast growing demand (for example, for quality branded wine, for dairy products in Asia, and for natural gas). In all cases opportunities involve scaling up activities, and effectively networking to mobilise appropriate resources—this is particularly true of wine and dairy, which contrasts with oil and gas engineering where effective lobbying has dominated.

These three sectors are diverse in their dominant mode of appropriation, but the players in each are generally in a strong position in relation to their own markets (for example, branding in wine, distribution and quality in dairy, and long-term contracts in oil and gas engineering).

In addition, the means of acquiring technology and developing skills in these sectors tends to be global, although skills training in Australia play a significant role in the wine and dairy.

## **B Australian sectors developing or renewing international competitiveness**

### *Minerals exploration, motor vehicles and computer games sectors*

These sectors have all developed international competitiveness. Our research makes it clear that the complementary roles of the organisations, institutions, and technological know-how (the knowledge-base) in these three sectors are key drivers of renewal and value creation. These sectors have had to mobilise their knowledge base to survive and compete. In general, institutions have aligned with these changes.

Mineral exploration stands out as a traditional industry sector in that it has kept at the forefront of technological development in Australia, and is a world leader in many ways. On the other hand, institutional change brought about by the Australian Government in the 1980s (the 'Button plan'), triggered industrial restructuring in the motor vehicles sector—organisational innovation, application of information and communication technologies and R&D have all played a major role.

In computer games, the driving force internationally is new platform technologies (software and hardware) and developing software and content. For Australian players, competition stems from aligning efforts with major international publishers to produce new content for these platforms.

## **C Australian sectors weakening in their international competitiveness**

### *Photovoltaics*

The photovoltaics sector in Australia is weakening, despite its strong science base. In the absence of mass production manufacture or a large market, Australia's excellent science feeds into international activity, or at best is involved in the development of small niches like remote area power supply. In addition, our skills base can also serve to install and maintain overseas generated consumer products.

Photovoltaics exemplifies sectors that are dominated by institutional problems (chiefly policy and legislative ones), market diversity, and particularly the mechanisms for appropriation.



# 4

## CONCLUSIONS AND DISCUSSION

To every complex question, there is always a simple answer—and it is always wrong!

H L Mencken

### 4.1 A new approach to the analysis of innovation in industry

This report charts a new path for Australia in analysing innovation and explaining its role in transforming industry. The new path takes an innovation systems route, but avoids a fixed national focus that blurs distinctions between industries and is blind to international realities. Instead, we focus on the global detail of the dynamic processes of change. These processes transform technology, products, services, organisational arrangements, interactions between organisations, and the nature of the market demand that ultimately drives the processes themselves. At the same time, we keep sight of the key institutional guideposts that determine local and national characteristics.

Our work confirms there are strengths in Australia's resource sectors, and shows that Australian organisations in these sectors are instrumental in changing the way competition occurs. In some other sectors, Australian firms have been largely reactive to how the terms of competition have been changed by foreign pace-setters and to the trends they have set in other nations. Australian firms have had to become more specialised to survive in this globalised division of labour. Even in sectors in which local research and training organisations play a key role, the knowledge base, technology and labour markets are global—providing us with a profound challenge.

In advocating a new approach, we do not suggest that a sectoral focus provides the only useful way of investigating innovation—we believe it complements other approaches, particularly those that focus on the role of generic or enabling technologies (such as information technology). We do, however, note the preponderance of technology-based studies of innovation in the past and argue for a greater appreciation of sectoral differences and a greater focus on sectoral studies.

### 4.2 General lessons from our case studies

#### Transformation in the sectors we studied

As discussed in Section 3, all the sectors we studied for this report are dominated internationally by either a blockbuster or mass production mode of appropriation. Patterns of innovation are aimed at, and tend to, regenerate and sustain these modes of appropriation. However, this was not the case, say, 20 years ago, for all of the sectors we studied. For example, the blockbuster mode of appropriation has only recently come to dominate the computer games sector.

All seven sectors we studied have become more complex over time. There are now larger markets, more types of organisations, a broader and deeper knowledge base, and more technologies. Consequently, specialisation and the division of labour have increased in all seven sectors. These changes in turn provide new business opportunities.

#### Australian patterns of economic transformation and innovation

In some sectors, Australian firms and other organisations are world leading. The best examples are mineral exploration and wine. In other sectors we studied, some better Australian firms have adopted a posture complementary to the world-leading firms. They take a lower key approach and achieve success as either specialist providers internationally, and/or they serve the Australian market—especially as service providers. In many cases, Australian firms 'learn while doing' and start to export these services.

One lesson from this is that—since Australian firms compete in an international arena—industry and innovation policy considerations should not just be Australia-focused. International analysis is vital for better understanding innovation and economic growth.

Nevertheless, in our sectoral case studies we saw several examples of the positive influence of *national* institutions, for example: the role of national surveys for minerals exploration; the Cooperative Research Centre Program and the network of levy-funded Rural Research and Development Corporations; CSIRO programs; and the science-based approach to rural innovation. But in other cases a momentum for change outside the sector had not been mobilised. New sectors sometimes may lack the ‘voice’ to mobilise external support. In the photovoltaic sector we observed a failure to attract substantial investment by major industrial firms and an inability to mobilise sufficient support to change national energy policy regimes. In both respects, this stood in sharp contrast to the situation in Japan and Germany. Similarly, in contrast with the film industry and despite its potential commercial significance, the computer games sector has not attracted substantial government support.

While some opportunities are lost, it seems clear that new opportunities always emerge. Some come about from the transformation of sectors, where new opportunities emerge while markets for sectors grow. However, these opportunities do not just come about automatically—firms and organisations must identify and act upon them.

Firms use innovation to improve their competitive advantage and to appropriate greater financial reward. But unless they *perceive* reward is likely to follow, firms will not pursue particular paths of innovation themselves, and will not seek to take up and commercialise the discoveries of others. Firms that are more competent will more accurately perceive the likelihood of reward and therefore be more likely to make successful choices and thus prosper. Since the knowledge base has broadened, deepened and become more complex in all of the sectors we studied, achieving high levels of competence is difficult for firms unless they specialise. Thus, as a sector matures, firms tend to adopt more specialised functions.

### **Evolution of firms and sectors**

Successful firms in our world-leading mineral exploration and wine sectors became internationally competitive through changes in both product innovations and process innovations. In these two sectors, new patterns of innovation emerged through the development of good interactions and connections between several types of organisations. The size and nature of demand has been influenced significantly by Australian firms in these successful sectors. There have been changes in activities, start-up of new organisations and changes in relations between others (such as firms and research organisations) that have transformed these sectors not just in Australia but worldwide.

There are a number of reasons for relatively less successful Australian sectors (noting that no sector we studied can be characterised as completely unsuccessful or shrinking). For example, while in photovoltaics there are issues with creating markets, there are also issues relating to the lack of entry of Australian firms with strong electronics and chemicals backgrounds in the design and manufacture of photovoltaic cells and modules, and their applications. However, we did not fully explore the detail of why some sectors are less successful in Australia than elsewhere—that question requires more study.

In the two highly successful sectors we studied, the success often involved government organisations or initiatives. However, in many ways government initiatives have not been a major driver. Instead, progress has been driven by both firms and non-business organisations themselves: including how they have changed the way they behave. Several major changes involving non-business organisations and business firms took place that have made Australia world-class in leading sectors. These instances demonstrate the systems nature of transformation and innovation. They are powerful examples of successful ‘self-organisation’—mutual coordination between different organisations in the same sector. For example, in mineral exploration such changes involved major governmental activities (geological surveys and funding of research organisations), as well as user-led studies—for example, through the Australian Mineral Industries Research Association.

### 4.3 Implications

Opportunities for innovation arise from many sources, such as changes in demand, knowledge base, and/or technologies. While most problems and opportunities that emerge are within the scope of at least the more capable and perceptive firms, some are beyond the scope of individual firms, and even groups of firms. These problems and opportunities may require additional resources to be mobilised—or legislative, regulatory or policy institutions to be changed. A collaborative approach is essential in such cases. Thus, a policy framework that provides mechanisms for collaboration is important—and it should also allow for international competitive analysis. More effective ‘self organisation’ (as exemplified in the resources example above) is facilitated by bringing government and private-sector organisations collaboratively into processes of analysis, diagnosis, option assessment, and strategic planning. As another example, the Australian wine industry demonstrates what can be achieved through such an approach. Facilitating such processes is one of the most important and potentially powerful roles of government.

As we have seen over the past 20 years, continuing globalisation will increase the pressure to specialise, forcing increased depth of knowledge and closer interaction and collaboration across sectors. Increasing specialisation also provides opportunities for entrepreneurs and for new sectors to emerge and existing sectors to grow. This ongoing pressure to innovate and specialise means innovation policy is increasingly important for the future economic wellbeing of a nation. Public policy on innovation should maintain such pressure—through that pressure, it influences the growth and future economic structure of a nation.

Our work confirms that the scope of innovation policy must include institutional, organisational, competence-building, and business relationship issues, together with issues of demand and marketing. National interests also require policy to maintain a watching brief on issues of appropriation—but one that takes full account of international sectoral aspects. The photovoltaics case study signals that a policy focusing on research and commercialisation is not by itself adequate. Policy focused solely on the effective operation of markets may not support new and emerging sectors and innovations. The experience in photovoltaics may well be relevant to policy for some aspects of biotechnology, where there has been a tendency to focus policy predominantly on research and commercialisation.

The sectoral studies indicate that public sector research organisations have played a significant role in problem-solving activities carried out jointly with the private sector. The sectoral studies also indicate a general trend toward a deepening of the knowledge base in all sectors. Public sector organisations, including policy advisory bodies, contribute to identifying opportunities and solving problems within sectors. The development and maintenance of competencies in these organisations is as important as the competencies of firms.

The increasing pace of change (due, for example, to technology, the growth of international trade and deregulation) makes improvement of competence even more important.<sup>1</sup> It has been suggested<sup>2,3</sup> that the innovation systems perspective has four implications for innovation policy.

1. The facilitation of learning and competence-building within firms needs to become a key policy objective.
2. Policies need to be context-specific and interactive. Since the impact of one policy depends on the existence of complementary policies, coordination is a key issue.
3. Because policies and the firms affected by them co-evolve, policies that are effective at one point in time may rapidly become less so. Hence, countries need to develop a portfolio of innovation programs which evolve over time in response to changing knowledge and priorities.
4. Innovation policy development and implementation is complex and knowledge intensive. As a result, continuous learning about innovation within advisory bodies—that is, continual competence-development—is central to the policy process, which should not be regarded as a purely generic skill.

This perspective recognises that cooperation in identifying and addressing common barriers to opportunity is often preferred to direct modes of intervention. It tends to favour incrementalism over sweeping change and it recognises that all major innovation policy decisions are made in a context of radical uncertainty. This approach also recognises the significance of providing transition arrangements during periods of rapid change, to permit those firms affected time for exploration among alternative future paths. Thus, taking an innovation systems approach favours dynamic efficiency—as opposed to static efficiency—which can reinforce undesirable path dependence.

Innovation is a complex issue and so cannot be dealt with simply. In seeking to support innovation, governments have typically adopted a range of generic policies (for example, tax incentives and granting schemes) that do not discriminate between sectors. It is well accepted that this approach is sound. What is less well accepted is that there are also grounds for formulating additional policies targeted at specific sectors. Policies of this kind may sometimes be criticised as an *ad hoc* 'quick fix' to appease a sectional interest group.<sup>4</sup> Nevertheless, we argue that the differences in patterns of innovation and modes of appropriation demonstrated across different sectors justify the need for sector-focused innovation policies to supplement generic measures.

Innovation involves a web of diverse relationships among firms and organisations whose behaviour is shaped by many signals, both price and non-price based. The effectiveness of a national sectoral system in generating and appropriating benefit from innovation is a key issue for public policy.<sup>5</sup> Further, we argue there are lessons from our approach for all participants in innovation systems. These lessons apply to firms seeking to prosper, to non-business research or support organisations seeking to assist in innovation or its commercialisation, to agencies needing to administer regulations or set standards, and to policy advisory bodies seeking to facilitate the effective operation of a sector and protect national interests. All types of organisations should focus more on identifying:

1. the characteristics of organisations engaged in a sector, nationally and internationally, and what their activities imply for future problems and opportunities.
2. the dominant means through which value is captured and maintained from innovation and what these means imply for the types of innovation most useful in the sector.

At the outset of this report, we asked whether Australia's innovation systems are sick, healthy or irrelevant. We can say with certainty that innovation is *not* irrelevant—there is abundant evidence that supports the important role it plays in economic development. *Innovation is essential*, not only for economic growth, but also for the health, social and environmental wellbeing of a nation.

Assessing whether our innovation systems are sick or healthy is complex. In this report, *we suggest—not merely that there is no simple answer, but that there is no single answer*. Instead, *we need to seek separate answers, sector by sector*, well informed by an understanding of sectoral specifics (globally and nationally), coupled with awareness of key generic factors in terms of technology and institutional settings.

Innovation is complex and ever-changing. We need to investigate and learn about it on a continuing basis. While we are faced with many opportunities and presented with many problems, there are no simple solutions.

## APPENDIX: Case study summaries

This Appendix provides a snapshot of the meta-analysis of the seven in-depth case studies discussed in Section 3 (motor vehicles, dairy products, computer games, minerals exploration, oil and gas engineering, photovoltaics, and wine). The case studies, while focusing on Australia, also examine the international context in which each sector operates. Underlying this is the 'value-stream' model developed by Davies.<sup>1</sup>

Although the conceptual framework and analytical foundations described in Section 2 and used to develop each case study summary are the same, different authors of the summaries presented below may have placed different emphasis on the factors supporting transformation and patterns of innovation in each sector.

### Appendix 1 Computer games

The computer games industry broadly refers to developers, publishers and distributors of computer games, and the suppliers of outsourced conceptual or technological work. Broadly, activities comprise the funding, creation, testing, distribution of games (software), middleware (software and hardware), and games platforms (hardware).<sup>2</sup> Console makers (Sony, Microsoft, Nintendo) cover all aspects, while large publishers with in-house studios may deal with all but console related activities. Australian firms are primarily 'games creation' companies, and a couple of middleware companies.

'Computer games' refer to games played on some mass-market type of computer (PCs, video consoles, handhelds, mobile phones) owned by consumers. During the past two decades the games industry exhibited a double-digit annual growth rate and reached the mainstream markets.

The structure of the games industry has changed dramatically over recent years, and now a handful of publishers dominate (through acquisitions and organic growth)—not just in publishing but also in developing large in-house studios. In addition, the size of projects to create games for the mature media (PCs or consoles) has grown from a handful of people, to as many as over 100. Generally, 18 to 24 months is spent developing a project.

A key driver of these changes is appropriation, which for this sector is increasingly dominated by blockbuster titles. The established franchises have sequels that come out annually or bi-annually. This pattern of innovation started to emerge in the late 1980s in sports titles and racing games. To create potential blockbusters, the complexity and size of computer games on mature hardware (especially consoles) has increased about ten times. The expansion in labour use includes increased emphasis on new activities, and consequent expansion of the knowledge-base such that animation (key framing and motion capture), artificial intelligence (AI), 3D graphics, sound and voice are increasingly integrated into projects. This requires larger teams and a greater degree of coordination of individual projects, thus leading to the need for improved project management.

The sector is dominated by large North American, Japanese and European publishers and an 'elite club' of independent, self-funded developers who own some proven intellectual property (IP). While the industry in Australia is a small, fee-for-service industry with around a one-thousand developers primarily located in Victoria and Queensland, the industry is growing rapidly, as is the number of students taking courses suitable for obtaining a job in the industry.

The international division of labour differs according to the type of genre and targeted platforms of products. For established genres developed for PCs or consoles (for example, role playing games, arcade games, first person shooters), there have been significant shifts towards larger projects. Generally, in the 'mature' areas,

*publishers* create or re-use an existing franchise or broadly design games in terms of genre, platform or platforms before they seek out *developers* (including in-house studios) to develop games. The same request for a proposed design of a game may go to several developers simultaneously. While the exact nature of individual deals may vary, in this model the publishers own the intellectual property (IP) while the developers are service providers creating the software—they have no stakeholding in the IP. Developers may be paid a royalty if the game is successful in the market; however, this is rare since most games fail to recover development costs. Almost all deals involving Australian companies follow this model.

Publishers tend to acquire successful and innovative developers to create access to good in-house development teams and franchises. This is fundamental since all major publishers have tried, or are trying to, create large in-house studios.

In an alternative model, a developer looks for a publisher for a game that is more or less finished. 'Almost finished' can include any development stage (fully developed game, beta, alpha, or a demo). These efforts can be rejected by publishers, but may also lead to publishers funding the developer on a fee-for-service basis, since the publisher can judge the potential of the developer.

The model where developers create their own games before going to a publisher is increasingly rare given the increased need for time and people-power to develop competitive games. The advantage for developers in this model is they may have a 'proven' game and can therefore obtain higher royalties on sales (compared to the fee-for-service model).

While there are no Australian publishers with in-house studios, there are a couple of international publishers with Australian development studios (Atari in Melbourne and THQ in Brisbane). However, any publisher may contract an Australian developer to create a game.

The international division of *innovative* labour of the industry comes in four forms. First, given the increased complexity of the features of some games, there is a move towards a greater use of middleware in the industry. The decision to make or buy a technology is, however, often decided project-by-project, even by larger studios. Second, the games design and programming is primarily done by the developer in-house. In terms of the design, sometimes this is in close collaboration or control from the publisher who may also decide who is to design the game. Third, part of the content (arts), including models and animation, may be subcontracted. For Australian firms, the latter is done locally, but there are cases where art creation is sourced to China or Vietnam. Because of the relative ease of outsourcing art, and the low labour costs in China, more work will be outsourced in the future. Fourth, developers may support user-created add-ons to games, often by releasing level editors to the public shortly before, or after, a game is released.

The computer game industry is a rapidly changing one, both in technology and content (including art and gameplay). The industry's history can be characterised as a sequence of opportunities (creation and destruction), in that technologies in hardware and software have improved dramatically over the years. With hardware, there have been releases of new consoles or handhelds (endogenous to the industry), new graphics cards, and improved PCs and mobile phones (exogenous to the industry). This has led to the creation of richer games in graphics and 'smarter opponents' through greatly improved and extended software technology. The same holds true for content, in terms of game design and art, where new opportunities have been identified in, for example, the creation of huge, multiplayer worlds or animated story-telling.

While it is increasingly difficult for new entrants to obtain funding to create and publish console games, other forms of gaming platforms, such as handhelds and (more recently) mobile phones, now offer opportunities for small companies to enter the industry. The breadth of platforms also means smaller companies can specialise in, for example, handheld games, giving them a chance to port well-known games to other platforms.

During the past ten years in Australia the types and number of organisations have increased. More importantly, there is now a breadth of games' developers here, targeting all hardware platforms and most if not all computer games genres. The majority of these developers originated in the mid-90s but there is continual entry of new companies—established by former games company employees or those eager to work in the industry. Immigrants or temporary non-Australian workers (especially from the United Kingdom) are an important source of expertise.

A number of educational institutions have identified business opportunities in games-related education. These include specialised games and game tools educators (for example, the Academy of Interactive Entertainment or QANTM College), and TAFEs and universities, all providing instruction on technology and on content. The current annual production of new graduates now corresponds with the number of employees in the industry.

Other players in the games market include State governments (in particular Victoria and Queensland) that have become active in supporting this young and emerging industry. The Australian Government, however, appears to be 'invisible'. Several State and Territory government initiatives have succeeded in ensuring the generation of games that otherwise would probably not have emerged. In addition, an Australian Games Developer's Association, created in 1999, runs an annual conference in Australia. Albeit starting from a low level, these and other changes indicate improved systemic interaction in Australia.

There are three types of innovation in the computer games sector: a) sequels to, or augmentations of, antecedent games; b) new innovative games that alter in a major way what has already been developed; and c) 'me-too' games that are not part of a franchise. The first two types are economically relevant games. In line with the international scene, many Australian games are not highly innovative—they do not break ground or create new genres.

As mentioned earlier, appropriation is primarily shaped by sales, the ownership of the intellectual property, and writing of a contract. Australian companies generally do not own IP which means they work from one project to another and do not make enough money to invest in the next step of their evolution. Thus, the Australian games sector generally exports services, not products.

An important trend in the gaming industry is that it is now mainstream in appeal—people of all ages play games. In fact, the majority of players are between 18 and 35 years old. This is because while 'gamers' grow up they continue to play games. This is reinforced by the presence of computers in households, which provides more people with ongoing access to games. The major bottleneck for many gamers is the amount of time available for gaming.

The computer games industry is moving away from creating games to focusing on testing user interaction before a game is released. Increasingly, games companies try to create game-play endings or multitudes of endings designed to please a larger number of game users. However, given the level of interaction, focus group testing has difficulty ensuring 'correct' endings. For major games a great deal of effort is placed on tweaking the game-play so it is balanced.

Opportunities are emerging for games companies in new markets. These are becoming available as simulation and gaming (military and increasingly education) converge. This convergence can be achieved through the role of tools while other aspects are more distinct, especially the design of the software from the players 'or users' perspective.

A similar convergence is taking place within the film and television industries, with franchises and technology and content (animation). Australian companies, however, still primarily focus on the Anglo-American markets and make little contribution to the rapidly growing Asian markets.

## Appendix 2 Dairy products

For at least the past 50 years the dairy product industry in all countries has been highly regulated for health and trade protection reasons. Technological change has been largely incremental, but the pace of change has increased. The evolution of the Australian dairy product industry—structure, products and technology—resembles most other OECD countries. However, the Australian dairy product industry has had a greater export orientation and more far-reaching deregulation.

A small proportion (eight per cent) of world milk production is exported. World dairy exports have grown from about US\$6 billion in 1986 to about US\$18 billion (current dollars) in 2003. Australia and New Zealand account for only about four per cent of world milk production but nearly half of all internationally traded dairy products. They specialise in high-quality, low-cost production, based on a well-regulated supply system and a strong knowledge base. In 2003–04 about 50 per cent of Australia's annual milk production was exported, mainly in the form of milk powder and cheese. But export products are increasingly specialised and customised to address customer and end-use applications.

Since the early 1980s Australia's dairy product export growth has focused on Asia, which now accounts for more than 70 per cent of Australia's exports. This reflects both the growth of Asian demand and also the continuing high levels of protection for the dairy product industry in Europe and the United States. In the 12 months to mid-2002 Australian dairy products exports were worth A\$2.4 billion. The dairy product industry employs about 60,000 people and is the largest processed food exporter. Australian dairy food companies export ingredients and bulk products to downstream processors.

While there have been phases in the transformation of the industry, there are several long-term trends:

- the level of concentration at all levels has been increasing
- products are becoming more diverse
- government support and regulation has been declining
- global dairy product firms are emerging
- new market channels (supermarkets, food service and other food processing segments) are growing in power and this is leading to an increasing tailoring, based on increasingly detailed knowledge of the properties of milk ingredients, of dairy products to the needs of specific markets and customers
- the knowledge base required for innovation is increasing.

Due to the very small role of international trade in the dairy product industry, the evolution of an international division of labour through competition and specialisation at the product level has been limited. The dairy product manufacturing segment is changing in response to changing consumer tastes, the search for higher value added products and new applications of by-products, and the growth of markets for ingredients to the processed food industry. This has led both to the fractionation of milk into a widening range of components (for example, lactose, milk proteins) and to the production of customised commodities (for example, products produced in bulk but to precise functional specifications of customers).

This increasing interdependence has led to increasing collaboration between dairy product manufacturers and food processors. The changes in the marketing of dairy foods resulting from changes in the structure of retailing, the growth of supermarkets, and improvements in packing, particularly with the growing use of plastics, opened the scope for new product development.

Some of the major international dairy product firms have become more active in foreign direct investment and processing and marketing alliances. In the 1990s and early 2000s the Kerry Group in Ireland and the Fonterra Group in New Zealand began a series of international acquisitions and alliances. There are substantial opportunities to increase Australian dairy products exports, particularly to Asia. There are also opportunities for large Australian dairy firms to evolve into global dairy firms, investing in processing and perhaps production in other countries and developing marketing (and other) alliances with other firms, including New Zealand firms.

There has been an increasing division of labour within Australia in the area of research and specialist services. The increasing depth of knowledge used by manufacturers has led to the establishment of specialised research groups with close links to users.

Innovation in the dairy product industry has been driven largely by problem solving, initially focused around quality and distribution problems. This shifted to cost reduction as competition increased, to product development in response to changing market demands and slow market growth, and more recently to include growing concern with environmental issues at all levels of the industry. In Australia most of the early dairy product technologies have been imported, although significant local adaptation was often necessary. As the level of regulation has declined the level of investment by dairy product manufacturers in product development, production technology and packaging has increased. While a focus on cost reduction remains essential, product development is of increasing importance. Consequently, competitiveness depends on investments in production technology and product innovation, and returns on investment depends on economies of scale and effective global marketing.

State governments, dairy processors and Dairy Australia (using producer levies and federal government funds) are the main current sources of funding for dairy product R&D, but patterns have changed. With the introduction of the research levy in 1958 and administration by the Dairy Produce Board, mechanisms of consultation, *coordination* and diffusion (extension) were established, as was increased funding for research. This system of consultation, coordination and funding was a key institutional development in the dairy industry. Over the past decade the role of the major dairy manufacturing companies in funding and collaborating in research has increased.

Over the past 30 years dairy product manufacturing has become larger in scale, more capital intensive, and more knowledge intensive. A much wider range of knowledge (process engineering, chemical engineering, microbiology, instrument engineering, software, and food technology) is required at increasing levels of competence.

The evolution of the dairy product industry has been strongly shaped by five types of institution:

1. regulatory regimes that have controlled intra-national and inter-national trade
2. regulations that have set health-related food standards
3. producer cooperatives that have mobilised resources to establish manufacturing and marketing
4. largely public sector supported arrangements to facilitate knowledge acquisition and diffusion
5. a wide range of industry and professional associations that have guided and facilitated industry development and knowledge flows.

In many countries, including Australia, these interrelated institutional arrangements are changing. Many countries have reduced barriers to intra-national trade but very few have removed import restrictions and export subsidies. Australia is now the most deregulated dairy product industry in the world, and one of the most export oriented.

There is a rich history of organisational development and evolution in the Australian dairy product industry. The role of Dairy Australia and its predecessor has been important in coordinating efforts to identify needs for new knowledge, acquire such knowledge and diffuse it. In the current phase of the industry's evolution, Dairy Australia plays a leading role in forming a collaborative process of dairy product industry strategic assessment, called 'Dairy Moving Forward' and enabling farmers and processors a greater role in shaping expenditure on R&D and marketing.

## Appendix 3 Mineral exploration

Mineral exploration comprises the systematic acquisition, processing and analysis of geologically interpretable data to assess whether a mine should be created and designed, and if and how existing mining activities should continue or terminate. The economic value of exploration comes from its decisive role in creating or improving mining and mining opportunities.

The exploration industry is global in that multinational mining companies and small independent explorers may explore for minerals in most countries. However, the majority of the activities take place in institutionally stable countries, especially Australia and Canada, with predictable exploration and mining rights; and which happen to have mineral rich areas identified through antecedent mining activities, and rich access to public or in-house exploration data.

The international division of labour in the industry is best summarised in terms of independent (junior) explorers, mining companies, and the availability of geological surveys. This division of labour refers to normal exploration activities in search of rich mineral deposits. Australia has a number of organisations in all these activities. These players are at the forefront in their ability to acquire and analyse various forms of exploration data and geology of the ground. They are supported by complementary industries, including drilling companies and other operators that acquire or analyse data, including airborne geophysical surveys, geochemical testing of drill samples, and/or remote sensing analysis.

Generally, exploration companies are small and independent. They are not mine owners *per se*, who have acquired exploration titles from governments or other organisations, and are funded by the stock market or mining companies. Mining companies do exploration using in house or contract resources or through joint-ventures.

Appropriation in this sector is generated from exploration or the mining titles that relate to a specified piece of land. Joint ventures between mining companies and junior explorers are common and rents are distributed according to the contract. However, many junior explorers funded by through listing on the Australian Stock Exchange may have their own exploration or mining titles.

Exploration has been transformed over the past decade or so since the *means* of searching for new minerals rich areas has changed. In particular, exploration has moved from a search for minerals based solely on the skills of independent explorers or prospectors to a multifaceted and systematic industry comprising different specialisations. The resultant division of labour has increased, bringing in new professions.

Exploration activity and expenditure worldwide and in Australia increased ten-fold from 1970 to the mid-1990s. A major reason for this was the rapid increase in the international gold price which followed the collapse of the Bretton Woods Agreement in the early 1970s. However, from the end of the 1990s turnover in the sector was reduced by about 50 per cent compared to its peak in the 1980s and early 1990s. This decrease stemmed from the dramatic reduction in risky green-fields exploration. In contrast, however, brown-fields exploration (a more risk-averse strategy in exploration) and other types of capital investment have remained roughly constant.

There are also structural changes behind the shifting emphasis in funding in exploration type (green-fields or brown-fields) and scale. The three major contributing factors are:

1. the creation of small independent exploration companies (junior explorers) especially in Australia
2. the recent disappearance (through takeovers) of medium-sized mining companies worldwide
3. the rise of collaborative research organisations aimed at developing exploration relevant technologies.

The first two factors relate to the industrial structure of exploration. The third refers to the industrial structure of exploration R&D.

The rise of independent explorers varies among countries, but in Australia the independent explorer sector was largely created during the Poseidon boom (1966–1971)—though it built on earlier booms such as that stimulated by the discovery of oil at Exmouth Gulf more than a decade earlier. As mentioned earlier, these explorers are funded by the stock market or by mining companies. A major reason they continue to exist is the regulatory regime that underpins their activities. Because of the inherent uncertainty and complexity of exploration, it is considered important to provide information that ensures investor confidence. After several cases involving severe problems such as fraud (during the Poseidon boom), it became clear that reporting standards were needed to keep confidence in exploration activities. Australian standards (the JORC code) were created as a result. They stipulate the ‘what’ and ‘how’ to assess ore character and concentrations—to ensure stock market funding is available for explorers. Other countries have replicated this standard code.

A more recent shift in the industrial structure of exploration is demonstrated by the increased size of mining companies. Middle-sized mining companies have virtually disappeared. This has affected the ‘upstream’ junior exploration sector since in earlier times mostly medium-sized mining companies outsourced their exploration projects. This change in industrial structure resulted in an increased emphasis on existing resources and their sustainability, rather than a search for pure novelty.

One reason for the earlier importance of the medium-sized mining companies was that they focused on smaller mines that were running dry. Furthermore, closure of just one mine could have a dramatic impact on these companies so they frequently needed to search for new mines. Large mining companies, on the other hand, have a larger range of mines and tend to concentrate more on mine management. A consequence is that the patterns of search for novelty has become more risk-averse, focusing mainly on optimising current operations. This shift in emphasis may lead to a shift in the nature of discoveries (patterns of innovation).

A further reason for the changed emphasis in the industry is that opportunities in exploration are characterised by decreasing returns, and thus there is a need to find new ore bodies. That is, to identify and act on mining opportunities there is a need to shift the means of exploration. The maturity and unusually complex nature of Australia’s geology has made it a leading nation in exploration, and necessitated the use of more sophisticated approaches. In particular, the regolith (the area between fresh air and fresh rock) is often very deep and weathered, compared to that in other countries. Consequently, Australian inventions and innovations have focused on the generation of new knowledge, concerning geological modelling, technologies and artefacts; and the collection and dissemination of high-quality geological data. In the absence of these innovations many new discoveries would not have been possible.<sup>3</sup>

Specifically, over the past three decades major technological change has involved shifting from superficial (two-dimensional) observations to subsurface data acquisition and analysis both at the large- and small-scale, a greater understanding and selective use of sampling techniques in complex (for example, weathered) terrains, and increased emphasis on understanding and modelling geological processes. In large-scale applications, these activities have been primarily undertaken by public organisations. However, exploration teams within large mining companies and small independent exploration companies that are financed by the stock market or mining companies have managed the small- (mine site or district) and medium-scale (regions).

The scale of exploration has also moved towards search , where the scale itself plays a complementary role. Large-scale activities are primarily the province of geological surveys, and provide a mechanism for explorers and mining companies to select sites where further work is needed. Exploration at the large-scale has shifted from a focus on 2-dimensional towards 3-dimensional (including depth) and 4-dimensional (including processes of change in the ground). This implies a shift in the knowledge base of explorers and increased emphasis on the expertise of geophysics (and geoinformatics).

The division of innovative labour aimed at changing the processes and technologies in exploration is divided between mining companies with in-house R&D teams, public sector R&D establishments, collaborative R&D projects, and research done by universities or geological surveys. Australia has adopted all these approaches, but in line with the international trend the country’s focus has moved to collaborative R&D projects, especially between the Australian Mineral Industry Research Association (AMIRA) and relevant exploration

Cooperative Research Centres (CRCs). While mining companies worldwide continue to perform R&D, such activities have been cut drastically since the end of the 1990s. The present research emphasis tends to be on software supported modelling and analysis rather than on the costlier work required to create and test new hardware or systems.

While most of the large-scale work by the Geological Surveys is largely funded by the states or the Australian Government, most R&D is funded by voluntary contributions made by the mining companies and coordinated under the auspices of AMIRA, Australia's collaborative mining and exploration R&D broker. The emergence of AMIRA was instrumental in renewing exploration opportunities in Australia through the support of technological innovations and conceptual work. This re-orientation of exploration research has been important, initially in geophysics and signal processing, but more recently in geochemistry.

Exploration and mining in Australia has also been driven by the rise in demand from Asian markets, starting with Japan from the 1950s and more recently other countries, including China. The emergence of major exports to Asia and a growing domestic market has created opportunities for Australia to maintain its position as a major mining nation.

## Appendix 4 Motor vehicles sector

The motor vehicles manufacturing sector in Australia is a global industry dominated by a few multinational corporations (General Motors Holden, Ford Australia, Toyota, and Mitsubishi) along with a few large multinational suppliers of technologies, systems and components, some of which are Australian-owned. During the last two decades, the sector has undergone some fundamental changes—it is increasingly characterised by a high international division of labour with fewer suppliers of motor vehicle sub-systems and components directly related to motor vehicle manufacturers. The sector also faces competition from imports generated by substantial overseas motor vehicles companies.

Specialisation has increased in the sector with the concentration of technological or product domains driven by large car assemblers and the globalisation of supply chains. Other drivers include the deregulation of national trade barriers, decreased costs of transportation and communication, and major upgrading in the competence of the labour force in low-wage countries.

Outsourcing of the design and manufacture of motor vehicles components has also increased dramatically since the 1980s. Not only are increasing numbers of components outsourced, but also suppliers in the first tier of the value-chain sometimes have full responsibility for their systems, including product development and the organisation of second tier suppliers. An important consequence is that motor vehicle design and production has become organised along value-chains, where suppliers are organised into a series of tiers. A further consequence has been the accelerated growth of some major suppliers.

Patterns of product innovation in the motor vehicles sector largely relate to expansion in the features and functions of the final product. Generally technology is first developed by luxury car producers in Europe and then replicated by producers in other countries and also incorporated into smaller cars. Particular aspects include adoption of the principles of safety (airbags), security (car alarms), control (sensors, telematics), convenience (mug holders), and consumer electronics (DVDs). However, many product innovations are much more incremental, and include improving quality, performance, handling, ride, and control of noise vibration and harshness.

A shift in the knowledge-base and technological structure of the Australian motor vehicles sector underlies the patterns of innovation. For example, both development and production use more sophisticated electronics and software management systems.

However, product innovation has run in parallel with organisational innovation and focused on quality assurance and cost-cutting. In addition, the increasing degree of international competition, and imitation of product and process innovation has led to cars now including an increasing range of features for roughly the same price as previous models without these features.

Perhaps one of the most important organisational aspects in the motor vehicles sector has been the diffusion and adoption by the Australian industry of the Japanese just-in-time (JIT) and total quality management (TQM) models. These standardised practices have assisted in the fundamental restructuring of the industry and provided at least one of the foundations through which economic value has been generated.

Given the increased speed of product development, innovation in the motor vehicles sector increasingly focuses on re-using technology and concepts. In particular, it has become standard practice to introduce modularisation of components and product systems to assist product development and coordination across the supply chain. These changes are supported by improvements in computer-aided engineering, design and manufacturing, and the application of virtual reality. The design capability of the sector has been enhanced through these technological changes and the rapid diffusion possible between parent companies and their Australian subsidiaries.

There have also been substantial changes in the demand for cars, brought about by the emergence of new markets, especially export markets. Examples include: the rise in the number of female car buyers; growth in

the demand for 4-wheel drive vehicles; and the rise in exports for larger vehicles to, for example, the Arabian market. Manufacturers that successfully tapped into such emerging markets early, by gaining head office export mandates, are appropriating large profits. Suppliers able to access the global supply chains in the industry have also gained with appropriation relying on: strong technological innovative capability; global supply ability; or the ability to supply specific niches of small run components or provide services.

Several low-cost countries are emerging with increasing importance to competition in the sector, especially from the Asian region, notably China. The response of the established motor vehicles manufacturers has generally been to establish production capabilities in these low-cost countries using existing designs and technology to access markets and lower costs of less skilled component manufacture. Within this scenario of the increasing international division of labour and competition, Australian foreign-owned and operated motor vehicles companies have increasingly become niche players.

For decades, the motor vehicles sector in Australia produced large, low-cost and robust family cars with few additional features. This localised market was largely specific to Australia. In addition trade barriers in place at the time led to a partially protected local market. The deregulation of the mid-1980s strengthened the industry—while the domestic market for large cars decreased, new export markets increased. Nevertheless, the production of cars in Australia is low volume compared to other countries. Despite this low volume, participating in Australia's motor vehicles industry provides vehicle and component manufacturers and service providers with the skills essential for them to further increase exports.

In summary, the successful restructuring of the Australian industry rests on three factors:

First, Australian motor vehicles companies (General Motors Holden, Ford Australia, Toyota, and Mitsubishi) radically improved the quality of their products and processes following deregulation in the mid-1980s, which increased their ability to compete with the global market. Without such improvements, it is safe to say there would be little motor vehicle production in Australia today. The transformation of the sector has been managed in large part by government but also in concert with motor vehicles companies.

Second, Australian motor vehicles manufacturing firms are largely technological followers with firm competencies in design (aesthetic and functional). This is important because while specialisation in low volume production does not allow for economies of scale, these can still be achieved when firms systematically re-use solutions already developed and tested elsewhere. The emergence of new export markets and the relationships with other actors permitted Australian companies to attain specialisation.

Third, the relatively small scale of the Australian motor vehicles industry created a considerable amount of expertise in flexible low-volume production. This expertise enables local operations to be involved in profitable niche operations.

## Appendix 5 Oil and gas engineering

The oil and gas engineering sector comprises activities related to creating systems for extracting and processing oil or gas or related hydrocarbons on-shore or off-shore. The economic importance of this relates primarily to subsequent oil and gas production. Oil and gas engineering includes the construction of a platform and geological services such as sub-sea surveying. Further, most projects are large in scale and demand high-level skills in project management, systems integration and maintenance. In reality, systems of innovation and production may be temporarily created and maintained during the life of many of these projects.

During the 1960s and the 1970s, the focus of the sector in Australia involved setting up oil processing plants. The search for oil and gas was both on-shore and off-shore in Bass Strait. The economic success of Bass Strait was, however, limited both in the number of successful findings and the size of those findings. In contrast, a major technological shift took place in the industry's switch from oil to gas production on the North-West Shelf. While exploration on the North-West Shelf goes back to the 1960s, major construction began in the 1970s, gas production for the domestic market in 1985, and gas production for exports in 1989.

The off-shore gas projects were much larger and more complex than the earlier Bass Strait projects. Because of this complexity construction shifted towards modular design of plants, where outsourcing specialised services played an increased role. Thus, the division of labour in these projects increased. In fact, the international division of labour also increased because of the need for specialised firms, regardless of where they were located in the world.

It is increasingly expensive to build new plants to extract oil and gas—not only because many new sites are in deep sea locations but also because the number of skills and technologies required to build and maintain platforms has risen. This includes undersea pipelines, knowledge and testing of new materials, material resistance (to corrosion, fatigue, stress conditions, etc.), and even wave physics. The knowledge-base employed has largely relied on old science and standardised and proven technologies, rather than on new scientific breakthroughs.

As an example, perhaps the most important innovation in the industry over the last 25 years has been floating production storage and off-load facilities (FPSO). Some sources say this may have originated as an idea in Australia, but the costs to manufacture an FPSO are so high that only a few players are large enough to afford the initial investment. Australian players have become increasingly specialised in niche activities. Consequently Australia has generally lost out on the manufacturing of capital goods, plants and instrumentation and specialised equipment.<sup>4</sup>

The (international) division of labour in oil and gas engineering is high, and includes many different organisations. Oil and gas companies are the operators and they tend to have in-house engineering teams. There are relatively few Australian oil and gas companies, but these have emerged from activities in Bass Strait and the North West Shelf. These Australian companies have developed specialisations in maintaining oil and gas rigs. They generally provide services to the sector, and their customers are governments (primarily gas), spot-markets or long-term contracts.

Other organisations in the oil and gas sector include explorers that both identify economically viable locations and construct the geological models that are decisive in operations planning. Today, many of the explorers are Australian in origin, but back in the 1960s when they were originally needed, Australia did not have any off-shore exploration skills. In fact, crucial for early discoveries of oil and gas exploration in Australia were the contributions of American, Canadian, French, and Russian explorers.

On the other hand, civil engineering is important for ancillary facilities. Funding for this tends to come from international sources, Australian banks and Japanese trading houses, where long-term contracts with the Australian government guarantees that further funding can be raised.<sup>5</sup>

A major driver on the demand side are the rapidly growing Asian markets for minerals, oil and gas, especially in Japan and, more recently, in China. These markets have been a driver of further investment in the sector. A further major change in the Australian oil and gas engineering market is the shift towards increasing demand for turnkey solutions being delivered by international providers.

Operators increasingly focus on appropriating the economic value to be obtained from the blockbusters. The demand for novelty and patterns of innovation in the industry are related to this. The preservation of the blockbuster mode is a critical element in the control of the industry. Exploration and geological expertise is fundamental to ensure additions to existing oil and gas reserves which are crucial for further liquid natural gas contracts.

From the perspective of generating economic value for operators, the division of labour in the oil and gas engineering sector in Australia has worked well. However, there have been limited spillovers in creating new sectors other than in specialised activities. In fact, Australian content is decreasing.

## Appendix 6. Photovoltaics

The photovoltaics industry encompasses the design and manufacture of modules of connected solar cells, the manufacturing equipment that fabricates the cells and modules and the manufacturing of the balance-of-systems for on-grid applications.

The knowledge-base underpinning the photovoltaic product markets includes the design and manufacture of solar cells (the building blocks of the modules). Patterns of innovation in the sector are primarily related to increasing the efficiency of individual cells, changing the materials from which the cells are constructed (silicon base to flexible plastics), or to producing and maintaining the modules to cut the cost of the electricity generated in the cells.

Photovoltaics were based on an invention by Bell Labs in 1956. The initial market for them was the space industry in the United States in the 1960s. Up to the early 1980s, photovoltaics could only be sold in niche markets where other energy sources were unavailable or prohibitively expensive. Australia's entry into photovoltaics came through infrastructural applications by Telecom Australia and Australian National Railways in the mid-70s. These organisations were interested in supplying electricity to remote areas in Australia. They did not diversify into the design or production of photovoltaics.

During the mid-1980s, an increasing range of photovoltaic applications were created, specifically targeting larger markets. There was therefore a shift from performance-focused niche markets with only a few, expensive alternatives of energy supply, to applications where the cost of the electricity produced was important. This shift also resulted in a split of the sector into two application areas: (i) modules connected to the electric utility infrastructure (on-grid); and (ii) modules that are stand-alone (off-grid).

For on-grid applications, photovoltaic-produced electricity is a commodity with no distinguishing feature over electricity generated from other sources (oil, hydro-electric power, or wind). This means that cost is the deciding, competitive factor. This is an issue, since photovoltaic-generated electricity is five to ten times more expensive than electricity produced by more established technologies. Consequently, growth of the market relies more on appeal to environmental concerns and the introduction of 'green' legislation. In contrast with Australia, and spurred on by a relatively short pay-back period (around 10 years), the international market for on-grid applications has grown at about 20 per cent per annum.

In some other countries, photovoltaics, as an emerging industry, is supported through legislation (for example tax rebates). Such legislation can be used to directly or indirectly support renewable energy generation (including photovoltaic-generated electricity) as a solution to environmental problems.

The leading nations in photovoltaic production for on-grid application include Japan, Germany, and the United States. In these countries the sector has benefited from government support (national or state) through legislation which has helped generate large domestic markets for renewable energy. Furthermore, these countries have promoted entry into the sector through large companies with backgrounds in electronics and/or chemistry, two major parts of the sector's knowledge-base. The entry of other types of organisations has helped expand the knowledge-base and resources available in the sector. At the same time, there has been an increase in the division of labour in the sector through the formation of specialised suppliers. The photovoltaics industry internationalised during the 1980s, with the leading companies being large firms that operate with economies of scale.

While Australia was an early player in on-grid applications in the area of research (funded through government support), the country has never become firmly established in photovoltaic design or production. The reasons for this include:

1. The focus here has been on university research in crystalline silicon. Any work on production techniques was sold to foreign ownership.
2. There has been limited experimenting with modular production—which would offer substantial change in the scale of production.

While research on increasing the efficiency of solar cells has received international acclaim, it has had little impact on industrial activity in Australia. The lack of industrial impact is exacerbated by the lack of long-term government initiatives to promote the industry, or encourage increased consumption of energy generated from renewable sources. Consequently, the division of labour within Australia remains low, even though Australia is part of the international division of labour through its research output and the import of photovoltaics.

With off-grid applications, especially remote access power supply (RAPS), Australia has been more successful. Australian companies have been active in RAPS technology since the late 1970s, especially targeting the outback and semi-rural markets for electricity generation or water pumping. The semi-rural lifestyle of many Aboriginal communities in Western Australia and the Northern Territory in the 1980s was supported by government and provided an expanding domestic market for RAPS technology. The domestic market also provided the foundation for increased exports. However, even in RAPS technology Australian companies have lost their leadership position in cell-production. Overall, while the photovoltaics sector experiences annual growth, Australia has increasingly become a niche player, with a slower than average international growth.

However, new opportunities have emerged for small- to medium-sized firms in Australia to participate in the sector by providing services. Some of these firms maintain some manufacturing capability. They often have backgrounds in electrical installation, and their services include assembly of systems, installation and maintenance. It has been estimated that around 50 per cent of the turnover in service provision results from exporting these capabilities.

## Appendix 7. The wine sector

The wine industry has a long history in Australia. During the past two to three decades, the industry has transformed itself. A major driver of this has been the expansion of production and marketing of branded packaged wine, due to demand shifts toward premium wines. This market segment dominates the exports of Australian wines and underpins the creation of a competitive Australian industry.

Branded wines are characterised by consistent taste, ongoing quality improvement and high value-for-money. For the Australian industry, quality improvements in mass-produced wines are a factor dominating the sector's growth. Since the 1950s, when the bulk of Australian wine demand and production was for fortified wines, there has been a substantial shift in demand to quality table wines and increasing scale of production. Production techniques and technology have improved dramatically, initially being imported, but as knowledge and experience have increased this has increasingly becoming local. Australia is now one of the world's leader in the production of consistent premium quality branded wine, with the innovation system supporting industry wide upgrading.

Moves to high value-for-money branded wines were underpinned by the increasing knowledge-base developed in the industry for the industry, including new methods of blending and testing wines. This continually expanding knowledge-base relates to growing grapes and wine making as well as to the logistics and marketing of wine. Indeed, Australia is a, if not the, leading player in wine business and marketing research and education in the world.

During the past three decades, the Australian wine industry has become increasingly international in focus and has witnessed substantial increases in exports. The biggest Australian wine companies are among the world's largest, operating at the upper scale of viticulture and production of premium wine. In the mid-1980s, as demand plateaued and overproduction occurred, the industry was motivated to pull out of lower quality vines, and focus on exports. Since then exports have increased and the industry has consolidated with a more co-ordinated focus on development and advances. Key to this was the *Strategy 2025* produced by the Winemaker's Federation of Australia in 1996, which outlined a common vision for the industry. The vision to be 'the world's most influential' supplier of branded wine has played a major role in the industry's development. Supporting this are international demand changes toward branded premium wines, in which Australian firms are leaders.

A related factor has been the propensity of industry players to share knowledge and collaborate in advancing competence across the industry. This culture emerged over time, from one of little collaboration in the 1950s to the current nation-wide systemic formal and informal collaboration and knowledge sharing.

Increases in the export of Australian wine, and the growth of the largest Australian producers—partly through mergers and acquisitions—has led to the creation of large domestic winemakers operating on high economies of scale and scope. These Chandlerian firms dominate the Australian wine export markets in volume, and consequently have a major impact on grape growing. Australia has emerged as the fourth largest wine exporter in the world, with more than half of all the wine produced exported.

Innovative and competitive, especially in mass market premium branded wines, the Australian industry is today dominated by a handful of very large wineries, operating alongside some 20 medium-sized and about 1900 small wineries. The industry is thus a dual system, where large scale producers and small, niche oriented wine producers co-exist. The latter also play a significant role in the Australian tourist industry.

The production of grapes in Australia is quite cost effective, given an abundance of good grape growing land supplemented by water irrigation. Behind the large-scale operations producing branded wine is the consistent and predictable quality of the grapes. The knowledge-base and expertise provided by the Australian agricultural 'innovation system has been important for the industry in viticulture and wine production. For example, research related to salinity is also of interest to many other agricultural industries. Over the last 20 years there have also been significant increases in funding for R&D and to wine education in Australia, and this, in turn, has resulted in, and continues to result in, advances emerging in other wine specific research.

Companies in the Australian wine industry have also benefited from two external circumstances.

First, European wine makers in particular are bogged down in regulatory and other institutional practices that stifle attempts to make similar moves towards innovation in the wine industry.

Second, the move to address the change in market demand to premium wine was untapped by traditional winemaking nations until after Australian wine makers were established in that market segment.

From an Australian perspective, the international division of labour is characterised by a significant number of Australian players involved in grape growing, wine making and process engineering. On the other hand, the capital goods associated with the wine industry in Australia continue to be acquired from specialised wine industry infrastructure companies in the United States, France, Italy, and Germany. Only a few Australian manufactures of capital goods are critical to the wine industry, although innovative new players are emerging.

The division of labour within the Australian wine industry has changed substantially and now includes specialised consultants, wine researchers and the growth of wine education organisations. These specialist players often serve the entire industry, with many small growers and winemakers relying on consultants and contractors for expertise and infrastructure.

Formal and informal networks underpin the spread of information and knowledge between industry players. This leads to efficient and effective information transfers at district, regional and national levels. Therefore, information and knowledge are disseminated across the entire industry, not just individual firms.

There is little doubt that changes in demand, and the quality control of branded wine has boosted the growth of Australia's wine industry. This has been further supported by the wine writers and promoters of the industry here and abroad, including cellar door visits.

In summary, there have been simultaneous changes in the demand for, and in the quality of, branded wines produced by the Australian wine industry. These have resulted in economies of scale and increasing returns at the level of individual firms and the industry. The dominant feature on the export front is the importance which must be attributed to the sales to large, retail chains, particularly in the United Kingdom and the United States.

Concurrent with the growth at the large-scale end of the market is the significant increase in the number of smaller wineries, which provides 'colour' and vibrancy to the industry, as well as introducing new grape varieties, wine styles and organisational and marketing methods.

## Endnotes

### Section 1

- <sup>1</sup> The Australian Systems of Innovation Study (AUSIS) was a three-year ARC-funded Linkage Project that began in 2002. AUSIS aimed to produce a comprehensive analysis of innovation systems in Australia. By combining recent theoretical and conceptual insights and empirical analysis, the project analysed the changes occurring in Australia's innovation systems and the drivers behind them. It examined the inter-relationships in the development of Australian innovation systems and selected industries. It sought to study the impact of globalisation, and to compare Australia's innovation systems with other countries. Members of the project team (Don Scott-Kemmis, Magnus Holmén, Antonio Balaguer, Robert Dalitz, Kevin Bryant, Alan J. Jones, and Judy Matthews) are preparing a number of publications reporting on this study.
- <sup>2</sup> Many earlier studies have approached research on innovation with a strong bias towards quantitative and statistically based analysis. Such analysis has relied mostly on R&D statistics as a proxy measurement of innovation, but sometimes has used other data as secondary indicators in an attempt to flesh out what is implicitly recognised as an inadequate picture. We do not disparage such an approach when used with caution, but point to the necessity of supplementing it with a realistic understanding of the complex factors and interaction involved in innovation. We recognise that studies of this type can be valuable in a number of ways and in some studies within our larger project (and in the contexts of other projects) have undertaken such analyses.
- <sup>3</sup> Innovation is a still improperly understood phenomenon which research has only begun to comprehend adequately over about the past two to three decades, but (despite some rhetorical use of new terminology) little of this new thinking has had much impact on serious discussion and decision-making in Australia. Extensive reviews of this work have become available only in relatively recent times. The most comprehensive include Dosi *et al.* (1988), Dodgson and Rothwell (1994), Freeman (1994), and, in particular, Fagerberg, Mowery and Nelson (2005). As working definitions of some fundamental terms, and based on this body of literature, we regard science as being about improving understanding, technology as being about finding ways of creating workable artefacts, processes or services, and innovation as being about meeting a demand for workable artefacts, processes or services in a practical way. Later in this report, we also point to the importance of 'appropriation'—the ability to capture economic value from innovation—as a pre-condition for innovation to be profitable (and therefore practical). It should also be noted that innovation need *not* include R&D. Industrial design, for example, is often as important as R&D or even more so—as is incremental innovation (see Thorburn and Langdale, 2003). The OECD's *Oslo Manual* (OECD, 1997) provides a comprehensive list of innovative activities.
- <sup>4</sup> This report does not outline the evidence demonstrating that innovation is crucially important for economic growth. This has been reviewed elsewhere. For example see OECD (2000), which draws on Cameron (1998) and Temple (1999).
- <sup>5</sup> See Malerba (2002, 2003 and 2004) and Edquist *et al.* (2004)—but note we have extended their approach in significant ways.
- <sup>6</sup> What this report means by 'sector' is dealt with in Section 2.
- <sup>7</sup> Nevertheless, the innovation systems approach was first initiated through a national focus and national aspects remain highly important. See the pioneering work of Lundvall (1992) and Freeman (1995).
- <sup>8</sup> Box 1 summarises the concepts central to innovation systems. The most relevant for this report are discussed at greater length in Section 2.
- <sup>9</sup> See also Scott-Kemmis (2004).
- <sup>10</sup> Traditional means of looking into expected future competitiveness is often approached by analysing R&D spending per capita (or per GDP), or patents per capita. These are clearly at a low level in Australia compared with most other OECD countries. For many observers, these two issues provide a foundation for a very negative view of the sustainability of Australia's economy.

- <sup>11</sup> One difficulty in assessing these alternative perspectives is the appropriateness and interpretation of the indicators that each relies on. For example, it has become increasingly clear that ‘traditional’ indicators of innovative activity based on R&D expenditure and patenting are quite inadequate in the Australian context. In addition, pessimists point to only a small proportion of the total commitment to business, technological or innovative activities being covered by the key economic indicators relied on by the supporters of the optimistic perspective.
- <sup>12</sup> This is based on a detailed analysis of R&D, scientific publications and patenting over the past three decades. See Balaguer *et al.* (2003). The pattern is notably distinct from industrial specialisation.
- <sup>13</sup> It is clear that Australia’s economic standing would be worse if it were not for the presence of a strong knowledge base. The dynamics of the changes brought about in using the knowledge base is a leading element in economic growth, though perhaps not an element that is adequately recognised. Nevertheless, in considering the degree of Australia’s innovativeness, we ought to draw more distinction between innovation that is directed towards greater productivity in the production of inherently low priced goods or commodities, and innovation for the purpose of achieving or maintaining a premium price.
- <sup>14</sup> See Balaguer *et al.* (2003).
- <sup>15</sup> Note that systems integration often requires problem solving that may draw on deep scientific knowledge. For example, geo-magnetic survey techniques relied largely on a United States’ developed technology, but its adaptation for Australia required leading edge signal processing capability and the interpretation of the data required new advances in geology.
- <sup>16</sup> We agree with the importance of *national* legal and social institutions (Zysman 1996).

## Section 2

- <sup>1</sup> We label the mechanisms for the capture of benefit as ‘appropriation’. *How* benefits are captured, and *who* captures them, are both important. This is also discussed in this section.
- <sup>2</sup> This should not be taken to imply that national characteristics are not relevant. Rather, the *international* sectoral characteristics add a necessary balance to what is otherwise a nation-centric and distorted analysis—given that the roles of nations and national firms are changing rapidly in response to international developments.
- <sup>3</sup> There is no correct definition of sectors. Our characterisation is an adaptation of Malerba’s definition of sectoral systems of innovation and production as ‘a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sales of these products’ (Malerba 2002, p. 248). Malerba’s definition and characterisation is useful because it highlights how important non-firm organisations are for the evolution and structure of sectors. Furthermore, it is sufficiently abstract to cater for broad differences among sectors in the real world. However, we have adapted the definition to move away from a ‘pure’ product (and manufacturing) focus to include services.
- <sup>4</sup> This way of describing sectors does not necessarily conform to any standard industrial or statistical definition. There is a central difficulty in the analytical use of top-down statistical classifications such as the Australian and New Zealand Standard Industrial Classification (ANZSIC) and the International Standard Industrial Classification (ISIC). These classifications are inevitably based on the reductionist principle that industry outputs and the firms producing them can be considered in isolation from other activities—yet in a real world economic system it is clear there are strong interdependencies and that no activities occur in isolation. This presents serious problems for the analysis of any systemic domain. For any system, the overall characteristics *cannot* be completely predicted by summing the characteristics of the constituent parts. Of course, this is not to argue against the use of ANZSIC, ISIC or similarly classified data. Rather, we argue that analyses based on such data need to take much more care (and apply more caveats) than is normally the case. In Australia particularly, the high quality of the statistical data available from the Australian Bureau of Statistics, together with the technical competence of many econometricians and other economic analysts in well-established ‘standard’ (i.e., neo-classical) methodologies, has frequently led to an over-reliance on quantitative approaches that have lacked any searching examination of their conceptual basis and its relationship to the real world.

- <sup>5</sup> Thorough sectoral studies generally need to include both vertical (upstream and downstream activities) and horizontal linkages—for example knowledge exchanges between sectors or university—industry linkages.
- <sup>6</sup> Following the classic terminology first introduced by Adam Smith (1776).
- <sup>7</sup> More specifically, sectoral transformation refers to non-reversible processes of qualitative and quantitative changes in the set of organisations, the skills and activities of the organisations, and the interaction and interdependencies among the organisations. These processes are a normal part of the market economy and are driven by perceptions of what innovative opportunities exist and the ability of organisations to act on these perceptions (Saviotti 1986, Dosi 1982).
- <sup>8</sup> See Smith (1776).
- <sup>9</sup> See Young (1928). This is not a tautological statement. The interdependence evolves over time.
- <sup>10</sup> Of course, organisations that solve indirect problems may have been unaware of the initial problem. Furthermore, many solutions can be said to be in search of problems to solve. This is related to the discussion of opportunities above.
- <sup>11</sup> This should be understood in terms of the evolution of individual sectors over a period of time. It is not possible to assess the relative degree of maturity of sectors by simply comparing the number of specialised activities relating to different sectors at one point in time.
- <sup>12</sup> A number of researchers in this field have introduced the term ‘roundabout’ to refer to indirect means of production in the sense described here. See Andersen (1996), for example.
- <sup>13</sup> See the example of a large chemical plant discussed in Section 2.2.3.
- <sup>14</sup> This is a generalisation of Chandler’s definition that refers to ‘the amount of materials processed within a production facility during a specified period of time’ (Chandler 1996).
- <sup>15</sup> While increasing returns are often thought of as resulting from large organisations, the opposite can also be true. The development of very large firms may often be stimulated by the prospect of increasing returns.
- <sup>16</sup> Appropriation refers to the capture of economic value by individual organisations.
- <sup>17</sup> In this way, large multinational or ‘Chandlerian’ firms (i.e., very large firms operating in a hierarchical manner, with several different divisions undertaking different functions) tend to shape the *international* division of labour in sectors. Many countries, including Australia, have few of these firms. Nevertheless, the operations of Australian firms in these sectors needs to be understood in relation to the multinational corporations, and thus an international perspective is essential for an adequate understanding of any such industry sector and the future prospects of its domestic firms.
- <sup>18</sup> That is, competition through innovation and the harvesting of returns from these innovations (i.e., appropriation) drives sectoral transformation. From a focus on types of competition due to innovation and appropriation of its value, it is natural to think of sectoral transformation as being driven by how firms perceive and act upon opportunities. If new opportunities are identified and acted upon, over time different organisations in the sector may tend to specialise in different ways. For example, changes in the division of labour in a sector may include introducing new financial models, information brokerage business models, or specialised consulting activities.
- <sup>19</sup> A personal computer with software applications and an attached hardware ‘mouse’ able to click-and-point at simulated buttons on a screen is a prime example of an innovative package consisting of a large number of individual but complementary innovations. A substantial package of integrated innovations such as this constitutes a far more competitive product than the individual innovations comprising it.
- <sup>20</sup> Essentially, these questions and the following discussion provide a relatively new perspective on issues relating to commercialisation.

- <sup>21</sup> The factors leading organisations to perceive an opportunity to innovate, or identify a problem to be solved, are sometimes referred to as the ‘selection environment’. Factors include demand, patterns of consumption, sets of related legislation, and public procurement.
- <sup>22</sup> See Dosi (1982), Teece (1986) and Robertson and Verona (2005, forthcoming).
- <sup>23</sup> The innovation systems’ literature generally adopts ‘institution’ in the sense used by the Nobel Laureate Douglass North (1990) to describe factors that set the rules of the game for the business environment in which firms (and other types of organisations) operate. It should be noted that in this usage, institutions are *not* organisations. Rather, they consist of the formal legislative, regulatory and policy rules established by governments, together with the less formal range of common social behaviours and instituted administrative practices which affect the practical details of business operations. The boundaries of accepted business and social behaviour, and the forms of instituted practices, may vary substantially between countries and even locally within a country. These practical variations, depending on their form, may produce quite different effects from the same set of formal rules applied in different places.
- <sup>24</sup> An important institutional means of appropriation derives from the ownership or control of valuable resources, such as property ownership or intellectual property rights. Examples include patent protection and licensing in the manufacture of drugs.
- <sup>25</sup> Based on studies of large innovating firms, and focused on the core competencies they rely on for success, Pavitt (1988, 1994) has suggested a five-fold technology-based taxonomy of business enterprises as being: supplier dominated; scale intensive; information intensive; science-based; or specialised suppliers. While this classification provides great insights on the characteristics of firms, and relates these to core activities associated with particular (statistically-defined) sectors, it provides only a partial guide when sectors are defined along the broader lines suggested by Malerba (2002) and used in this study.
- <sup>26</sup> Applying the term ‘blockbuster’ in the context of innovation appears to us to be a new usage. This is accredited to our colleague Magnus Holmén.
- <sup>27</sup> Malerba (2002) offers distinction between sectors that in practice proves to be similar. He refers to sectors characterised by creative destruction as consisting of Schumpeter Mk I firms, and those characterised by creative accumulation as being dominated by Schumpeter Mk II firms—so called since these were patterns of innovation broadly described in different works by Schumpeter (1934, 1942). See also note 35 below.
- <sup>28</sup> See Holmén (2005, forthcoming).
- <sup>29</sup> A large mine, for example, with a substantial proportion of known world reserves in a particular mineral would be another instance of a ‘blockbuster’. In recent years the film industry has become a less typical case as video and DVD rentals have increased in importance.
- <sup>30</sup> This is the process of ‘creative destruction’ famously described by Schumpeter (1934).
- <sup>31</sup> See Langlois (1999).
- <sup>32</sup> See Langlois (1999, 2003) and Holmén (2005).
- <sup>33</sup> The role of increasing returns is closely related to the emergence and role of large firms. In particular, the case of large (Chandlerian) firms can be viewed as an extreme case of appropriation. That is, these firms can appropriate large returns from innovations through their mastery of a large set of complementary capabilities to exploit increasing returns. Such capabilities may include those that enable take-overs or purchase of smaller innovative firms.
- <sup>34</sup> See Klevorick *et al.* (1995).
- <sup>35</sup> A number of authors have labelled these different patterns of innovation as ‘Schumpeter Mk I’ and ‘Schumpeter Mk II’ (since they were first characterised, and in that order, in the early and late writings of Joseph Schumpeter). See Malerba (2002).
- <sup>36</sup> See Klevorick *et al.* (1995).

<sup>37</sup> Major types of problems can sometimes only be tackled by a group of organisations. This is why collaborative projects or involvement by government can be crucial to bringing about certain innovative projects.

<sup>38</sup> They are never neutral.

<sup>39</sup> See Freeman (1987), Holmén *et al.* (2004, 2005) and Balaguer (2005).

<sup>40</sup> In its extreme forms, it is caricatured internationally as 'neo-liberal', while in Australia the term 'economic rationalism' is often applied.

<sup>41</sup> While there are many critiques of neoclassical economics that could be referenced, one comprehensive argument (with an emphasis on innovation) is provided by Nelson and Winter (1982) in the course of their advocacy of a simulation model of the economy that makes relatively realistic assumptions based on studies of business behaviour. See also McKelvey and Holmén (2005).

<sup>42</sup> This is expressed mathematically by the use of a single 'production function' within the standard model. However, this is by no means the only difficulty that innovation presents. Another is the concept of 'optimality' that the standard model rests on, leading to the assumption there is always a 'best' solution. While this may seem an intuitively attractive idea, there are two main objections. Firstly, from a theoretical perspective, there are many instances where the mathematics that accurately describe natural phenomena lack the form required for a single solution. Secondly, in practice, dynamic situations can change so rapidly and unpredictably that a 'best' solution at one time may turn out to be very poor at another time.

<sup>43</sup> We do not argue that there are no insights to be gained from neoclassical economics. Rather, although they have provided some useful perceptions, we consider that neoclassical approaches have often been applied outside their sphere of applicability. Of course, economists working in neoclassical tradition often go beyond the simple model. For example, they attempt to adjust for particular failures in it. The difficulty with this is that in any real situation there are multiple failures. Perhaps the most sophisticated approach is embodied in 'endogenous growth' theory ('new growth' theory). However, this is also difficult because it relies on the assumption of average behaviour expressed by the use of a single production function.

<sup>44</sup> In particular, see Lundvall (1992).

<sup>45</sup> See Malerba (2002, 2003 and 2004).

### Section 3

<sup>1</sup> While our choice of sectors was partly driven by practicalities, including the background knowledge of team members and ease of timely access to information, people and firms, we aimed to study sectors in the Australian economy that fell into one or more of four categories:

1. long-established sectors, where it is widely perceived that Australian players face substantial challenges
2. successful sectors
3. emerging sectors
4. sectors showing significant growth relative to the Australian economy overall.

<sup>2</sup> Changes in Australian trade data (particularly in the 'revealed comparative advantage' of different goods) show that Australia has increased its degree of specialisation dramatically in export sectors that have long been considered as strong. Australia's trade specialisation (with respect to the rest of the world) in new areas is almost negligible.

<sup>3</sup> Again, an examination of revealed comparative advantage data in trade justifies this observation.

<sup>4</sup> The shift to a mode where both exports and consumption are increasingly dominated by mass production has been paralleled by changes in industrial structure—so that production has come to be dominated by large firms and, increasingly, multinational ones.

- <sup>5</sup> Pharmaceuticals and mining are quite different examples of extension. Monopoly appropriation of blockbuster drugs was helped in recent years by extending the life of patent rights. (Another technique, long applied, has been the use of ‘protective’ patenting—multiple patents taken out in the general area of a primary patent so potential competitors are hindered from patenting related drugs.) While this represents an example of change in legal institutions being used to achieve extension, in other sectors technological change may be used. A prime example of the latter kind is extending the life of gold mining in Kalgoorlie, where it has proved possible to replace traditional mine operations with open-cut mining applied on a massive scale. This was enabled by using modern excavation techniques and applying high throughput (24-hour operation) to permit gold extraction at an economic cost from relatively low grade ore.
- <sup>6</sup> Keith Smith has pointed out that Roseworthy College in South Australia was the first educational establishment to begin wine-making courses with lectures on biochemistry. This practice began in the 1930s.

#### Section 4

- <sup>1</sup> See Archibugi and Lundvall (2001).
- <sup>2</sup> See Lundvall (2001).
- <sup>3</sup> See Teubal (2002).
- <sup>4</sup> Institutional means—for example, criteria setting standards of probity and opening processes to public scrutiny—are the way to address the difficulty of dealing with special interests.
- <sup>5</sup> The term ‘system failure’ is sometimes used to refer to the ineffective operation of a system. The major types of system failure are those associated with weak interaction or relationships among organisations, the inadequate development of new competencies or new firms, and a misalignment with legal or social institutions (Malerba 1996, Smith 1999, and Edquist 2001). Relationships among players may be national, international or local in scope, making the geographic focus another factor. System failure is a concept that promises to be useful, but one that is yet to be fully developed. See Smith (1999), Bryant (2001) and Woolthuis et al. (2004). As part of our broader project, we have undertaken a study of ‘failed’ innovative firms to assess any association with wider innovation system problems (Jones and Scott-Kemmis, 2005 forthcoming).

#### Appendix

- <sup>1</sup> See Davies 2004.
- <sup>2</sup> This study deals with digital interactive entertainment with a focus on computer games. Computer games should be understood as games played by players on some mass-market type of computer. In particular, this involves video consoles played on the TV monitors, PCs, handheld gaming devices (for example, Nintendo’s GameBoy), or mobile phones. Interactive entertainment is excluded where technology (computer technology) plays a minor role (for example, participant theatre). Note that the boundaries are changing—the emerging field of interactive or enhanced television may merge with this sector in the near future, although so far this has not occurred. Other fields, such as gambling or simulation, are related in terms of technological similarities and to some extent a pooled labour market, but given the relative distinctness in terms of gambling’s pure relation to chance and simulation’s life-like nature rather than *entertainment*, these fields are not treated here. While some of the major firms in games are strong in arcade games as well (Konami, Nintendo) this study excludes them from the analysis given their poor relationship with Australian games companies.
- <sup>3</sup> While these shifts may be a natural part of any industrial evolution, it should be stressed that these fundamental changes have been necessary, at least in Australia. The reason is that the easy finds tend to be made first, which means the next finds are harder. That is, the ore bodies which are visible at the surface are readily identified while ore bodies not readily discernable at the surface remains undisclosed. Thus, the pre-war approach of local search for outcrops has shifted towards search for ore below the ground.
- <sup>4</sup> The last FPSO had less than 35 per cent Australian content.
- <sup>5</sup> Other sectors include transport, such as liquid natural gas tanker operators for gas and tankers for oil. The operators are primarily foreign. In terms of maintenance, there are many specialised international and Australian companies.

## References

- Andersen ES 1996 'The evolution of an industrial sector with a varying degree of roundaboutness of production' *DRUID Working Paper 96/13* Aalborg: Danish Research Unit for Industrial Dynamics.
- Archibugi, D and Lundvall, B-Å 2001 *The Globalizing Learning Economy*. Oxford: Oxford University Press.
- Balaguer, A, Bryant, K, Dalitz, R, Holmen, M, Jones, A.J, Matthews, J, and Scott-Kemmis, D 2003 Overview of the First Phase of the Australian Innovation Systems Project *AUSIS Working Paper 5* Canberra: Innovation Management and Policy Program, National Graduate School of Management, The Australian National University.
- Balaguer, A 2005, forthcoming 'The role of problems and opportunities in innovation systems' Working Paper, Innovation Management and Policy Program, NGSM, Australian National University.
- Bryant, K 2001 'Promoting innovation: an overview of the application of evolutionary economics and systems approaches to policy issues' in Foster, J and Metcalfe, JS *Frontiers of Evolutionary Economics* Cheltenham: Edward Elgar.
- Cameron G 1998 'Innovation and growth: a survey of the empirical evidence' available from <http://hicks.nuff.ox.ac.uk/users/cameron/papers/empiric.pdf> as at May 2005.
- Chandler, AD; Hagström, P. & Sölvell, Ö. (eds) 1998, *The Dynamic Firm*, Oxford, Oxford University Press.
- Davies, A 2004 'Moving base into high-value integrated solutions: a value stream approach' *Industrial and Corporate Change* 13(5):727-756.
- Dodgson M and Rothwell R (eds) 1994 *The Handbook of Industrial Innovation* Aldershot: Edward Elgar.
- Dosi G, Freeman C, Nelson R, Silverberg, G and Soete L (eds) 1988 *Technical change and economic theory* London: Pinter.
- Dosi G 1982 'Technological paradigms and technological trajectories. A suggested interpretation of the determinants of directions of technical change' *Research Policy* 11: 147–162.
- Edquist, C 2001 'The Systems of Innovation Approach and Innovation Policy: An account of the state of the art' Lead paper presented at the DRUID Conference, June 12–15, 2001, Aalborg.
- Edquist, C, Malerba, F, Metcalfe, JS, Montobbio, F and Steinmueller, WE 2004 'Sectoral Systems: Implications for European Technology Policy' in Malerba, F. (ed.) *Sectoral Systems of Innovation* Cambridge: Cambridge University Press.
- Fagerberg J, Mowery D and Nelson R (eds) 2005 *The Oxford Handbook of Innovation* Oxford: Oxford University Press.
- Freeman C 1994 'The economics of technical change' *Cambridge Journal of Economics* 18: 463–514.
- Freeman C 1995 'The "National System of Innovation" in Historical Perspective' *Cambridge Journal of Economics* 19: 5–24.
- Holmén, M 2005, 'Sectoral transformation in Australia', *Working paper, Innovation Management and Policy Program*, NGSM, Australian National University.
- Holmén, M, Magnusson, M and McKelvey, M 2004 'What are 'innovative opportunities?' Paper presented at the International Joseph A Schumpeter Association Conference, Milan.
- Holmén, M, Magnusson, M and McKelvey, M 2005, forthcoming 'Innovative Opportunities: Interdependencies as one force driving flexibility and stability' in McKelvey, M and Holmén, M (eds) *Flexibility and Stability in the Innovating Economy* Oxford: Oxford University Press. McKelvey and Holmén (eds).
- Jones, AJ and Scott-Kemmis, D 2005, forthcoming 'Case studies of "failure" in innovative Australian firms' Working Paper, Innovation Management and Policy Program, NGSM, Australian National University.

- Klevorick, AK, Levin, RC, Nelson, RR, and Winter, SG 1995. 'On the sources and significance of inter-industry differences in technological opportunities'. *Research Policy*, 24(2): 185–205.
- Lachmann, LM 1978 *Capital and its Structure—Studies in Economic Theory*, Kansas City Sheed, Andrews and McMeel.
- Langlois, RN 1999 'The Coevolution of Technology and Organisation in the Transition to the Factory System' in Robertson, PL *Authority and Control in Modern Industry* London: Routledge.
- Langlois, RN 2003 'The vanishing hand: The changing dynamics of industrial capitalism', *Industrial and Corporate Change* 12(2): 351–385.
- Lundvall B-Å (ed.) 1992 *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* London: Pinter.
- Lundvall, B-Å 2001 'Innovation Policy in the Globalizing Learning Economy' in Archibugi, D. and Lundvall, B-Å 2001 *The Globalizing Learning Economy*. Oxford: Oxford University Press. p. 273.
- Malerba, F 1996 'Public policy in industrial dynamics : an evolutionary perspective' *EC TSER-ISE Program Paper, submitted under sub-project 3.1.1: System Theories of Innovation: Policy Implication* Milan, December 1996.
- Malerba, F 2002 'Sectoral systems of innovation and production' *Research Policy* 31: 247–264.
- Malerba, F 2003 'Sectoral systems and innovation and technology policy' *Revista Brasileira de Inovação* 2(2): 329–375.
- Malerba, F (ed.) 2004 *Sectoral Systems of Innovation* Cambridge: Cambridge University Press.
- McKelvey, M and Holmén, M 2005, forthcoming 'Introduction' in McKelvey, M and Holmén, M (eds) *Flexibility and Stability in the Innovating Economy* Oxford: Oxford University Press.
- Nelson, RR and Winter, SG 1982 *An Evolutionary Theory of Economic Change* Cambridge, Mass: Harvard University Press.
- North DC 1990 *Institutions, Institutional Change and Economic Performance* Cambridge: Cambridge University Press.
- OECD 1997 *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: 'Oslo Manual'*, second edition, Paris: OECD/Eurostat.
- OECD 2000 'Innovation and economic performance—the empirical links' pp. 118–125 in *OECD Science, Technology and Industry Outlook 2000* Paris: OECD.
- Pavitt K 1987 'Patterns of technical change: towards a taxonomy and a theory' *Research Policy* 13: 343–373.
- Pavitt K 1994 'Key characteristics of large innovating firms' in Dodgson M and Rothwell R (eds) *The Handbook of Industrial Innovation* Aldershot: Edward Elgar.
- Robertson, PL and Verona, G 2005, forthcoming 'Post-Chandlerian Firms: Technological Change and Firm Boundaries' in McKelvey, M and Holmén, M (eds) *Flexibility and Stability in the Innovating Economy* Oxford: Oxford University Press.
- Saviotti, PP 1986 'Systems Theory and Technological Change' *Futures* 18(6): 773.
- Schumpeter, JA 1934 *The theory of economic development*. Cambridge, Mass: Harvard University Press.
- Schumpeter, JA 1939 *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process* New York: McGraw Hill.
- Scott-Kemmis, D 2004 'The Australian Systems of Innovation Study (AUSIS)' in Marsh, I *Innovating Australia* Melbourne: Committee for Economic Development of Australia.
- Smith, A 1776 (reprinted 1977) *The Wealth of Nations* Harmondsworth: Penguin (Pelican Books).

- Smith, K 1999 'Innovation as a systemic phenomenon: rethinking the role of policy' in Bryant, K and Wells, A *A New Economic Paradigm? Innovation-based Evolutionary Systems: Discussions of Science and Innovation 4* Canberra: Department of Industry, Science and Resources.
- Teece DJ 1986 'Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy' 1986, *Research Policy*, 15: 285–305.
- Temple J 1999 'The new growth evidence' *Journal of Economic Literature* 37: 112–156.
- Teubal, M 2002 'What is the systems perspective to Innovation and Technology Policy' *Journal of Evolutionary Economics* 12: 232–257.
- Thorburn, L and Langdale, J 2003 *Embracing change—case studies on how Australian firms use incremental innovation to support growth: Consultancy report undertaken for the Science and Innovation Mapping Study* Canberra: Advance Consulting.
- Woolthuis, RK, Lankhuizen, M and Gilsing, V 2005 'A system failure framework for innovation policy design' *Technovation* 25: 609–619.
- Young, A 1928 'Increasing Returns and Economic Progress' *Economic Journal*, XXXVIII, 148: 527–542.
- Zysman, J 1996 'Nations, Institutions, and Technological Development' *International Journal of Technology Management* 12: 651–678.

