Assessing Australia's Innovative Capacity in the 21st Century

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(with foreword by Michael E. Porter)

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Foreword

A body of research on the determinants of innovation at the national level began in 1999 with the National Innovation Index Project at the Council on Competitiveness. This study aimed to diagnose the long-term challenges for sustaining innovation and competitiveness in the United States. Scott Stern and I identified the centrality of regional clusters and a strong national innovation infrastructure as key drivers of the ability of companies to innovate at the global frontier. The Innovation Index Project has now developed into an ongoing line of research and is an annual component of the World Economic Forum's Global Competitiveness Report.

Initially published at the height of the "dot-com" era, our analysis and policy recommendations contrasted with claims that the Internet and globalization had eliminated the crucial role of location in innovation. We emphasized that, as open borders and information technology erode *traditional* advantages, competitive advantage would increasingly depend on companies exploiting location-specific advances to innovate. This message has become more urgent in a less forgiving economic environment; the viability of companies increasingly depends on their ability to connect the specific strengths of their local environment with opportunities for global competitive advantage through innovation.

In this report focused on Australia, Joshua Gans and Scott Stern have completed a significant extension of earlier studies of innovative capacity at the national level. This study takes advantage of an updated dataset including a wider range of countries and more refined empirical measures. The analysis confirms the key findings of prior work, including the importance of world-class research-oriented universities and the crucial role played by regional clusters.

These findings, and the policy recommendations that flow from them, should be at center stage as Australia faces the next competitiveness challenge. Macroeconomic stability and microeconomic reform have transformed Australia from an adopter to a producer of global technology. However, the challenge of establishing Australia as a first-tier innovator remains. Achieving a higher level of innovative capacity requires attention to all aspects of the innovation system. Australia must ensure the availability of a world-class pool of technically trained people, and an investment environment that encourages the deployment of risk capital. Deep and dynamic clusters are central to the ability of Australian companies to compete on a global level, requiring that policy continues to encourage vigorous domestic competition and strong protection of intellectual property. As Gans and Stern point out, historical strengths in agricultural and life sciences research, complemented by a distinct proclivity among Australian R&D personnel towards the life sciences, make the potential for cluster development in these areas particularly promising. A strong system of research-oriented universities and related institutions for collaboration will be particularly important for Australia to evolve into a first-tier innovator economy.

Though individual companies are the ultimate engine for innovation, the national innovation environment has a strong influence on whether companies are able to develop and commercialize new products and processes at the global technology frontier. With a highly educated workforce, mature political institutions, and a rich history of growth and adaptability, Australia has great promise to establish itself as a source of global innovation. Achieving this objective will require systematic attention to the drivers of innovative capacity in the Australian context; this report identifies those drivers and thus the central foundations for such a transition.

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Executive Summary

International competitiveness increasingly depends on innovation, especially in advanced economies. With a decade of structural reforms and with continued operational improvement in education and infrastructure now a given, Australian companies are able to rapidly acquire and deploy technology from around the world. But competitiveness can no longer be sustained by producing standard products using standard methods. Prosperity flows from the ability of a nation's companies to create and then globally commercialise new products and processes, shifting the innovation frontier as fast as rivals catch up.

This report presents new findings regarding the drivers of global innovation across advanced nations and provides an assessment of the evolution of the Australian environment for innovation over the past two decades. Building on the national innovative capacity framework (Porter and Stern, 1999; Furman, Porter and Stern, 2002), we demonstrate how a nation's relative performance in producing global innovation is linked to three factors: (1) the strength of a common innovation infrastructure; (2) the vitality and innovation orientation of regional clusters and (3) the quality of linkages between the innovation infrastructure and a nation's clusters.

A detailed empirical examination of the drivers of global innovation across the OECD over the past two decades is at the heart of the analysis and subsequent recommendations. In this regard, three empirical findings stand out. First, no single factor uniquely determines the ability of a country to produce global innovation; innovation depends on strength along multiple dimensions. A healthy innovation environment depends on the quality of human resources, effective public policy, and innovation-oriented corporate investment. Second, since companies are the ultimate engine for innovation, vital clusters in which firms compete on the basis of innovation but cooperate on shared priorities is a crucial to the process of producing global innovation. Third, by facilitating knowledge transfer and cumulative step-by-step progress, universities and other "institutions for collaboration" play an especially important role in determining the innovative capacity of a particular location. Overall, global innovation is driven by nuanced factors, many of which can, nonetheless, be enhanced by effective policy interventions.

These findings are at the foundation of assessing Australian innovative capacity. Over the past quarter century, both public policy and private sector initiatives have transformed Australia from **a classical "imitator"** to a **second-tier innovator** economy. This improvement is the consequence of policies ensuring macroeconomic stability and the implementation of microeconomic reforms that have opened Australia up to global competitive forces. While Australia has improved its innovative capacity over time, it has not done so *as fast as* key international competitors. Some have leapfrogged Australia through sustained policy action. This **international perspective** on innovation policy and innovative capacity yields specific insights into Australia's relative strengths and specific policy challenges.

Though Australia has **enhanced its commitment** to innovation policy, establishing Australia as a first-tier innovator nation requires a systematic upgrade in the Australian innovation environment. Innovation policy reform in Australia should impact the innovation infrastructure, the cluster innovation environment, and the strength of linkage mechanisms. At the broadest level, policy should be focused on training (and retaining) a world-class innovator workforce, and providing opportunities and incentives for the deployment of risk capital. At the same time, Australia must address key imbalances in the resource and investment choices of the public and private sector. Australia's historical strengths have led to a nascent capability for innovation throughout the life and agricultural sciences; the recent global success of the Australian wine industry reflects the impact of a strong cluster environment on international competitiveness. While 'picking winners' is a recipe for policy failure, Australia can position itself as a global innovator by allowing labour, capital, and domestic product markets to reward long-term investments that leverage specific strength areas. As well, a great deal of the increase in Australian business R&D investment has been *inward-looking*, focusing on how to tailor global technology to the Australian context. The competitiveness of Australian companies, however, will depend on their ability to develop new-to-the-world technology and processes with global application. Finally, the Australian university system is an historic strength and nurturing this asset (as well as other institutions for collaboration) will be crucial for establishing and retaining a higher level of innovative capacity.

Above all, we caution **patience** with regard to the application and realisation of the fruits of innovation policy. Returns on innovative capacity investments only manifest themselves over time. Addressing weaknesses requires a consistent, long-term strategy and not periodic bursts of policy initiatives. This commitment must be similar in scope and duration to the process of microeconomic reform that has resulted in durable policy institutions such as COAG and the Australian Competition and Consumer Commission.

Australia currently faces an historic opportunity to redefine its position in terms of innovation. Undertaking investments and implementing policies to achieve this objective are essential if Australian companies are going to compete effectively in a global economy. More importantly, as the central driver of productivity over the long term, enhancing the Australian innovation environment is crucial for ensuring long term improvements in national prosperity and welfare.

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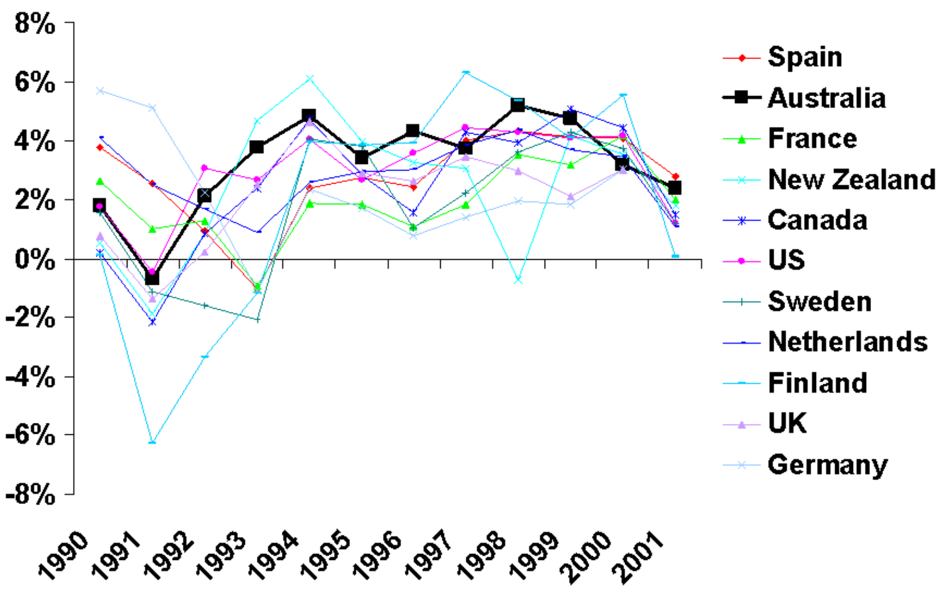
1 Introduction

During the 1990s, Australia has been an outstanding economic performer amongst leading economic nations in the world (**Figure 1-1**). In recent times, real growth per capita has averaged above 4 percent per year. This growth has been driven by real advances in productivity, rather than simply catching up from a low productivity baseline (**Figure 1-2**).

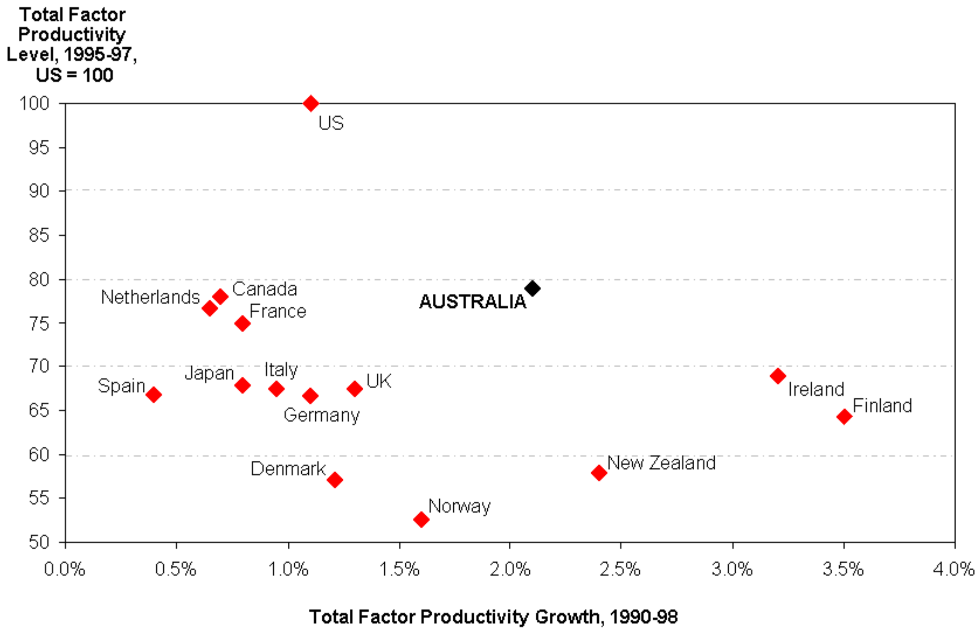
It is easy to point to several drivers of this success. Relative macroeconomic stability, a substantial modernisation of the tax system, the reform of public utilities in key infrastructure areas such as telecommunications and energy, the strengthening of competition policy, and the creation of institutional reviews of existing government policies (e.g., through the Productivity Commission and National Competition Council) are all contributors to this substantial level of achievement. Indeed, there is good reason to believe that Australia has only just begun to feel the impact of these reforms on productivity, and reform-driven growth can continue at least in the medium term.

Figure 1-1: Real GDP Growth Rates



Source: EIU (2001), OECD (2002), Singapore Statistics (2002).

Figure 1-2: Catch-Up?



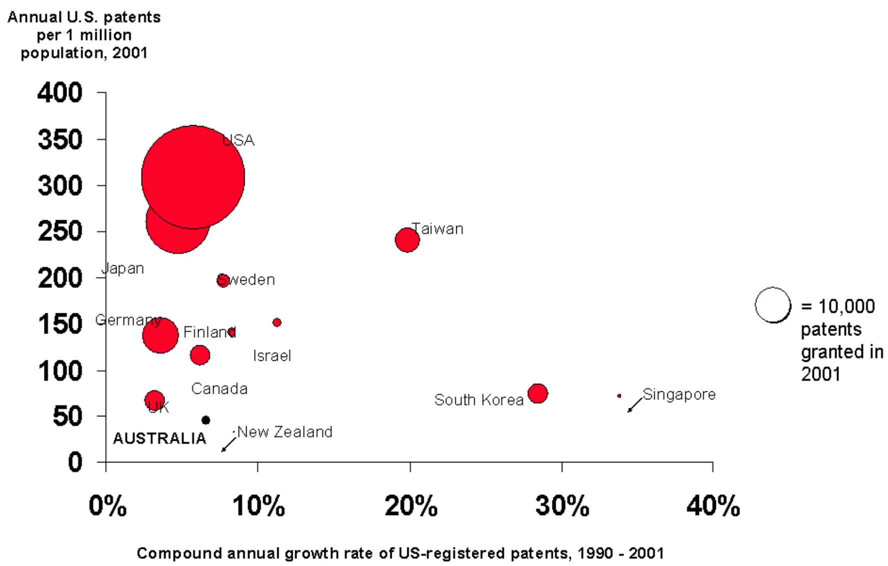
Source: IMF (2001)

However, over the longer term, the basis for growth and international competitiveness will increasingly rely on innovation. Across advanced economies, structural reforms and operational effectiveness are now a given, and companies can acquire and deploy global technology. Producing standard products using standard methods will no longer sustain competitive advantage. Indeed, the prosperity and welfare of countries will flow from the ability of companies within a location to create and globally commercialise new products and processes, shifting the innovation frontier as fast as rivals catch up.

This shift in the basis of international competitiveness poses a new and difficult challenge for Australia. Relative to other advanced economies, Australia is a poor performer in terms of global innovation, both in terms of ideas generated as well as the growth rate of ideas production (**Figure 1-3**). And it is not difficult to see why. Australian firms employ fewer potential innovators than other leading nations (**Figure 1-4**) while capital expenditure on R&D lags substantially (**Figure 1-5**). Without basic inputs in these areas, a nation cannot expect to generate innovative outputs.

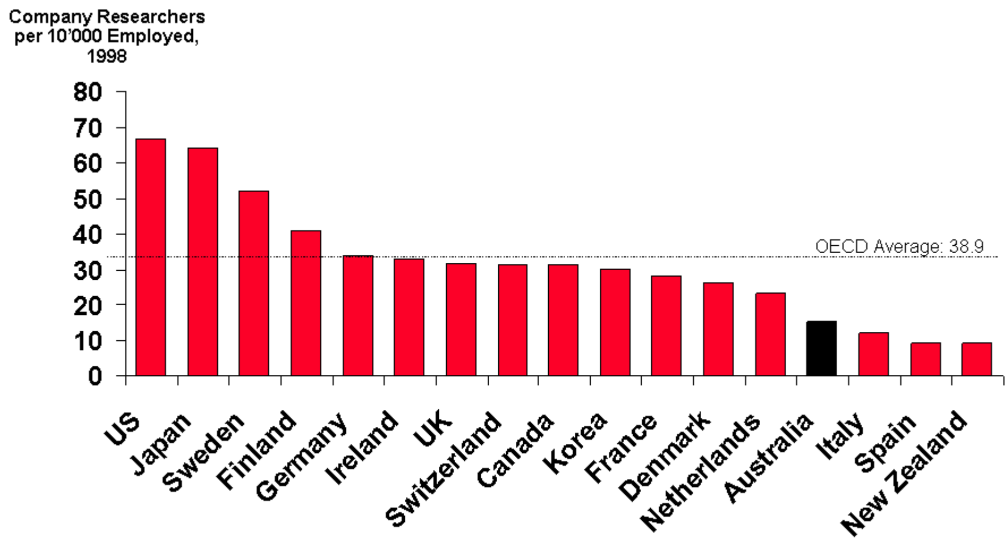
The real concern for Australia's future prosperity lies in innovative performance. Innovation is the well-spring of economic growth and no country can live off of the fruits of its natural endowments. Investment has to be continual and well placed. This requires both governments and firms to be attentive to long-term issues and avoid temptations to rest on the laurels of strong near-term economic performance.

Figure 1-3: Patents versus Patent Growth



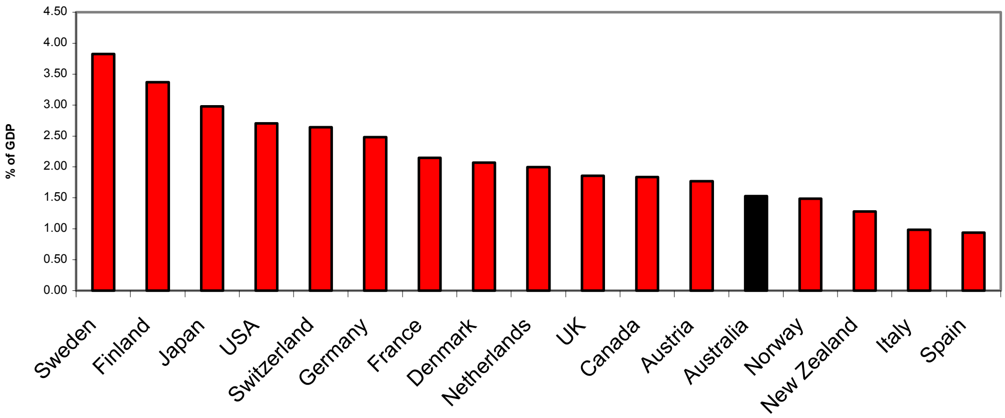
Source: US Patents and Trademarks Office, Author Analysis

Figure 1-4: Scientific Employment



Source: OECD Science, Technology and Industry Scoreboard 2001.

Figure 1-5: R&D as a percentage of GDP in 2000



Source: OECD Science, Technology and Industry Scoreboard 2001.

These concerns are already showing visible manifestations. The number of important company failures and corporate relocations are a wake up call, shaking confidence in Australia's corporate basis. In addition, Australia has few clusters or sectors that are well developed and can be relied upon for future prosperity. While there are some documented successes such as the wine cluster, potential clusters with the highest level of promise – such as biotechnology – have not yet delivered meaningful economy-wide benefits. There is clear pressure from many sectors for Government to "do something" but there is no clear vision what the next policy push should be, following on from the successes of microeconomic reform.

This leads us to the theme of this report. The innovation challenges for Australia's future prosperity are connected and require a coordinated strategy to address them. However, working out what that strategy needs to be requires a clear understanding of the role of global innovation in determining future competitiveness, and the specific strengths and weaknesses of the Australian innovation environment. Our overall objective is to provide an examination of the drivers of global innovation in order to shed light on the sources of Australia's innovation performance relative to other nations. Rather than a "scoring" exercise, the chief purpose of this benchmarking is to identify an informed set of policy options that can facilitate Australia's future as an innovator economy.

The report proceeds in three sections. In Section 2, we describe the national innovative capacity framework, identifying the key drivers of global innovation and describing a method for evaluating innovative capacity in a systematic quantitative way. Section 3 provides the main results from this quantitative assessment. It represents a significant update on prior innovative capacity benchmarking studies (Porter and Stern, 1999), including several years of additional data, additional countries, and more refined empirical measures. The results highlight a number of striking issues for Australia, motivating the policy assessment in Section 4. Simply put, Australia has made important gains in innovative capacity throughout the 1990s, but has not yet translated those gains into first-tier innovator status. The final section offers some concluding thoughts on the motivations for Australian innovation policy in the future.

2 The Foundations of Innovative Capacity

World class competitiveness and prosperity depends on *national innovative capacity* – that is, the ability to develop and commercialise "new-to-the-world" technologies, products and business organisations.[1]

2.1 The Link Between Innovation and Prosperity

The prosperity of any economy depends on its productivity, or the value created by a day of work or a dollar of capital invested. Productivity sets the wages that a nation can sustain and the returns earned by holders of capital, the two major contributors to per capita national income. The central role of technological innovation in productivity improvement, long-run economic growth, and in determining a nation's standard of living is well recognised by both economists and policymakers.[2] In the

[1] The term "innovative capacity" has been used extensively by prior researchers in the economics, geography and innovation policy literatures. For example, in the economics and innovation policy literature, Pavitt (1980), along with co-authors at the Sussex Policy Research Unit, employed the term in a similar way as used here in the economics and innovation policy literature. Suarez-Villa (1990, 1993) provides a fuller articulation of the concept within the geography literature, focusing on the specific linkage between invention and innovation. See Neely and Hii (1998) for a more detailed discussion of the origins and definition of innovative capacity in the academic literature. The framework presented here builds directly on research reported in Porter, Stern and COC (1999) and Furman, Porter and Stern (2002) and the references cited therein.

[2] Bush (1945) provided an early and eloquent rationale for sustained public investment in the nation's science and technology base. The centrality of innovation in economic growth has been appreciated since the seminal contributions of Schumpeter (1943), Solow (1957) and Abramovitz (1956). Rosenberg, however, was the first to identify how innovative activity of the macroeconomy was inherently the result of more microeconomic processes and their interaction with the environment and national institutions (Rosenberg, 1963; 1982). Building on such early work, Nelson (1990), among others, focuses on the elements of the national innovation system (most closely resembling our concept of the common innovation infrastructure described below) while Porter (1990; 1998) conceptualises the critical importance and workings of clusters and their role in innovation and competitiveness. Our work also links these more microeconomic-oriented approaches to the macroeconomic approach employed by Romer (1990; 1996), who focuses on the relationship between the "ideas" sector of the economy and the overall process of productivity growth in the economy. For a more detailed discussion of the motivation for this work and its relationship to prior studies in

absence of sustained innovation, the rate of productivity growth in labour-constrained economics will ultimately fall to zero. Over time, an even tighter link between innovative capacity and prosperity has emerged, especially for advanced nations such as Australia. The challenge for policymakers is to foster an environment where innovation flourishes.

Productivity, contrary to popular usage, is more than just efficiency. It is equally driven by the *value* of the products and services a nation can produce, where value is measured by what customers are willing to pay for them. Italy, for example, supports high wages and profits in shoes because of the high value that consumers place on its products, not because Italian shoe manufacturers produce shoes more cheaply than others. Moreover, national productivity is an aggregate of the productivity of each of a nation's industries, not just those whose products are exported or technology-intensive. Local industries can either contribute to or detract from national productivity and play an instrumental role in influencing the productivity of more visible export industries.

Indeed, in a modern economy, it is not only *what* a nation produces but also *how* it goes about it that matters. Innovation can drive productivity improvement across all industrial sectors. In this sense, there are no "low tech" industries—only low technology companies that fail to incorporate new ideas and methods into their products and processes. Innovation opportunities are present today in virtually any industry. Although industries producing enabling technologies such as computers, software, and communications have received much attention, opportunities to apply advanced technology are present in fields as disparate as textiles, machinery, and financial services. For example, the historical success of Australian agriculture in international markets is due in no small part to the development and application of advanced technologies specific to the agricultural sector, including farming techniques guided by computers and agricultural biotechnology.

Innovation—the transformation of knowledge into new products, processes, and services—involves more than just science and technology. It involves discerning and meeting the needs of customers. Improvements in marketing, distribution, and service are innovations that can be as important as those generated in laboratories involving new products and processes. Indeed, some of the most important innovations today occur in sales and distribution. Consider, for example, the revolution in small-package delivery that has occurred over the past 15 years— and the resulting U.S. global pre-eminence in this industry.

the economics of technological change, see Stern, Porter, and Furman (1999) and Porter and Stern (1999).

History teaches us that, ultimately, the private sector is the engine for innovation. The transformation of knowledge and new ideas into wealth-creating technologies, products, and services is the province of firms, not governments or universities. Nonetheless, national policy and public institutions create an environment that can encourage or detract from firms' innovative activity. The U.S. pharmaceutical industry, for example, has benefited greatly from intellectual property laws that encourage investment in discovering new drugs; by contrast, patent laws in Japan and pricing laws in France historically discouraged investment in new medications, resulting in less innovative companies within these nations' borders. Similarly, Australian leadership in the international wine industry reflects an effective mix of vigorous domestic competition alongside public/private cooperation in areas of shared interest, such as basic research. The foundation of international competitiveness begins at home with an effective public policy environment and dynamic clusters competing on the basis of innovation and value enhancement (Porter, 1990; 1998). A higher rate of innovation in one nation does not come at the expense of others. The ability of firms in one country to create new ideas can be enhanced by innovations created in others. Raising their rates of innovation can improve the prosperity and productivity of all nations, and collectively speed the rate of world economic growth. Indeed, as many advanced nations face the prospect of declining population growth, a stepped-up rate of innovation is needed to drive the faster productivity growth that will be required to sustain healthy economic growth rates. The studies reported on here do not aim to designate winners and losers but to measure how countries are performing relative to their potential, and suggest ways in which the innovative capacity of all nations can be nurtured.

In summary, the capacity for innovation determines the standard of living in the global economy. No individual economy can support high wages and profits by simply producing standard products or services made with standard techniques. Australia's future prosperity depends upon:

- Creating **high value** products and services
- Developing **unique** products, features and processes
- **Staying ahead** of technology diffusion

Innovation is more than simply a process of scientific discovery, and goes beyond simply adopting best practices and technology from other countries. Instead, innovation requires the identification of *new* opportunities for value enhancement and translating nascent opportunities into commercial practice, both domestically and abroad.

2.2 Sources of National Innovative Capacity

Why are some nations so much more innovative than others? This is not the same as asking why some countries publish more scientific papers than others, nor is it the same as asking why some countries are able to achieve higher scores on standardised tests in maths, science, or engineering. Instead, the answer requires identifying those factors that influence the ability of a nation's firms to identify economically valuable new products, services, and processes and develop them commercially.[3]

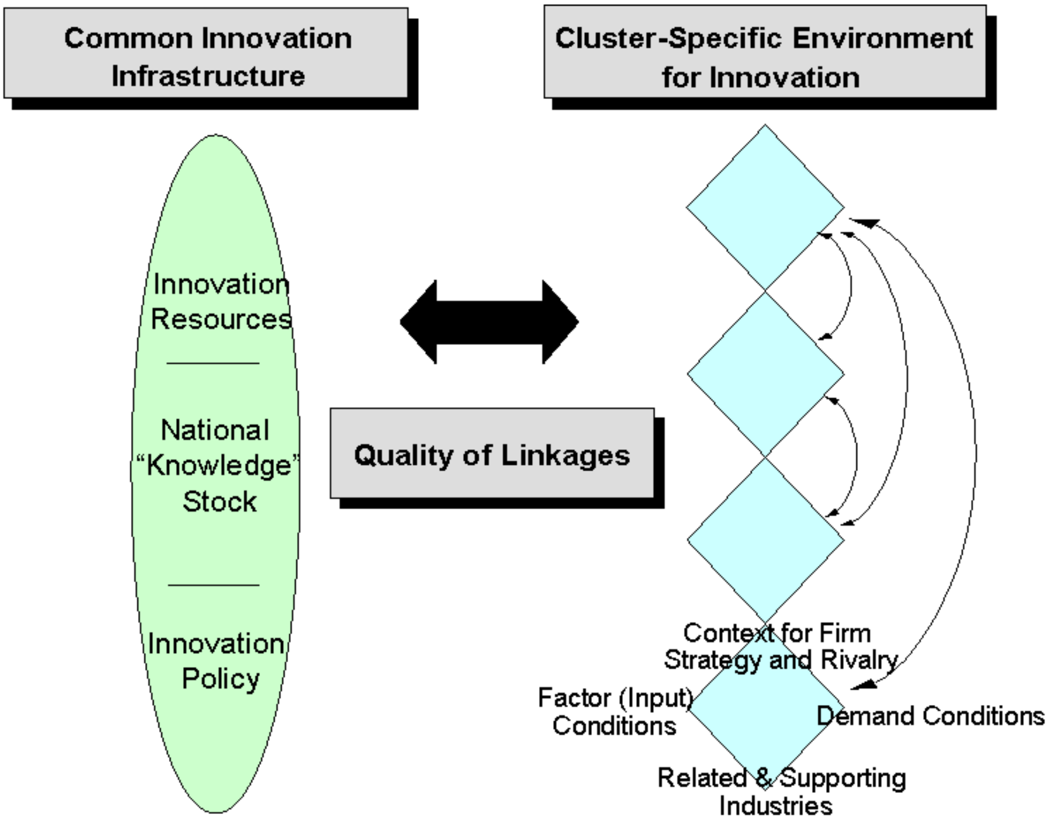
The vitality of innovation in a location is shaped by *national innovative capacity*.[4] National innovative capacity is a country's potential -- as both a political and economic entity -- to produce a stream of commercially relevant innovations. National innovative capacity is distinct from purely scientific or technical achievements, and focuses on the economic application of new technology. Innovative capacity is not simply the realised level of innovation but aims to measure the fundamental conditions that create the environment for innovation in a particular location. Innovative capacity depends in part on past technological sophistication and the size of the scientific and technical work force, but also reflects a series of investment and policy choices by government and private sector that affect the incentives for research, development and commercialisation activities in a country and their productivity.

Sharp differences in innovative output across locations make clear the importance of local circumstances in R&D productivity. However, taking advantage of the local environment for innovation is far from automatic. Companies based in the same location can and do differ markedly in their

[3] History is replete with examples in which scientific or conceptual advances have been identified in one country but commercially developed in another. The powerful nineteenth-century German chemical industry, for example, was very much dependent on the discoveries of a British chemist. In more recent times, it was Japanese companies that built upon the initial invention of the video cassette recorder (VCR) in 1956 by Ampex (a U.S. company) and turned the VCR into an overwhelming commercial success. History also offers numerous examples in which national industries developed and maintained innovation and international competitive advantage for decades, such as the American computer and German automobile industries. Australia has been responsible for a wide range of inventions that have been commercialised by companies in *other* countries, ranging from the "black box" flight recorder to the lawnmower. In each of these cases, innovative and competitive success was supported by a wide range of supporting circumstances. The continued success of the German chemical industry, for example, has been underpinned in large part by a highly developed university system that encourages innovative research partnerships with industry.

[4] *See* footnote 1 for a discussion of the origins and prior uses of the term *national innovative capacity*.

Figure 2-1: Drivers of National Innovative Capacity



success at innovation. Harnessing the local environment for innovation requires that companies pursue appropriate strategies and make appropriate investment choices.

Building on Porter and Stern (1999), we propose a framework for understanding the drivers of national innovative capacity (also see Furman, Porter and Stern (2002)). National innovative capacity is composed of four broad elements that define how location shapes the ability of a company to innovate at the global frontier (*see* **Figure 2-1**). Although the framework was created for application at the national level, it can also be employed to evaluate innovative capacity at the regional or local level.

Figure 2-1 illustrates the Porter-Stern framework. The left-hand side represents the cross-cutting factors that support innovation throughout many if not all industries: investments in basic research; investment in education; a network of universities conducting research and training scientists, engineers, and others in advanced problem-solving; and policies that affect the incentives for innovation in any industry. The diamonds on the right side signify the innovative environment in groups of linked industries termed clusters.[5] Clusters are geographically proximate groups of interconnected companies, industries, and associated institutions in a particular field, linked by commonalities and complementarities. It is appropriate to focus on clusters (e.g., information technology) rather than individual industries (e.g., printers) because there are powerful spillovers and externalities that connect the competitiveness and rate of innovation of clusters as a whole. Dotted lines connecting some cluster diamonds to others indicate that spillovers occur across clusters as well. For example, innovation in automotive products draws to some extent on national innovative capacity in the information technology and advanced material clusters. Because of the importance of proximity, the focus of innovation in clusters is often at the *regional* level in countries with geographically disparate centres of industrial activity such as Australia and the United States.

Finally, there is also an important reciprocal interaction between the common innovation infrastructure and cluster-specific circumstances. Each cluster in the nation draws on the common innovation infrastructure, but its investments and choices also *contribute* in some respects to the development of that common innovation infrastructure. Biotechnology firms draw on technology and people from university science departments and schools of medicine, but typically support them through grants and contract research. The internal research and clinical testing of biotechnology firms advance the knowledge base in these institutions. Often through trade associations, biotechnology firms also participate in specialised training activities that boost the nation's stock of skilled talent.

Both the Innovation Index developed in the next section and the policy implications we draw from it depend on each element of the national innovative capacity framework. We, therefore, explore each area in greater detail before turning to the benchmarking analysis.

2.2.1 Common Innovation Infrastructure

A nation's common innovation infrastructure is the set of crosscutting factors supporting innovation throughout an entire economy, including the pool of human and financial resources devoted to scientific and technological advances, the economy wide public policies bearing on innovative activity, and the economy's inherited level of technological sophistication (**Figure 2-2**). The foundation of a nation's common innovation infrastructure is its cadre of scientists and engineers involved

[5] For a discussion, see Porter (1990, 1998).

Figure 2-2. The Common Innovation Infrastructure

- Investment in basic research
- Tax policies affecting corporate R&D and investment spending
- Supply of risk capital
- Aggregate level of education in the population
- Pool of talent in science and technology
- Information and communication infrastructure
- Protection of intellectual property
- Openness to international trade and investment
- Overall sophistication of demand

in innovation. Government funding is the mainstay of virtually every nation's investment in truly frontier research. Sustained support for research, particularly university-based research, also tends to augment the pool of scientists and engineers because research funding often includes stipends and assistantships that attract young talent.

The set of technically trained personnel and the aggregate level of education in the population constitute another important cross-cutting element of national innovative capacity. Certainly, the ability of firms to develop specialised expertise in designing innovative products and processes depends critically on the availability of suitably talented technical employees. While technological work is performed by only a small subgroup of the labour force, innovative personnel are not necessarily technical staff. Innovation arises in numerous domains, including marketing, service, and management. The ability of a nation to develop individuals with such abilities depends on whether the educational system provides a high-quality cognitive skill base from which all firms can draw.

Support for research and education alone, while necessary to support innovation, is not sufficient. High scores in international mathematics exams may increase the potential to develop engineers but do not ensure innovative success. Even the quality of science in a country, as measured by the number of important publications, is only a weak predictor of national success in commercial innovation (Stern, Porter and Furman, 1999). Other cross-cutting institutions that enhance the strength of the common innovation infrastructure upon which clusters can draw are a strong information infrastructure and an accessible supply of risk capital. The recent changes wrought by the Internet are ample demonstration that information technology and the infrastructure to disseminate it can drive innovation across a wide array of industries in the economy.

Risk capital is a vital lubricant to innovation, especially for the translation of innovations into commercial products and services. There is a tendency these days to equate risk equity with venture capital, but the institutional structure for providing risk capital can take different forms in different nations. In Japan, for example, most risk capital comes from large corporations. As any nation seeks to improve its supply of risk capital, it should build on its unique institutional strengths. For Australia, public policy can encourage renewed energy in corporate venture investing or providing the context for the long-term rise of a distinct venture capital sector.

A set of important federal and state policies constitute another element of the common innovation infrastructure. It is well understood that the incentive to innovate disappears when firms cannot reap returns on their investments. As a consequence, policies that protect intellectual property are essential for creating a pro-innovation environment. Particular policies associated with innovation, such as patent and copyright laws, are more important in some industries than others.[6] However, one can distinguish countries with respect to the overall environment ensuring the appropriability of returns to innovative investments. Other policies—such as the extent of R&D tax credits, a regulatory environment that encourages competition, and efficient taxation of capital gains—affect incentives for innovation across the economy. Policies toward the openness of the economy to international competition are also an essential component of the national innovative environment; open borders encourage upgrading through increased competition and the inflow of ideas.

A further aspect of the common innovation infrastructure is the overall sophistication of a country's consumers. The drive for innovative products is derived in great measure from the nature of demand in the domestic economy. In Australia, farmers have acted as a demanding and early customer for many important technologies arising from government funded organisations such as the CSIRO as well as biotechnology companies such as CSL. In this case, it is not so much the size of the home market in a nation that matters but its character.

Finally, a nation's common innovation infrastructure also depends on its level of overall technological development. This harder-to-measure condition is the result of the accumulated array of learning and investments over time in the economy.

[6] In particular, the strength of IP can impact upon key commercialisation choices (see Gans, Hsu and Stern, 2002; Gans and Stern, 2003).

2.2.2 The Cluster-Specific Innovation Environment

While the common innovation infrastructure sets the basic conditions for innovation, the development and commercialisation of new technologies take place disproportionately in clusters — geographic concentrations of interconnected companies and institutions in a particular field. The cluster-specific innovation environment is captured in Porter's "diamond" framework (**Figure 2-3**).[7] Four attributes of the microeconomic environment surrounding a cluster bear on its overall competitiveness and innovative vitality -- the presence of high-quality and specialised inputs; a local context that encourages investment together with intense rivalry; pressure and insight gleaned from sophisticated local demand; and the local presence of high quality related and supporting industries.

The importance of clusters reflects important externalities in innovation that are contained in particular geographic areas. Presence within a cluster offers advantages to firms in perceiving both the need and the opportunity for innovation. Equally important, however, are the flexibility and capacity present in clusters to turn new ideas into reality. Within a cluster, a company can rapidly assemble the components, machinery, and services necessary for commercialisation. Suppliers of essential inputs and "lead" buyers become crucial partners in the innovation process; the relationships necessary for effective innovation are more easily achieved among participants that are nearby. Reinforcing these advantages for innovation within clusters is sheer pressure — competitive pressure, peer pressure, customer pressure and constant comparison. We focus on clusters (e.g., information technology) rather than individual industries (e.g., printers), then, because of powerful spillovers and externalities across discrete industries that are vital to the rate of innovation.

The innovation environment of a cluster is fundamental to its competitiveness. For example, the Finnish pulp-and-paper cluster benefits from the advantages of pressures from demanding domestic consumers, intense rivalry among local competitors, and local Finnish process-equipment manufacturers who are world leaders, with companies such as Kamyr and Sunds leading the world in the commercialisation of innovative bleaching equipment. Similar examples of cluster vitality in innovation occur in many fields, from pharmaceuticals in the United States to semiconductor fabrication in Taiwan.

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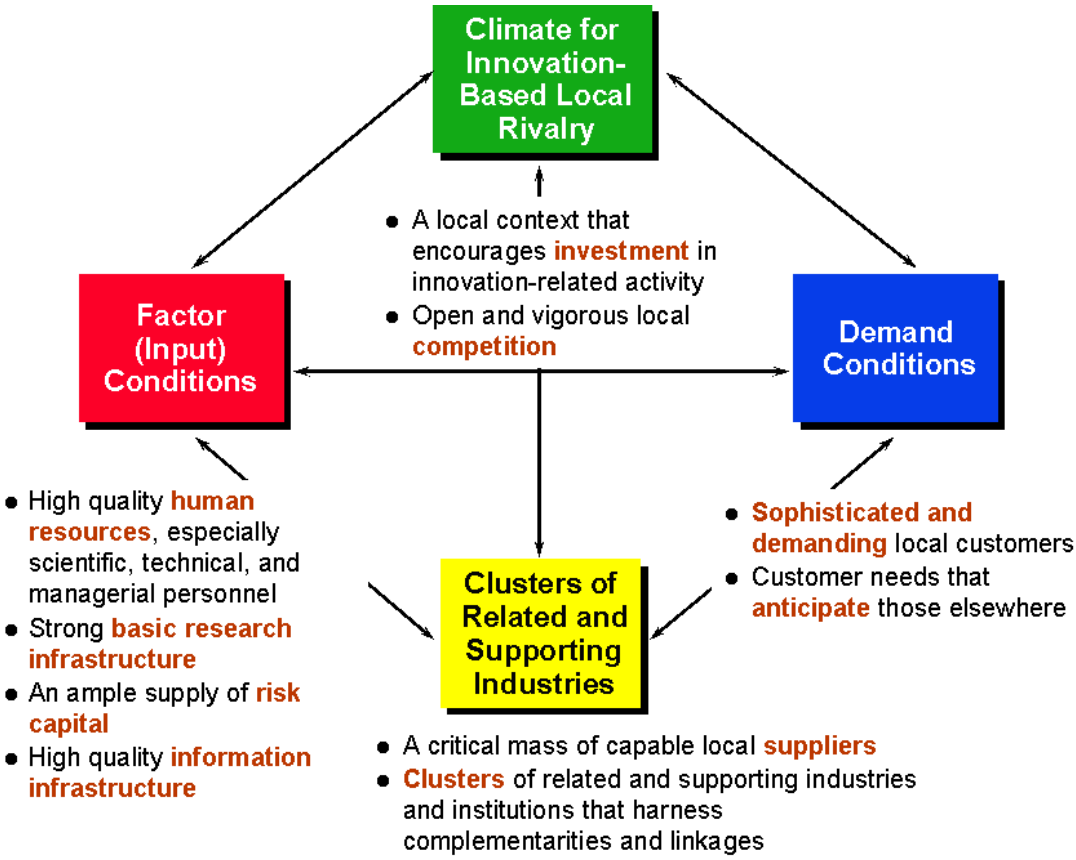
[7] For a more complete exposition of the diamond framework and its role in understanding the origins of national competitive advantage, see Porter (1990, 1998).

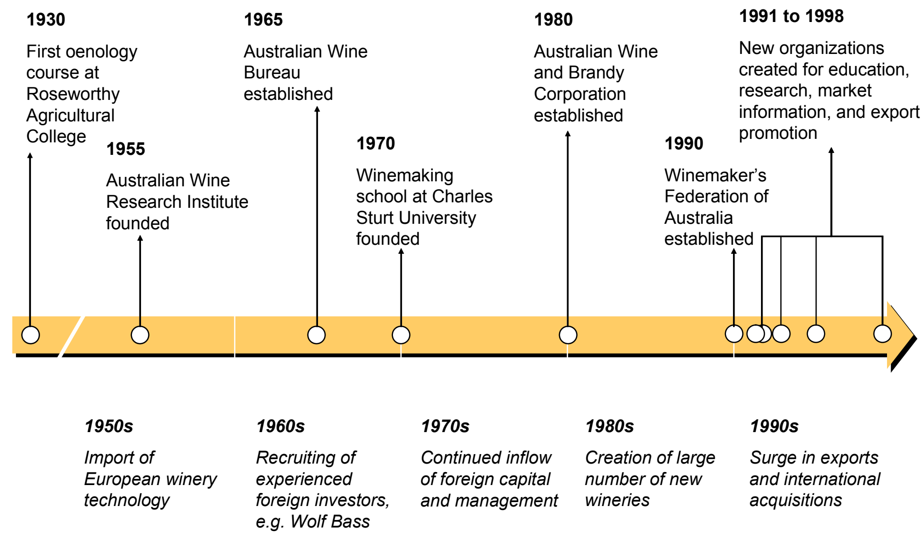
Figure 2-3: Porter's Diamond Framework



Perhaps the single most visible recent cluster in Australia centres on the wine industry. Though it has only recently emerged as a leading force international market, the growth of Australia's wine is the consequence of decades of investment, from the establishment of the Australian Wine Research Institute in 1955 to the flurry of institutions for collaboration on international markets founded over the past decade (see **Figures 2-4 and 2-5**). Building on unique advantages in terms of natural resources, and enhancing the value of those resources through research and innovation, the Australian wine industry epitomises how an effective mix of domestic competition and public/private cooperation in key areas facilitates international competitiveness.

Figure 2-4

The Australian Wine Cluster
History



Source: Michael E. Porter and Örjan Sölvell, The Australian Wine Cluster – Supplement, Harvard Business School Case Study, 2002

Figure 2-5

The Australian Wine Cluster
Recently founded Institutions for Collaboration

Winemakers' Federation of Australia

- Established in 1990
- Focus: Public policy representation of companies in the wine cluster
- Funding: Member companies

Cooperative Centre for Viticulture

- Established in 1991
- Focus: Coordination of research and education policy in viticulture
- Funding: other cluster organizations

Australian Wine Export Council

- Established in 1992
- Focus: Wine export promotion through international offices in London and San Francisco
- Funding: Government; cluster organizations

Grape and Wine R&D Corporation

- Established in 1991 as statutory body
- Focus: Funding of research and development activities
- Funding: Government; statutory levy

Wine Industry Information Service

- Established in 1998
- Focus: Information collection, organization, and dissemination
- Funding: Cluster organizations

Wine Industry National Education and Training Council

- Established in 1995
- Focus: Coordination, integration, and standard maintenance for vocational training and education
- Funding: Government; other cluster organizations

Source: Michael E. Porter and Örjan Sölvell, The Australian Wine Cluster – Supplement, Harvard Business School Case Study, 2002

2.2.3 The Quality of Linkages

The quality of the connections between a nation's common innovation infrastructure and individual industrial clusters is crucial to innovation. It is also reciprocal: strong clusters feed the common infrastructure and also benefit from it. Without strong linkages, upstream scientific and technical advances can actually diffuse to other countries more quickly than they can be exploited at home. For example, although early elements of VCR technology were developed in the United States, it was three companies in the Japanese consumer electronics cluster that successfully commercialised this innovation on a global scale in the late 1970s.

A variety of formal and informal organisations and networks — which we term 'institutions for collaboration' — are present in many nations and link the two areas. In most cases, effective institutions for collaboration involve participation by the public and private sector. Consider the National Stem Cell Centre (NSCC). Though funded initially at the federal level (namely, the Australian Research Council), the NSCC activities now facilitate interaction between the state and federal government, university researchers, as well as companies and industry associations. As with many new technologies, the scientific and commercial impact of stem cell research depends on an effective legal environment and public acceptance of potential ethical issues; the NSCC has taken a leading role in helping to define this debate in the Australian context. Overall, institutions for collaboration can leverage nascent areas of strength by (a) enhancing the ability of researchers to exchange knowledge and build on each others' discoveries and (b) helping to establish the legal and institutional framework for effective commercialisation efforts.

A particularly important linking institution is a nation's university system. A strong university sector serves as a key channel by which basic, fundamental research catalyses the emergence of innovation-oriented domestic clusters. Conversely, by pressuring universities to conduct relevant research and produce high-quality students with specific technical skills, private funding and involvement in the university sector fosters a link from the clusters to the common innovation infrastructure. University graduates serve in both the public and private sector, providing a more informal type of linkage, and many universities receive both public and private funding, reinforcing linkages between government initiatives and commercial priorities.

2.3 Measuring National Innovative Capacity

This study extends the National Innovative Capacity Project conducted by Michael E. Porter, Scott Stern and several co-authors over the past several years. The goal of this project is to document the drivers of global innovation and provide an empirical foundation for public policy initiatives in this area. This report updates prior studies in the Project by using more up-to-date data for a wider range of countries and incorporating a more refined set of measures.[8]

Attempts to measure and benchmark innovative outputs have become common across advanced economies[9] The distinctive feature of the Porter-Stern approach is a clear distinction between innovation output (specifically, **international** patenting) and its drivers (infrastructure, clusters and linkages) as well as a careful determination of the 'weights' attached to each innovation capacity driver.[10] Each weight is derived from regression analysis relating the **development** of new-to-the-world technologies to drivers of national innovative capacity. This has the advantage of avoiding an 'ad hoc' weighting of potential drivers and instead using the actual relationship between innovative capacity and innovation to provide those weights. Thus, measures which historically have been more important in determining high rates of innovative output across all countries are weighted more strongly than those which have a weaker (though still important) impact on innovative capacity. The end result is a measure of innovative capacity that is measured in per capita terms to allow for international comparisons as well as a set of weights that focuses attention on **relative** changes in resources and policies both over time and across countries.

[8] Prior studies by Porter, Stern, and co-authors have employed two distinct methodologies for benchmarking innovative capacity. The first methodology employs a panel data approach and publicly available measures of the innovation environment (see the Council on Competitiveness (1999) co-authored by Porter and Stern; Furman Porter and Stern (2002) is an academic publication discussing the key methodological issues in some detail). Second, over the past two years, data from the *Global Competitiveness Report* (GCR) have been employed to provide a "snapshot" of the innovation environment for over 70 countries at a point in time. While each approach has its advantages, this report builds upon (and focuses its discussion on) the first approach; please see the GCR for the results of the second approach.

[9] We do not review this voluminous field here. However, good starting points are the benchmarking programs of the European Union (trendchart.cordis.lu).

[10] See Appendix A and Furman, Porter and Stern (2002) for a more thorough discussion of this methodology and prior research in this area. In particular, our approach builds on a line of research that includes, among others, Dosi, Pavitt, and Soete (1990) and Eaton and Kortum (1996).

2.3.1 Measuring Innovative Output

In order to obtain the weights for the Innovation Capacity Index, we must benchmark national innovative capacity in terms of an observable measure of innovative output. In this study, we use the number of "international" patents applied for in a given year (and subsequently granted) for each country in the sample, as captured by the number of patents granted to inventors of a given country by the United States Patent and Trademark Office.[11,12] While no measure is ideal, measures of international patenting provide a comparable and consistent measure of innovation across countries and across time.[13]

Three important factors drive the decision to use international patents. First, patenting over countries and time is highly likely to reflect actual changes in inventive outputs rather than spurious influences, especially in measuring innovativeness at the world frontier. Patenting captures a sense of the degree to which a national economy is developing and commercialising "new to the world" technologies—a necessary prerequisite for building international competitiveness on the basis of quality and innovation. In short, international patenting is "the only observable manifestation of inventive activity with a well-grounded claim for universality."[14]

Second, while international patenting is not a perfect measure, other measures suffer from greater conceptual or data limitations. Copyrights, for example, are potentially important indicators of innovative activity, particularly in industries such as software. However, copyrights vary greatly in their definitions and importance across countries and over time,

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[11] As we discuss further below, we include a US dummy to account for the fact that US patenting abroad may differ from other countries' patenting in the US. This dummy variable turns out to be both small in impact and insignificant.

[12] Our use of patent applications within a given year is a refinement on the initial Porter and Stern methodology. In their initial studies, they employed the number of patents granted within a given year and assumed a three year "lag" between application and grant times. Of course, patent applications and patent grants (three years forward) are highly correlated, and the use of one or the other measure as the innovation output measure does not affect the core findings of this study.

[13] Other recent measures proposed include citations of patents and academic publications. As is well known, the latter data can suffer from distortions because of self citation (see Gans and Stern, 2002, 2003).

[14] Trajtenberg (1990) provides a thorough discussion of the role of patents in understanding innovative activity, stretching back to their use by Schmookler (1966) and noting their ever-increasing use by scholars in recent years (e.g., Griliches, 1984; 1990; 1994). Our use of international patents also has precedent in prior work comparing international inventive activity (see Dosi, Pavitt, and Soete, 1990; Eaton and Kortum, 1996).

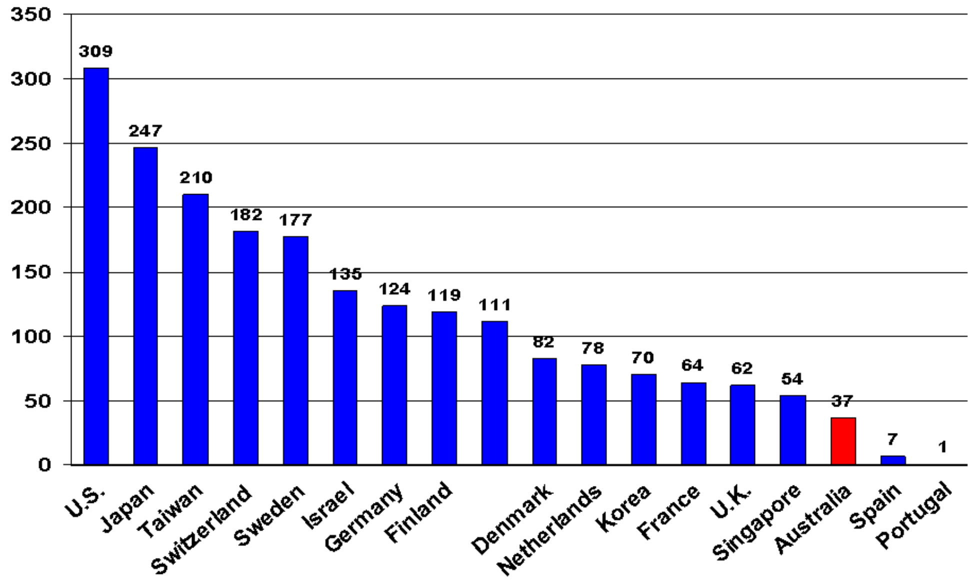
and prove not to be very useful for international comparisons of aggregate innovative activity. The number of scientific journal articles, while a precise and standardised measure of innovative output across countries, is an indicator of more basic activity that is closer to scientific exploration than to commercial significance. As well, the intensity of patenting is correlated with other manifestations of innovative activity.

It is important to keep in mind that the Index itself is not the number of international patents, but rather a weighted sum of the types of measures described earlier (such as national R&D employment, weighed by their demonstrated influence on international patenting). Therefore, the Index *reflects the actual resource and policy commitments of a country* and not simply a country's propensity to patent or its involvement in patent-intensive industries. The choice of patents as a measure, then, only modestly influences differences in the weights used in the Index calculation. The Index captures R&D personnel and funding even in those sectors which do not rely heavily on patenting. Even though areas such as software are much less patent-intensive than, say, the life sciences, the employment of software engineers and R&D expenditures in software *is* part of the Index.

A final consideration in selecting international patents as our measure of innovative output is their connection with commercial significance. Obtaining a patent in a foreign country is a costly undertaking, which is only worthwhile for an organisation that anticipates a commercial return in excess of the substantial costs. This insight is confirmed in a suggestive way by examining the relationship between international patenting and more general international economic data. As discussed further in Porter, Stern and COC (1999), international patenting is strongly correlated with alternative measures of innovative output such as the number of scientific journal articles and also with outcome measures such as a country's market share in high-technology industries. After controlling for the level of international patenting, however, more upstream measures (i.e., scientific journal articles) do not have a significant relationship with outcome measures (success in international markets). In other words, international patenting seems to encompass alternative measures of innovative output and is also closely associated with patterns of success in innovation-driven international competition.

Figure 2-6 shows the variation in international patenting across countries on a per capita basis. Notice that there is considerable international variation and that Australia ranks towards the low end of leading countries. The analysis documented below explains this variation as well as providing a way of predicting how a given nation's performance might change in response to changes in policy, patterns of investment, or the cluster environment.

Figure 2-6: Patents per Million of Population, 2000



Source: USPTO.

2.3.2 Calculating the Index

The Index is calculated and evaluated in three stages, summarised in **Figure 2-7** (Appendix A provides a more comprehensive discussion of the methodology). The first stage consists of creating the database of variables relating to national innovative capacity for our sample of 29 OECD countries from 1980 to 2000. These measures are described in the box "Distilling Measures of National Innovative Capacity." This database is used to perform a time series/cross sectional regression analysis determining the significant influences on per capita international patenting and the weights associated with each influence on innovative capacity.

In the second stage of the analysis, the weights derived in the first stage are used to calculate a value for the Index for each country in each year given its actual resource and policy choices. It is in this sense that we refer to national innovative capacity: the extent of countries' current and accumulated resource and policy commitments. The Index calculation allows us to explore differences in this capacity across countries and in individual countries over time.

Figure 2-7. Calculating the Innovation Index

Stage I
- Create a database for 29 OECD countries from 1980 to 2000
- Employ a time series/cross sectional regression analysis to determine the significant influences on innovative output and the weight associated with each influence

Stage II
- Calculate the Innovation Index for each country for each year using the weights from Stage I
- Evaluate the differences in the Index among countries and changes in the Index over time

Stage III
- Project the Innovation Index into the future for each country, given the recent trajectory of its policy and resource commitments
- Evaluate projected shifts in the Index among countries and the influence of various policy areas

The Index, interpreted literally, is *the expected number of international patent applications per million persons given a country's current configuration of national policies and resource commitments.* It is important *not* to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process.

The third stage of the analysis uses additional statistical modelling to provide a projection of national innovative capacity into the future, based on recent historical trends in investment and policy choices. This is a projection rather than a "forecast" in the sense of being predictive. The recent trajectories of countries' resource commitments and policy choices are extrapolated into the future, and then the weights developed in the first stage are used to project national innovative capacity in the future. Hence this exercise provides insight into the potential implications of "staying the course." Clearly, the innovative capacities that will actually be realised in the future depend on both the public and private policy decisions made in the interim. Our methodology is meant to establish a baseline for comparative analysis and provide a context for current policy debates.

Distilling Measures of Innovative Capacity

The theoretical framework of Porter and Stern suggests that measures included should reflect the common innovation infrastructure, the innovation environment in clusters, and the quality of linkages between these two areas. The Index includes the best available measures of the strength of each area. No single influence alone, whether it be the quality of scientists or the strength of international property laws, ensures a healthy stream of innovative output. When several of these influences improve concurrently, however, national innovative capacity will tend to rise.

Along some dimensions, particularly those which capture the strength of the common innovation infrastructure, direct measures are available and are included in the analysis. More subtle and multi-faceted concepts, such as the cluster-specific innovation environment, cannot be quantified directly from available and internationally comparable data. This challenge is addressed by employing an intermediate measure which does not capture the underlying drivers of national innovative capacity in a particular area but measures an outcome associated with the strength of those specific drivers. The quality of the innovation environment within clusters is inherently difficult to measure, for example, as it involves such areas as the supply of specialised talent and the degree of domestic customer sophistication in particular fields. However, the amount of collective R&D activity funded by a nation's clusters provides an indicator of these more fundamental circumstances.

With the distinction between direct and indirect indicators in mind, we review the specific variables used in the calculation of the Index and how each relates to national innovative capacity.

The Quality of the Common Innovation Infrastructure

Aggregate Personnel Employed in Research and Development. A critical determinant of the underlying innovative capacity of an economy is the overall supply of scientific and technically trained individuals available. Both private and public entities engage the skills of these individuals, whose continuing learning builds on their formal training. An intermediate measure of the more fundamental process by which individuals choose to invest in scientific and technical skills, the level of personnel employed in R&D-related activities in a nation reflects the baseline level of human resources which can be utilised for purposes of innovation across the economy.

Aggregate Expenditures on Research and Development. In addition to human resources, a strong national innovation infrastructure includes the availability of funding for innovation-related investments. While the determinants of investment in an individual cluster will be a function of relevant technological and commercialisation opportunities, the aggregate level of such investments by both business, non-profit, and public institutions reflects the overall availability of R&D-directed capital. It is crucial to note that while specific forms of financing (e.g., venture capital) are often cited as being the most efficient form of providing capital for innovation, countries have developed a variety of institutions for delivering a high *level* of R&D capital, including investment by large corporations and cooperative R&D (Japan), interlocking cooperative funds centred around small- and medium sized companies (Northern Italy), and the American venture capital model. Aggregate R&D expenditure is also an intermediate measure reflecting more fundamental drivers of investment, not the least of which are national R&D tax policy and the existence of regulations facilitating capital market institutions such as venture financing.

Strength of Protection for Intellectual Property. Of the policies affecting national innovative capacity, perhaps the most basic is the provision of appropriate rewards for innovation by private inventors. We measure the extent to which a nation's policies protect intellectual property rights through patents, copyrights, and the like. Intellectual property protection contributes to national innovative capacity in two ways. First, strict defence of intellectual property encourages domestically based firms to invest in innovative activities and signals the attractiveness of the country as a site in which to locate innovative activity. Second, obtaining the benefits of such protection requires public disclosure of information describing the innovation. In this way, intellectual property protection encourages the diffusion of knowledge throughout the economy. While a cross-cutting measure, the impact of legal intellectual property protection is more salient for some clusters than for others. For example, while the pharmaceutical industry has long depended upon strong patent protection throughout most of the OECD, emerging areas such as software are still developing appropriate and effective intellectual property institutions.

Share of Gross Domestic Product Spent on Secondary and Tertiary Education. The availability of high quality workers, with both technical and non-technical backgrounds, is an additional and basic element of a nation's common innovation infrastructure. Investment in higher education creates a base of highly skilled personnel upon which firms and other institutions across the economy can draw; in both formal R&D activities and more informal problem-solving, skilled workers are better able to recognise, choose, and execute innovation-oriented strategies in the pursuit of competitive advantage. The intensity of national investment in higher education is therefore a crucial determinant of national innovative capacity. By sustaining investment in higher education, a country can slowly but surely upgrade the ability of its workforce to innovate and to commercialize new technologies at the international frontier.

Gross Domestic Product per Capita. Beyond direct investments and policy choices, a nation's common innovation infrastructure is affected by the general level of domestic customer sophistication and the overall accumulated level of domestic technological knowledge. These are measured in the Index by gross domestic product (GDP) per capita adjusted for exchange rate differences. The level of wealth achieved by an economy both reflects the technological stock upon which innovators draw and influences the degree to which sophisticated domestic customers exert pressure on firms to upgrade the quality of their product offerings. It is important to note that GDP per capita ultimately depends on the accumulated history of public and private choices, investments, and outcomes rather than short-term economic policies.

Cluster-specific Innovation Environment

Percentage of R&D Expenditures Funded by Private Industry. The degree to which a nation's clusters contribute to innovative capacity depends, in large part, on whether the environment of individual clusters encourages firms to commercialise new products and processes. While there is no measure of this which is comparable across clusters, time, and countries, the extent of R&D funding by private firms is a reflection of whether cluster-specific conditions are conducive to R&D investment. Across clusters, the more favourable the innovation environment, the higher national private R&D spending will be. Controlling for total R&D expenditures, then, the percentage of total R&D expenditures funded by private industry is an intermediate measure of the cumulative innovative activity of a nation's clusters and an observable manifestation of the more fundamental conditions affecting innovation in those clusters.

Concentration of Patents Across Broad Technological Areas. As innovative clusters will be associated with technologies from particular technological areas, we use the relative concentration of innovative output in chemical, electrical and mechanical USPTO patent classes to proxy for innovative concentration. This measure of specialisation is too coarse to identify particular clusters but it does potentially capture the consequences of cluster dynamics and the relative specialisation of national economies in a particular area.

The Quality of Linkages

Percentage of R&D Performed by Universities. National innovative capacity is reinforced by strong linkages between clusters and the common innovation infrastructure. While these linkages take different forms in different national contexts, one commonality across countries is the leading role that universities play in mediating the relationship between private industry and elements of the innovation infrastructure. A strong university sector provides an important conduit through which basic, fundamental research results serve to catalyse the emergence of innovation-oriented domestic clusters. Conversely, by placing pressure on universities to conduct relevant research and produce high-quality students with specific technical skills, private funding and involvement in the university sector serve to foster a key reverse linkage from the clusters to the common innovation infrastructure.

Controlling for the overall level of R&D investment, then, the percentage of R&D performed by universities is an indicator of the strength of linkages. It measures the degree to which innovative activity, whether funded by companies, government or other institutions, is centred in institutions which are suited to encouraging interplay between the different entities that contribute to national innovative capacity. It is important to note, however, that we cannot capture in the Index the full range and diversity of institutions (e.g., research cooperatives in Japan and elsewhere) which have arisen across countries to contribute to such linkages.

2.4 Findings on Innovative Capacity

The regression analysis reveals a strong and consistent relationship between each measure of the strength of national innovative capacity and per capita international patenting. This result is interesting in its own right: while countries differ in the institutions and mechanisms used to influence and conduct innovative activity, there is a clear relationship between a small set of measures of the innovation environment and a key measure of innovative output which holds across all the countries. Overall, the measures of the strength of national innovative capacity explain more than 97 percent of the variation in international patenting, highlighting the strong relationship between the measures and observed innovative output (see Appendix A for a complete discussion). As discussed further in Stern, Porter, and Furman (2002), these results are robust to a variety of alternative specifications. For example, the qualitative results are the same for a smaller data sample composed solely of those observations after 1985. Hence, the determinants of innovative output appear to have been quite consistent over time.

Further, each of the measures identified above proves to be both statistically significant and quantitatively important in explaining innovative output at the national level. One of the strongest influences turns out to be the relative size of the R&D workforce—the pool of available technical talent. For example, a 20 percent increase in the size of the R&D workforce in a country would lead to a change in the predicted value of the Index of just over 14 percent. Both the level of R&D expenditures and the proportion of funding from industry also play decisive roles in determining the level of innovative outcome. The results suggest that increasing the percentage of total R&D expenditure funded by private industry by 10 percentage points (e.g., by shifting industry's share from 50 to 60 percent of total expenditures) increases the level of innovative capacity by over 13 percent. Although the magnitude of their effects is somewhat smaller, the other measures, including the strength of intellectual property and the extent of public funds devoted to education are of substantial importance as well.

The suggestive but imperfect measure of the strength of linkages—the share of R&D performed by universities— also turns out to be a significant but modest contributor to international patenting performance. GDP per capita is a strong statistical determinant of international patenting as well, reflecting the importance for innovative capacity of a strong accumulated knowledge pool and a sophisticated and demanding domestic customer base.

Finally, working in the opposite direction is a "raising the bar" effect. The productivity of international patenting (i.e., the number of patents produced for a given level of innovative resources) is declining over time, a result consistent with prior studies. Taken together, the statistical analysis confirms the notion that no single factor is determinative in creating a favourable innovation environment, and that concurrent progress is necessary in a variety of areas to substantially upgrade a nation's innovative capacity.

3 Australian Innovative Capacity

In this section, we examine more closely the determinants of Australian Innovative Capacity. Prior to doing so, it is instructive to place Australia's performance in a global context.

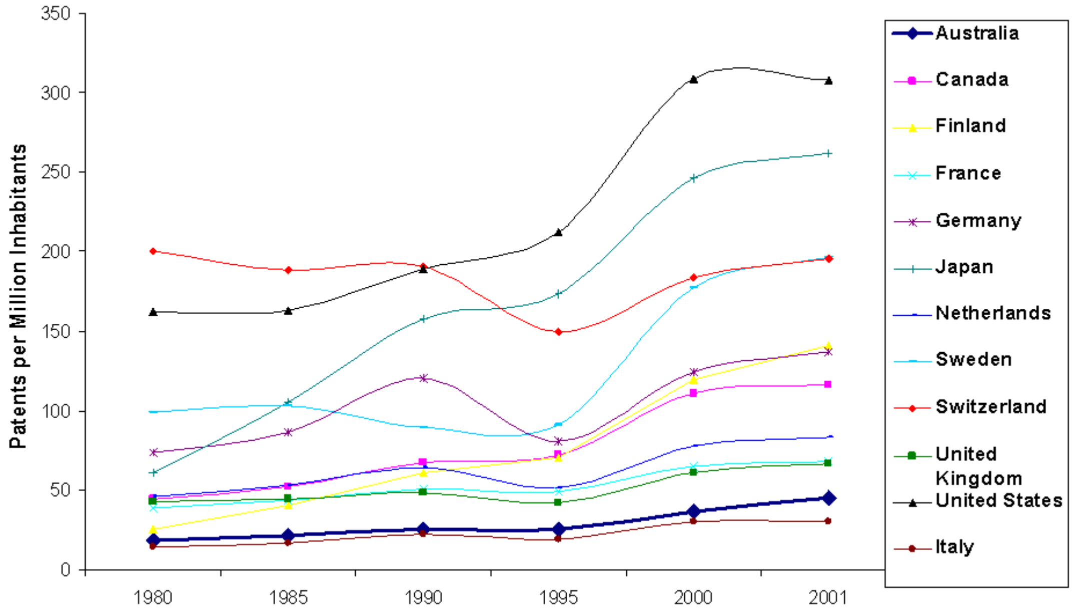
3.1 Innovative Capacity Across the World

In terms of innovative output, compared with other leading economic nations, Australia has been historically a weak performer (**Figure 3-1**). However, during the 1990s, there has been noticeable growth in Australia's performance. What concerns us here, however, is the identification of the causes of Australia's historic performance and assessment of areas for policy concern going forward.

To understand this, we turn to the Innovation Index. **Figure 3-2** depicts the Index value for each country over time. The Index, interpreted literally, is *the expected number of international patent applications per million persons given a country's current configuration of national policies and resource commitments.* It is important *not* to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process.

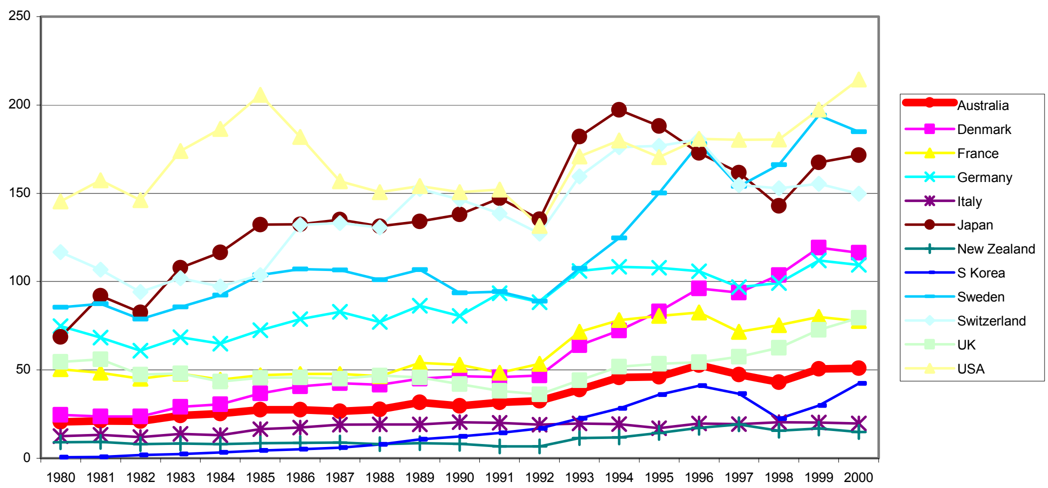
The Index yields a number of interesting findings. Over the three decades examined, countries fall into three relatively stable groups in terms of innovative capacity (see **Figures 3-2** and **3-3**). The United States and Switzerland consistently appear at the top of the Index, and were joined there in the 1980s by Japan and Sweden. These countries constitute the innovator group. A second group of countries, including the remaining Scandinavian countries, constitute a middle group. This group now includes Australia. The third group, including Italy, New Zealand and Spain, lag behind the rest of the OECD over the full sample. There are quite substantial differences across the groups in terms of the value of the Index. Predicted per capita innovative capacity for the top group is more than 5 times the level of capacity attributed to countries in the lowest tier.

Figure 3-1: Patenting Across Leading Economic Nations



Source: USPTO

Figure 3-2 The Innovation Index for Selected Countries



From 1980 to 1989, the Index is based on data for West Germany only

Figure 3-3: Innovation Index Rankings

Country	1980 Rank	1980 Innovation Index
USA	1	145.4
Switzerland	2	116.8
Sweden	3	85.4
Germany	4	74.8
Japan	5	68.6
Netherlands	6	55.8
UK	7	54.6
France	8	50.4
Canada	9	49.5
Norway	10	31.8
Hungary	11	31.8
Belgium	12	28.5
Finland	13	28.2
Denmark	14	24.5
Austria	15	24.4
Australia	**16**	**20.6**
Italy	17	12.5
Iceland	18	10.5
New Zealand	19	9.1
Ireland	20	4.9
Spain	21	3.2
Portugal	22	0.8
S Korea	23	0.6
Greece	24	0.5
Turkey	25	0.4

Country	1985 Rank	1985 Innovation Index
USA	1	205.7
Japan	2	132.2
Switzerland	3	103.7
Sweden	4	103.6
Germany	5	72.5
Canada	6	65.6
Netherlands	7	48.8
France	8	46.9
Norway	9	45.6
UK	10	45.5
Finland	11	42.5
Belgium	12	40.3
Denmark	13	36.7
Australia	**14**	**27.5**
Austria	15	24.9
Hungary	16	23.0
Italy	17	16.4
Iceland	18	13.8
New Zealand	19	8.5
Ireland	20	6.0
S Korea	21	4.3
Spain	22	3.4
Portugal	23	1.2
Greece	24	0.9
Turkey	25	0.5

Country	1990 Rank	1990 Innovation Index
USA	1	150.7
Switzerland	2	146.4
Japan	3	138.0
Sweden	4	93.5
Germany	5	80.5
Finland	6	57.0
Canada	7	53.2
France	8	52.9
Netherlands	9	47.8
Denmark	10	46.5
UK	11	41.9
Belgium	12	41.8
Norway	13	38.7
Australia	**14**	**29.7**
Austria	15	27.9
Italy	16	20.4
Iceland	17	15.5
S Korea	18	12.3
Hungary	19	11.2
Ireland	20	9.8
New Zealand	21	8.2
Spain	22	7.3
Portugal	23	3.1
Greece	24	1.6
Turkey	25	0.3

Country	1995 Rank	1995 Innovation Index
Japan	1	188.1
Switzerland	2	176.9
USA	3	170.5
Sweden	4	150.0
Germany	5	107.8
Finland	6	84.2
Denmark	7	83.1
France	8	80.5
Canada	9	71.2
Norway	10	67.6
Netherlands	11	61.5
Belgium	12	60.3
UK	13	53.5
Australia	**14**	**46.0**
Austria	15	44.7
Iceland	16	38.1
S Korea	17	35.9
Ireland	18	33.4
Italy	19	17.1
New Zealand	20	14.3
Czech Rep	21	13.2
Spain	22	11.1
Portugal	23	4.9
Slovak Rep	24	4.4
Greece	25	4.2
Hungary	26	3.3
Poland	27	2.4
Mexico	28	0.5
Turkey	29	0.4

Country	2000 Rank	2000 Innovation Index
USA	1	214.4
Sweden	2	184.9
Finland	3	173.1
Japan	4	171.6
Switzerland	5	149.7
Iceland	6	130.7
Denmark	7	116.3
Germany	8	109.5
Canada	9	81.4
UK	10	79.4
France	11	77.6
Norway	12	75.1
Belgium	13	75.1
Netherlands	14	68.7
Ireland	15	62.3
Austria	16	52.4
Australia	**17**	**50.9**
S Korea	18	42.3
Italy	19	19.7
Spain	20	17.3
New Zealand	21	14.9
Czech Rep	22	14.5
Greece	23	12.0
Portugal	24	11.1
Hungary	25	5.4
Slovak Rep	26	3.5
Poland	27	3.5
Turkey	28	1.4
Mexico	29	1.2

An important finding from the analysis is that the relative advantage of leader countries has been declining over time. As can be seen in **Figure 3-3,** not only has the top tier expanded to include Japan, and Sweden, but some middle tier countries, such as Iceland and Finland, have made major gains in innovative capacity. Moreover, this convergence seems to be built on fundamentals rather than transient changes. Consider the case of Germany, where innovative capacity grew strongly throughout the 1980s. Despite a drop-off resulting from reunification with the East beginning in 1990, Germany maintained a relatively high level of innovative capacity throughout the 1990s. Indeed, looking across the OECD, there seems to have been a slow but steady closing of the gap between the innovation leaders and nations with historically lower levels of innovative capacity.

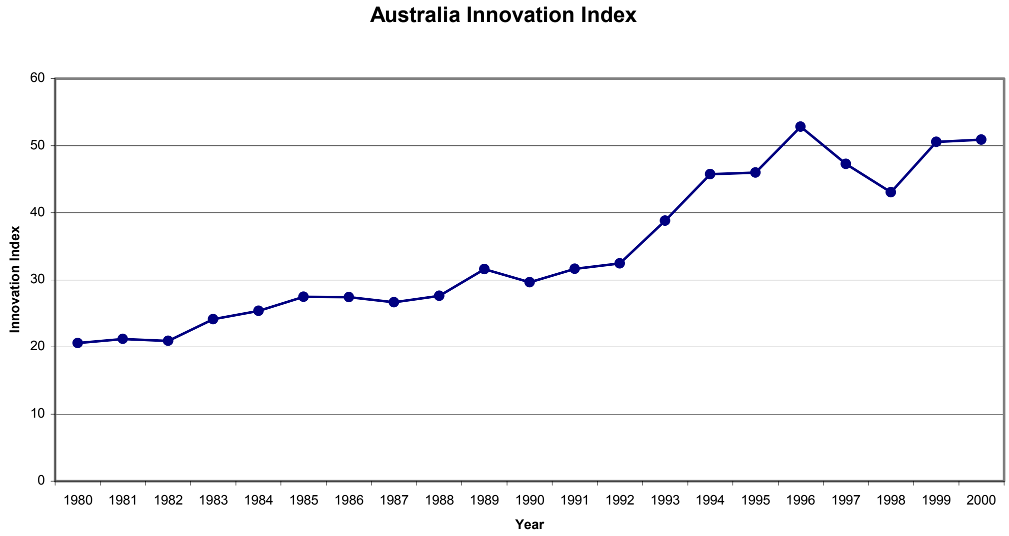
It is important to note, however, that some important countries, most notably Italy and Canada have at best remained constant in their innovative capacity. Finally, the Netherlands has seen an alarming fall off in its innovative capacity. Compared to other economies that have been able to achieve relatively strong improvement, then, these countries have eroded their relative innovative capacity over the past quarter century by neglecting investments in common innovation infrastructure and in supportive cluster innovation environments.

3.2 The Evolution of Australian Innovative Capacity

Over the past twenty years, Australia has substantially enhanced its innovative capacity (**Figure 3-3** compares Australia to a group of leading countries, while **Figure 3-4** presents Australia's performance in isolation). During the 1980s, Australia's positioning could be characterised as a "classical" imitator economy – productivity improvements were primarily driven by the ability to import technology and ideas developed elsewhere. Over the past decade, Australia has more than doubled its level of innovative capacity (relative to its levels in the early 1980s) and transformed itself into a second-tier innovator economy (though somewhat at the lower end of this group).

As a consequence of these improvements, Australia no longer simply relies on the fruits of innovations seeded elsewhere. Australia has achieved an innovation environment that allows it to be a solid though not leading contributor to global innovation. However, rather than continuing the upward trajectory observed during the early 1990s, innovative capacity in Australia over the past half decade has remained stable. Given that both advanced and emerging economies throughout the world are investing substantially in innovative capacity, stability in the Australian context raises the risk of falling back in relative terms.

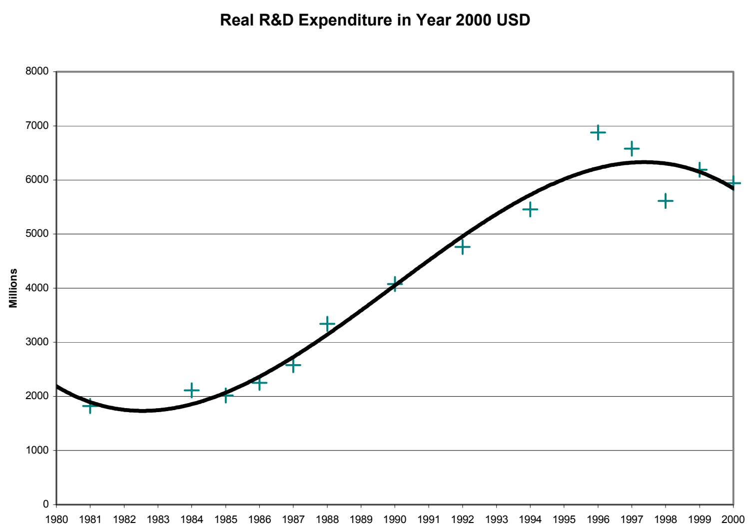
Figure 3-4: Evolution of Australia's Innovative Capacity



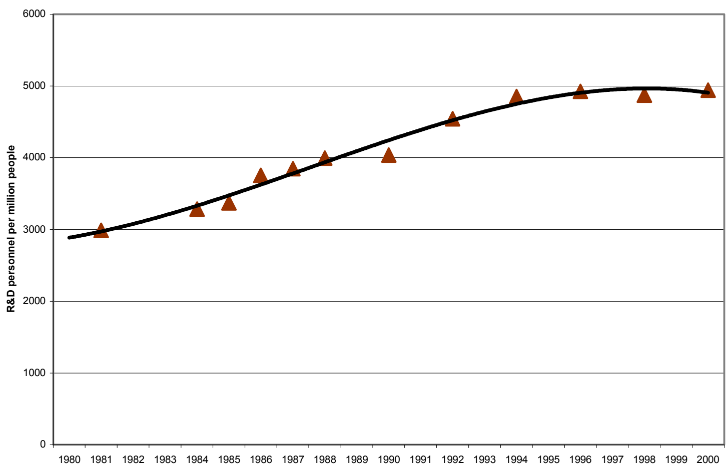
The evolution of Australian innovative capacity can be assessed more carefully by considering the movement over time in each of the drivers of innovative capacity. **Figure 3-5** presents each the changes over time in each of the measures used in the benchmarking analysis.

Figure 3-5: Drivers of Australia's Innovative Capacity

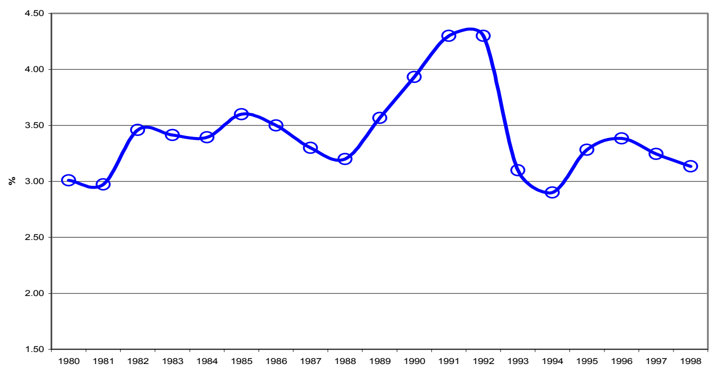
Common Innovation Infrastructure



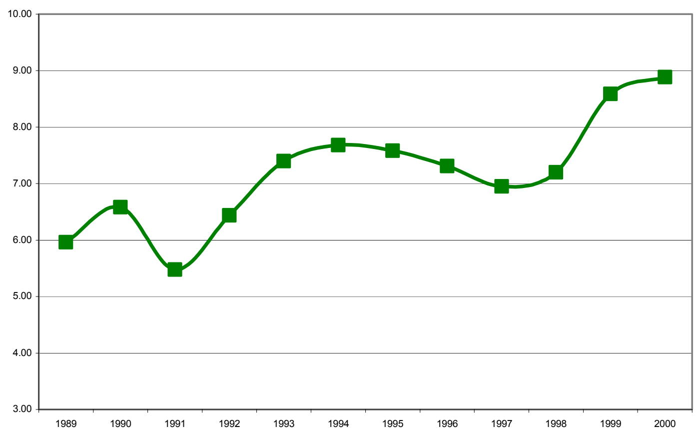
R&D personnel per million people



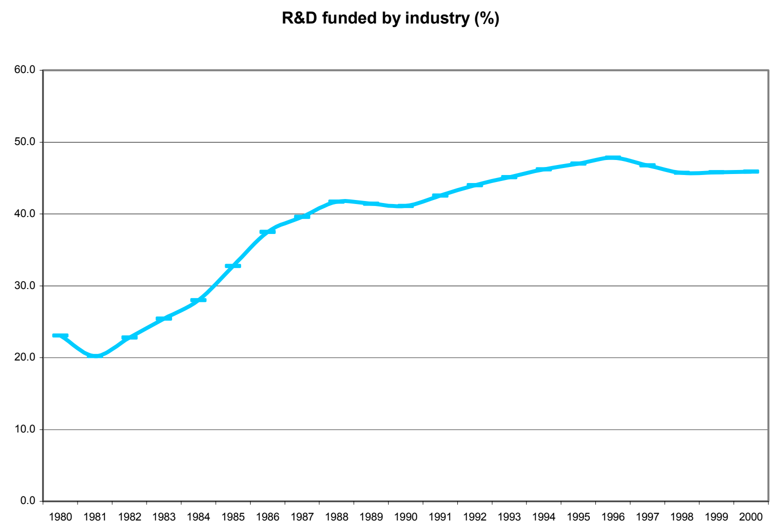
Education share of GDP



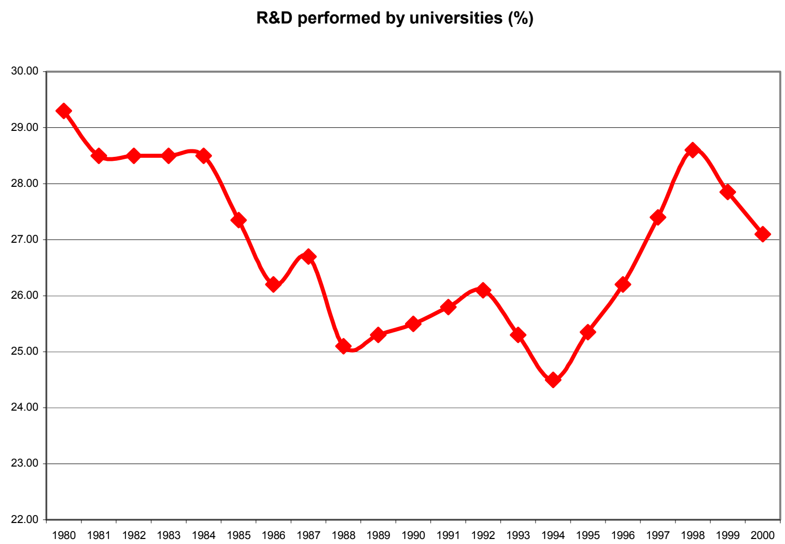
IP protection



Cluster-Specific Environment



Quality of Linkages



Prior to 1980, Australia was an imitator economy. Despite a reasonable standard of living, the national economy was characterised by a low level of R&D expenditures and a relatively small share of these expenditures were funded by the private sectors. From an historical perspective, Australia has maintained a high share of national income devoted to higher education and university R&D performance. Indeed, these investments in a research-oriented educational sector were the stepping stones upon which the improvement in Australian innovative capacity was founded.

Australia experienced its first phase shift in innovative capacity between 1980 and 1991. While this took some years to be reflected in improved international patenting (a phenomena common to many economies improving their innovation environment), steady increases in R&D expenditures with maintenance of educational levels lead to a steady but higher level of innovative capacity than in previous decades. An important driver for this was important improvements in Australia's economic productivity (as reflect in real GDP per capita growth) that resulted from sound macroeconomic policy and key microeconomic reforms.

The growth in Australian innovative capacity accelerated between 1991 and 1996. This improvement in the fundamentals of the Australian innovation environment was driven by a combination of interrelated factors. First, Australia experienced steady growth in R&D expenditures, GDP per capita and private sector R&D funding. Each of these drivers was an important consequence of key reforms to Australia's competition policy, increasing openness and other factors making Australia an attractive location for foreign investment. Further, though it is difficult to transform the R&D workforce of a national economy in the short term, the early 1990s saw a surge in Australian employment of research personnel. Finally, proactive policy change in intellectual property protection and other areas improved the perception of how conducive the Australian environment was for innovation. Together, a record of sound macroeconomic policy, microeconomic reform and openness, and an enhanced R&D workforce all contributed to Australia's ability to achieve second-tier innovator status by the mid-1990s. Finally, since 1996, by and large, growth in Australia's innovative capacity has levelled off. On one level, year-to-year fluctuations reflect short-term changes in the global economic environment (such as exchange rate variation and fluctuations in economic growth rates). However, at a more fundamental level, the acceleration in Australia's innovative capacity during the early 1990s has, to some extent, stabilised. Moreover, this stagnation in the growth of innovative capacity reflects a deteriorating environment on two bulwarks of the Australian system: higher education expenditures and a high level of university research performance. Since 1997, there has been a downward trend in both of these variables; in contrast, in most other advanced economies, these are exactly the measures where policy attention has been the most intense.[15]

[15] This is despite government initiatives like the *Backing Australia's Ability* set of programs. While some of these are designed to put in place long-term institutions to attract core researchers to Australian universities (i.e., the Federation Fellowships program) others have been highly specific projects for particular high technology areas. Consequently, the set of projects does not appear to have built into a persistent cycle of growth in innovative capacity. See West (2001) for a background analysis.

At the same time, Australia's recent stability reflects its status as a second-tier innovator. Whereas achieving second-tier innovator status was accomplished by upgrading on well-defined dimensions such as improvements in intellectual property policy, the key challenges facing Australia today rely on coupling the different aspects of the innovation system together in a more coordinated fashion.

For example, consider the "imbalance" between Australia's unique strengths in terms of R&D personnel and its sectoral distribution of R&D funding. **Figure 3-6** (compiled by the Allen Consulting Group) compares the distribution of Australian graduates across broad sectors compared with other countries. Whereas engineering graduates are the principal component of R&D manpower in most countries, Australia stands by itself as the *only* country where life sciences graduates dominate all other sectors. This difference in the composition of new entrants to the R&D workforce reflects an historical commitment to world-class life sciences university research and substantial investments in teaching capacity and effective curricula. However, the sectoral composition of R&D expenditures paints a quite different picture, particularly with regards to innovation and commercialisation activities (**Figure 3-7**). R&D expenditures are focused in the areas of engineering and software, and the overwhelming majority of investment is by the private sector. In

Figure 3-6

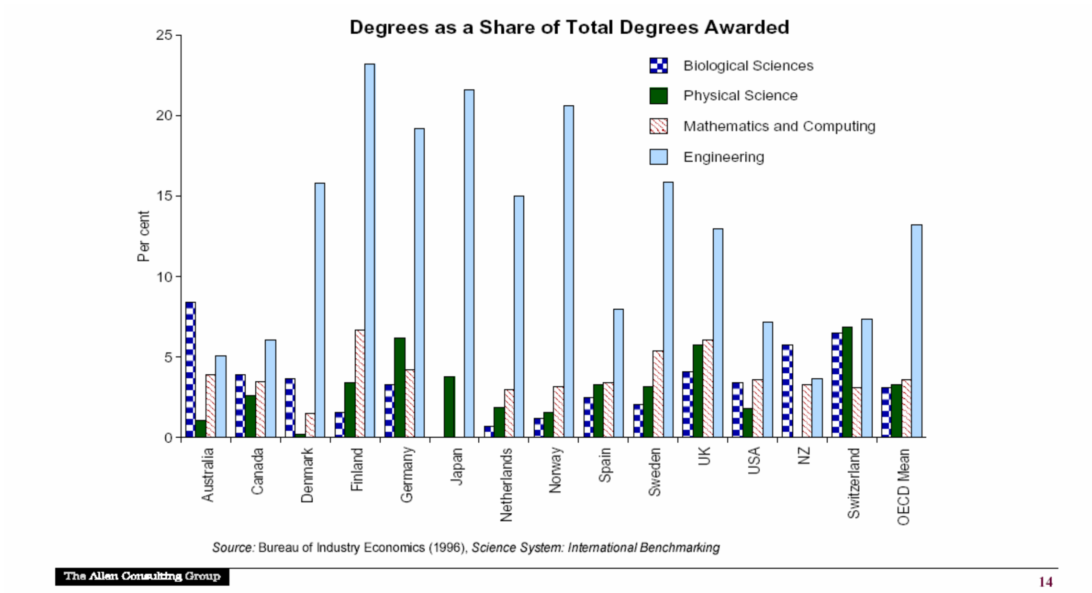
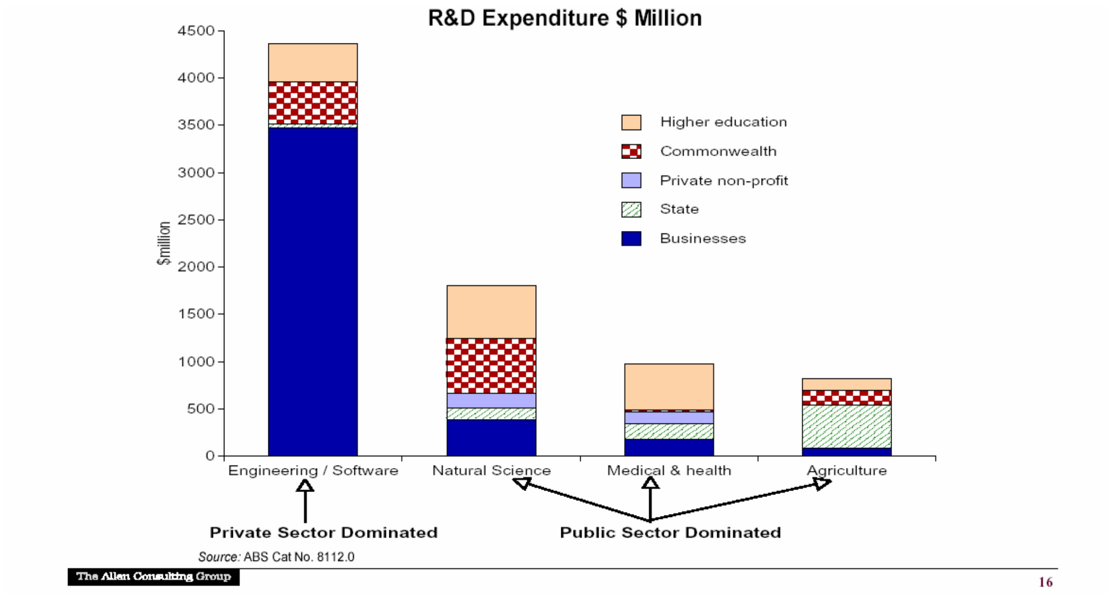


Figure 3-7



contrast, only a tiny fraction of private R&D investment is located in those sectoral areas more closely related to Australia's historical advantages and investments, such as agriculture and life sciences.

Policymakers may have been to ignore such imbalances during the period where Australia was developing its baseline innovation capabilities. However, the persistent mismatch between capital and labour investments may now be impinging on R&D productivity. Public sector investments are not effectively commercialised, while private sector R&D cannot draw upon local knowledge for global advantage. Enhancements to Australian innovative capacity going forward must be premised on a closer connection between public and private sector priorities. While Australia has improved its common innovation infrastructure and cluster-specific environment, Australia's challenge today is to reverse the decline of institutions central to the quality of innovation linkages across the economy and it must connect the investments in public sector basic research more closely with the innovation priorities of Australian clusters with an opportunity for global competitiveness.

3.3 Projecting Australia's Future

Finally, we use the Innovation Index formula to calculate the *projected* evolution of innovative capacity going forward, based on historical trends in investment and policy choices. In particular, for each country, we extrapolate each driver of innovative capacity to its level in 2005, assuming that the trend from 1990-2000 continues until 2005. We emphasise that rather than being a prediction, this calculation represents a projection of the likely evolution of innovative capacity in the absence of a shift in priorities, investments, or policies.

While such forecasts are inherently difficult, our projects indicate several interesting trends. **Figure 3-8** lists the Innovation Index and country rankings for 2005. For Australia, the index level grows grow but the relative rank remains flat. While personnel employed in R&D activities are projected to continue to grow, this enhancement is offset by the projection of a continuing decline in the share of national income devoted to higher education. A low rate of growth is a cause for concern insofar as other leading nations are investing more intensively in various facets of innovative capacity. For instance, while Australia is expected to still outrank New Zealand in 2005, that country is predicted to nearly double its innovative capacity rating between 2000 and 2005, in part because of its sustained investments in education and a supportive environment for industrial innovation.

Past efforts that have placed Australia as a second-tier innovator may be squandered as the innovative capacity of other second tier innovators continues to grow while Australia remains at a constant level. For example, Iceland, Finland and Denmark (whose 1980 innovative capacity levels were quite similar to Australia) are predicted to achieve first-tier innovator status over the next few years. The performance of Iceland, in particular, is striking; as recently as 1995, Australia and Iceland recorded a similar level of innovative capacity, but a gap between these two countries has grown since that time.[16]

As a comparison, the United States is also projected to face a decline in its innovative capacity, though the reasons are somewhat different. For the U.S., deterioration in innovative capacity is linked to the declining size of its R&D workforce and a very high rate of variation in its level of R&D investment activities. Long-term improvements in innovative capacity are facilitated by a self-sustaining and steady growth path rather than sporadic bursts of investment and policy activity. Indeed, though the long-term consequences are not yet clear, the backlash from the 1990s technology boom may undermine US leadership in innovative capacity in the future.

[16] This performance is in part due to Iceland's status within our dataset as an emerging nation. Removing this reduces Iceland's relative rank in recent times; although its improvement remains dramatic.

Figure 3-8: The Predicted Innovation Index in 2005

Country	2005 Rank	2005 Innovation Index
Sweden	1	258.0
Iceland	2	208.9
USA	3	204.9
Finland	4	198.8
Japan	5	186.3
Denmark	6	181.4
Switzerland	7	156.0
Norway	8	97.8
Germany	9	97.1
France	10	93.5
Ireland	11	91.1
Canada	12	84.8
Netherlands	13	84.2
UK	14	84.0
Belgium	15	81.4
S Korea	16	73.7
Australia	**17**	**63.9**
Austria	18	60.8
New Zealand	19	29.0
Greece	20	19.0
Spain	21	16.3
Czech Republic	22	15.3
Italy	23	14.9
Portugal	24	14.4
Slovak Republic	25	6.1
Poland	26	4.4
Hungary	27	2.3
Turkey	28	1.4
Mexico	29	1.4

As well, regional effects seem to be increasingly important in driving enhancements to innovative capacity. As a group, the Scandinavian nations are experiencing the highest growth rates in innovative capacity, a fact which has had a marked impact on patterns of international competitiveness and prosperity. Rather than luck or circumstance, the rise of companies such as Nokia reflects steady improvements in education, R&D resources and policy in Finland and the other Scandinavian countries.

In contrast, Australia is less connected to the innovative efforts of its neighbours. For example, while several East Asian nations such as Singapore and Taiwan have substantially enhanced their innovative capacity over the past decade, the key clusters in these countries are quite different than leading Australian clusters. Enhanced investments in the common innovation infrastructure, the innovation environment for clusters, and linkage mechanisms will be required for Australia to improve its innovative capacity position over the medium term.

4 Nurturing Australia's Innovative Capacity

Our analysis of Australia's innovative capacity indicates that macroeconomic stability, improved competitiveness in terms cost and quality, the diversification of Australian industry away from traditional sectors and the prime examples of burgeoning clusters (e.g., wine and biotechnology) have combined to provide a sound basis for future development and innovative potential. The key question is *how to build upon this capacity to turn Australia a world class innovator?*

Here we outline an innovation policy agenda for Australia that is informed by our analysis of innovative capacity across countries. Our purpose here is to provide some principles and examples that can illustrate how Australia might move forward rather than specific policy proposals per se.

4.1 Invest in the Common Innovation Infrastructure

The backbone of an effective innovation system is the national innovation infrastructure. In the absence of a well-trained pool of scientists, engineers, and entrepreneurs, or effective public policy towards areas such as intellectual property, the prospects for innovation-driven growth are low. As well, innovative capacity is especially sensitive to one or two areas of specific weakness; as a result, investments in the innovation infrastructure should be balanced along multiple dimensions, from investments in basic research towards the facilitation of openness to international competition and investment. With this in mind, the analysis suggests a few key priorities for Australian innovation policy going forward.

4.1.1 Human Capital

First, and perhaps most importantly, Australia must expand its efforts to develop **an effective pool of trained innovators**, including trained scientists and engineers as well as encouraging entrepreneurship and managerial training. While there has been a substantial growth in the number of scientists and engineers in Australia over the past decade, Australia still lags behind leading innovator economies, such as Japan, Finland, and the United Kingdom.

The decade-long decline in the share of expenditures devoted to higher education is particularly troubling in this regard. Had Australia maintained its historic share of expenditure on education, its innovation index in 2000 would have been *over 16 percent higher*. Such an improvement was predicted to shift Australia from the lower portion of second-tier innovators to the middle of this grouping.

Several specific initiatives can help Australia achieve growth over time in the proportion of the workforce with strong science and engineering backgrounds or who possess the strong problem-solving skills so crucial for innovation. First, though Australia is geographically remote, talented scientists, engineers and innovators increasingly compete in a global labour market. The "brain drain" of top R&D personnel needs to be arrested. The Federation Fellowships are a very positive step in this direction, and there is a strong case for encouraging those with scientific and technical backgrounds to remain in Australia on a broader scale. Such a policy might include specific tax incentives and educational subsidies (which we discuss further below). As well, by international standards, the wages for scientists and engineers whose compensation is under the authority of the government (e.g., most university and government laboratory researchers) is relatively low; given this imbalance, upgrading wages for government-funded researchers will place upward pressure on the relative wages for all Australian scientists and engineers.

Second, while scholarships encouraging postgraduate studies *within* Australia are an effective inducement, these programs may be enhanced in order to provide a more systematic foundation for global innovation. Specifically, while the Australian university system is excellent in many regards, the best scientific and engineering program for a particular student may often be international. In order for Australian companies and industry to produce global innovation, Australian researchers should be encouraged to received world-class training, whether this occurs at home or abroad. Top undergraduates should be encouraged to pursue graduate studies, but, particularly in those broad skill areas that contribute to cluster development, incentive programs should not be limited to Australian universities. An explicit focus on international training for scientists, engineers, and innovators has been a longstanding hallmark of the Finnish policy environment, and is often credited with helping Finland to develop an R&D personnel base that has allowed companies like Nokia to emerge on a global scale.

Third, substantial educational investment *across* society needs to be secured and enhanced. Development of universal problem-solving skills, maintenance of access to higher education and an improved commitment to postgraduate educational opportunities all have historically assisted in fostering the skills required for cluster development.

4.1.2 Risk Capital

Innovation carries a substantial level of risk relative to other investments, and the fruits of innovative investments are often only realised long after investments have been made. Therefore, for companies to take advantage of new technology and innovation prospects, the investment environment must be friendly to risky and long-term investment opportunities.

There are two policy priorities in this area. First, Australia must continue upgrading the effectiveness of its intellectual property system (and the business, legal and regulatory environment more generally). Given the substantial technical and market uncertainty associated with innovation, legal and/or regulatory uncertainty is an unnecessary and inefficient tax on corporate investment activities. While the precise scope of patent law and regulatory intervention may be debated, *uncertainty* about the scope of patent law or the extent of regulation reduces the ability to enforce policy once decided and discourages innovative investment.

Second, while an aggressive program of tax incentives seems to have been important in spurring Australian business R&D investment in the first half of the 1990s, business R&D investment has levelled off after a modest reduction in the tax incentives. In terms of generosity, Australia compares favourably with many (though not all) other nations in terms of R&D tax incentives. However, an effective R&D tax incentive system should attempt to maximise the benefits for each dollar of lost tax revenue. As such, ensuring a healthy supply of risk capital for innovation will benefit from a much more targeted tax incentive program. Similar to the recommendations of the Federation of Australian Scientific and Technological Societies (FAST), our analysis supports the idea of a "sliding scale" for tax incentives with higher tax incentives for those companies operating at a higher level of innovation investment intensity. As well, tax incentives should favour those companies who are undertaking cooperative research with universities, consortia or government-sponsored research centres. Targeted R&D tax incentives are likely to raise the effectiveness of this tax subsidy per unit of tax dollar foregone, and encourage innovation investment in areas that are most likely to result in global advantage for Australian industry.

4.1.3 Cumulativeness

Cumulative research is at the very heart of the process by which science and innovation investments contribute to the long-term growth of the economy. Rather than the technology or process developed by any one company at a point in time, economic growth and prosperity result from step-by-step progress by many innovators over time. Though the cumulativeness of research is often assumed by many policy analysts, policy plays a key role in determining the degree of cumulativeness across innovations.

Two issues stand out in this regard. First, for many companies, trade secrecy is a key mechanism for ensuring an economic return from innovation. While secrecy may be in the interest of an individual firm, secrecy reduces the powerful externalities and spillovers at the heart of innovation-driven regional economic growth. Enhancement to the intellectual property system to encourage the disclosure of new technologies and inventions, as well as facilitating standard-setting bodies that coordinate technical interfaces, can be effective elements in enhancing the degree of spillovers among companies and researchers within Australia.

Second, while the hallmark of scientific research is openness and disclosure, secrecy issues are playing an increasing role in scientific research projects with potential commercial application. Both government policy and scientific research societies must provide clear guidelines for ensuring that government-funded scientific research projects are adequately disclosed. This disclosure process should involve both timely publication of research papers reporting results as well as rules to provide access to materials or equipment required to build on prior research.

4.1.4 Innovation Policy

Finally, while the principal elements of national innovation policy largely reflect international "best practice," Australia must continue to expand its effort at establishing open markets, vigorous antitrust enforcement that supports innovative investment, and provide effective protection for intellectual property. As emphasised earlier, effective improvements in the Australian innovation infrastructure require balanced upgrading on multiple dimensions; areas of past strength should not be neglected when other areas become the focus of policy attention.

4.2 Encourage Cluster-Based Economic Growth

Cluster development is a key driver of innovative capacity, and crucial if Australia is to raise its innovative capacity to a world-class level. In the absence of domestic firms from interrelated industrial areas engaging in vigorous, innovation-based competition, the likelihood of any given firm achieving global leadership through innovation is remote. Moreover, an innovation-oriented cluster environment able to compete on global markets must have its foundations in the unique strengths and capabilities of the local economy. From the textile cluster in Northern Italy to the electronics clusters in Japan and Finland, traditional sectors serve as the foundation for clusters with global impact.

Policy towards cluster development must trade off two criteria. First, though clusters are a key element to innovation-driven growth, it is important to emphasise that appropriate government intervention must **avoid picking winners.** Successful cluster development must evolve according to market signals and individual firms should be protected against the pressure of competition from domestic or foreign firms. Conversely, the number of clusters in a particular location which can compete globally is limited by the size of the region and the stage of economic development. For small or medium-sized countries, most firms able to compete on a global scale will be drawn from a small number of key clusters. For example, Taiwanese success in the semiconductor industry reflects a deep electronics cluster, with little diversification to other high technology areas such as biotechnology. While the government must avoid picking winners, it must also **avoid imposing diversification**.

Effective public policy must incorporate both of these criteria. First, and perhaps most importantly, the foundations of dynamic clusters lay in the ability of investors and companies (both domestic and foreign) to direct financial and human resources towards those opportunities which can yield global competitive advantage. As a result, government-imposed barriers to entry or excessive regulation can hinder effective cluster development. As well, clusters can only nurture firms with the potential for global leadership by subjecting those firms to vigorous domestic competition; vigorous yet sophisticated antitrust enforcement ensures that no firm exploits market power at the expense of industry development.

Beyond providing a strong microeconomic environment from which clusters emerge, government can exert leadership and provide incentives for public/private partnerships through the establishment of institutions for collaboration. From basic research consortia to organised export groups, government can facilitate the process by which firms – competing vigorously in domestic and international markets on the basis of innovation – can nonetheless cooperate on shared priorities.

The logic of dynamic cluster development holds additional implications for Australian managers, investors and other stakeholders in Australian economic development. Though operational challenges and near-term tactical concerns often dominate managerial time and attention, global competitive advantage requires from strategic positioning within clusters that have the potential for world-class competitiveness.

The analysis in Section 3 offered some preliminary (though by no means definitive) evidence bearing on these choices. Relative to first-tier innovator economies, Australian innovation resources are out of balance. Despite unique historical strengths in life sciences, agriculture and mining, the majority of R&D investment by Australian companies is in the area of information technology. Moreover, the vast majority of these information technology investments are *inward-looking*, focusing on how to tailor global technology to the Australian context. Though such investments are clearly important and make sense when viewed in isolation, adaptation of global technologies to the local economy does not provide a basis for sustainable global advantage. Instead, Australia's historical advantages lie in the exploitation of natural resources and the development of a first-class university research system, with particular strength in the areas of agriculture and life science research. Though still at an early stage, the foundations for dynamic cluster development in these areas seems to be strong, particularly when compared to potential international competitors.

At the same time, for investors to nurture the development of Australian companies with the potential for global competitive advantage requires assessing the unique advantages of the Australian environment. In this regard, public R&D funds are most effective when **spurring complementary follow-on** private sector research and commercialisation investments.[17] Recent initiatives by firms within Australia's fledgling venture capital sector to focus on areas such as biotechnology reflect private sector leadership in spurring the exploitation of unique Australian capabilities. In other words, the choices of policymakers, managers, investors, and other stakeholders impact not only the near-term dynamics of an individual firm or program but can spur the development of dynamic clusters competing globally on the basis of innovation.

4.3 Foster Linkages

Though Australia's university system is an historical source of strength, Australia must upgrade its institutions that link the common innovation infrastructure to individual regional clusters. In many respects, enhancing the effectiveness of linkages is perhaps the most difficult area of innovation policy, as many of the most important functions served by linkages and even the institutions themselves depend on informal mechanisms and governance structures. For example, effective industry association boards tend to be those that are self-organised (rather than imposed by the government) and much of the knowledge flows facilitated by universities occurs through informal exchanges and networks. With these challenges in mind, we highlight a few specific areas for policy concern in this area.

First, universities must continue to upgrade their role as key linkages in the Australian innovation system. In leading innovator economies, the university system provides required training for a technically skilled labour force. It also undertakes "basic" research investments that serve as the **foundation** for a country's industrial clusters. Finally, by serving as a neutral broker within and among companies themselves, universities serve to serve as a knowledge hub through which spillovers are achieved. Though Australian universities have been historically isolated from industry and national innovation policy initiatives (relative to the US), they are today playing a key role in one of Australia's most promising clusters, the life sciences.

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[17] For example, Zmood Innovations – a Melbourne-based start-up company developing applications of Micro Systems Technology to printing systems, identification systems and medical diagnostic devices – has found new opportunities for domestic and offshore R&D precisely because of the development of complementary inputs. Their technology has potential applications in electronic systems as well as biosensors and other applications in medical devices. This start-up has been spurred on by two developments: First, another private company – MiniFAB – has invested in clean room facilities which are absolutely essential for start-ups like Zmood Innovations to use to fabricate working models of their devices. Second, the government has coordinated the Australian Synchrotron project; a key infrastructure development for scientific and technological applications in the fields of nano- and micro systems technology.

During the last several years, a number of excellent initiatives to enhance research grants encouraging linkage between industry and universities, as well as establishing Cooperative Research Centres to promote R&D performed by universities, have been implemented. While the broad outlines of these programs are excellent, there has been a tendency to micro-manage the process of funds disbursement and use.

R&D tax incentives may serve as a more decentralised solution. For example, a direct incentive for companies to engage universities in the research process would be to offer a greatly enhanced R&D tax credit for company funding of university research. In so doing, the process of interaction between universities and industries would be induced directly, and might focus industry attention on the potential benefits of working with university researchers. As well, joint research projects with universities are more likely to satisfy the criteria that the investments eligible for the credit themselves be truly innovative.

In addition to universities, Australia must encourage the development of other linkage mechanisms. For example, though often viewed simply as an investment fund, the fledgling Australian venture capital industry should explicitly seek out a linkage role in order to be successful. In the United States, venture capital serves not only as a source of funds but as a source of specialised expertise in managing the commercialisation of new technology and a network to enhance the commercial and social impact of a given innovation. As well, more active involvement by industry associations can play a critical role in raising the bar with aggressive quality standards as well as openness to new technologies.

4.4 Summary

In a global economy, innovation-based competitiveness provides a more stable foundation for productivity growth than the traditional emphasis on low-cost production. Having secured a position as a leading user of global technology and creating an environment of political stability and regional leadership, Australia has an historic **opportunity** to pursue policies and investments to establish itself as a leading innovator nation. Australia must build upon a foundation of openness to international competition and the protection of intellectual property rights. However, Australia needs to focus upon the areas that appear to have become neglected over the past two decades. In particular, Australia should significantly increase its investment in order to:

- Ensure a world-class pool of trained innovators by maintaining a high level of university excellence and providing incentives for students to pursue science and engineering careers

- Provide incentives and opportunities for the deployment of risk capital
- Facilitate innovation as a cumulative step-by-step process
- Continue to open up Australia to international competition and investment and upgrading the effectiveness of intellectual property protection
- Maintain a vigorous yet sophisticated approach to antitrust enforcement
- Reduce barriers to entry and excessive regulation that hinder effective cluster development
- Build innovation-driven dynamic clusters based on unique strengths and capabilities
- Enhance the university system so that is responsive to the science and technology requirements of emerging cluster areas
- Encourage the establishment and growth of institutions for collaboration within and across industrial areas.

Australia's innovation policy must be cohesive in order to create a favourable environment for private sector innovation. Rather than micro-management of individual projects or short-term schemes that do not necessarily fit within the overall plan, innovation policy must be consistent and allow markets and investors to ultimately choose where to deploy resources and capital for global innovation. Indeed, in the Australian context, high-technology investments may not be in what are conventionally regarded as high-technology industries, as Australia's key strengths build on historical advantages in primary industries. Ultimately, policy should not be judged on whether a particular company or industry flourishes but on whether, taken as a whole, Australian firms are increasingly able to develop and commercialise innovation for global competitive advantage and as a source of prosperity for Australia going forward.

5 Final Thoughts

At present, the bulk of the world's innovations are developed and commercialised by a relatively small number of top tier innovator economies. These nations have put themselves in that position through commitments to enhance and sustain innovative capacity within their country. In some cases, such as for the United States and Switzerland, top tier innovators have reaped the benefits of that position for decades. Other countries' emergence is more recent. For example, building on a decade of systematic policies to enhance innovative capacity, Finland has become a global leader in telecommunications innovation, simultaneously serving as the foundation for the competitiveness of companies such as Nokia and bestowing an important gift on other citizens throughout the world who benefit from that innovation as consumers.

Some have claimed that, as a relatively small and geographically remote economy, Australia need not invest in innovation but simply be content to adopt the best of global technology. We disagree. It is Australia's duty as a leading member of the world community to itself become an active contributor to the world's knowledge pool. As a prosperous nation, our payment for innovations developed by companies in other countries should be a reciprocal contribution ourselves. While individual companies invest in innovation to serve the interests of their investors and stakeholders, government investment in the innovation environment can be premised on ensuring Australia's appropriate place in the community of nations.

The role of the government is to ensure that the basis exists in Australia's innovative capacity by investing heavily on the three dimensions identified in this report – a common innovation infrastructure, the cluster-specific environment and the quality of linkages. We should not expect that Australia will become a leading innovator across all industrial area; instead, Australian strength in a few key areas can serve as the basis for international competitiveness and the source of Australian new-to-the-world innovation. Achieving this goal requires building on Australia's many areas of strength and undertaking proactive investments to address key areas of concern, from human capital development to the university-industry interface.

Appendix A: Econometric Methodology

This Appendix provides a brief, more technical review of the procedures underlying the calculation of the Index and includes the results from our regression analysis. We proceed by reviewing the procedures associated with each of the four stages of the analysis.

Stage I: Developing a Statistical Model of National Innovative Capacity

The first stage consists of creating the database of variables relating to national innovative capacity for our sample of 29 OECD countries from 1980 to 2000. This database is used to perform a time series/cross sectional regression analysis determining the significant influences on per capita international patenting and the weights associated with each influence. Variables, definitions, and sources are listed in Table A-1. Table A-2 lists the 29 countries in the primary sample. Finally, Table A-3 provides some summary statistics.

Data choices are discussed in Furman et.al. (2002). Importantly, the data draws on several public sources, including the most recently available data from the OECD *Main Science and Technology Statistics,* the World Bank, and the National Science Foundation (NSF) *Science & Engineering Indicators*. Where appropriate, we interpolated missing values for individual variables by constructing trends between the data points available. For example, several countries only report educational expenditure data once every other year; for missing years, our analysis employs the average of the years just preceding and following. The primary measure of innovative output employed in the Index is international patent output. The data are provided by the United States Patent & Trademark Office. For all countries except the United States, the number of patents is defined as the number of patents granted in the United States. Since nearly all U.S.-filed patents by foreign companies are also patented in the country of origin, we believe that international patents provide a useful metric of a country's commercially significant international patenting activity. For the United States, we use the number of patents granted to establishments (non-individuals) in the United States. To account for the fact that U.S. patenting may follow a different pattern than foreign patenting in the United States, we include a dummy variable for the United States in the regression analysis (the coefficient is however statistically insignificant). It is crucial to recall that patenting rates are used only to calculate and assign weights to the variables in the Index. The Index itself is based on the weighted sum of the actual components of national innovative capacity described in Section 2 and in Table B-1.

Table A-1: Variables & Definitions

VARIABLE	FULL VARIABLE NAME	DEFINITION	SOURCE
INNOVATION OUTPUT			
PATENTS $_{j,t}$	International Patents Granted by Year of Application	For non US countries, patents granted by the USPTO. For the US, patents granted by the USPTO to corporations or governments. To ensure this asymmetry does not affect the results we include a US dummy variable in the regressions.	USPTO patent database
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE			
FTE R&D PERS$_{j,t}$	Aggregate Personnel Employed in R&D	Full time equivalent R&D personnel in all sectors	OECD Science & Technology Indicators
R&D \$$_{j,t}$	Aggregate Expenditure on R&D	Total R&D expenditures in Year 2000 millions of US$	OECD Science & Technology Indicators
IP$_{j,t}$	Strength of Protection for Intellectual Property	Average survey response by executives on a 1-10 scale regarding relative strength of intellectual property	IMD World Competitiveness Report
ED SHARE$_{j,t}$	Share of GDP Spent on Secondary and Tertiary Education	Public spending on secondary and tertiary education divided by GDP	World Bank, OECD Education at a Glance
GDP/POP$_{j,t}$	GDP Per Capita	Gross Domestic Product per capita, constant price, chain series, US$	Penn World Tables GDP & population series.
GDP$_{j,t}$	GDP	Gross Domestic Product constant price, chain series, US$	Penn World Tables
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT			
PRIVATE R&D FUNDING$_{j,t}$	Percentage of R&D Funded by Private Industry	R&D expenditures funded by industry divided by total R&D expenditures	OECD Science & Technology Indicators
SPECIALISATION$_{j,t}$	E-G concentration index, excluding the US	Relative concentration of innovative output in chemical, electrical and mechanical USPTO patent classes	Computation from USPTO data
QUALITY OF LINKAGES			
UNIV R&D PERF$_{j,t}$	Percentage of R&D Performed by Universities	R&D expenditures performed by universities divided by total R&D expenditures	OECD Science & Technology Indicators

Table A-2: Sample Countries (1980-2000)

REGRESSION DATA FROM 1980-1998 INDEX CALCULATIONS FROM 1980-2000				
Australia	Finland	Ireland	Norway	Sweden
Austria	France	Italy	Poland	Switzerland
Belgium	Germany*	Japan	Portugal	Turkey
Canada	Greece	Mexico	Slovak Republic	United Kingdom
Czech Republic	Hungary	Netherlands	South Korea	United States
Denmark	Iceland	New Zealand	Spain	

Czech Republic, Mexico and Poland have index calculations from 1993, Slovak Republic from 1995

* Prior to 1990, figures are for West Germany only; after 1990 results include all Federal states

Table A-3: Means & Standard Deviations

VARIABLE	Observations	Mean	Standard Deviation
INNOVATION OUTPUT			
PATENTS	525	3113	9301
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE			
FTE R&D PERS	512	170431	356016
R&D $	507	13343	32652
IP	277	6.22	1.29
ED SHARE	499	3.09	1.02
GDP/POP	525	16418	5652
GDP	525	661	1256
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT			
PRIVATE R&D FUNDING	508	47.8	17.1
SPECIALISATION	523	0.152	0.126
QUALITY OF LINKAGES			
UNIV R&D PERF	516	25.4	12.5

An interactive dummy variable is also included to account for the low innovation base of several of the emerging countries. The coefficient is significant and is an area for future development.

The statistical model draws heavily on a rich and long empirical literature in economics and technology policy (Dosi, Pavitt, and Soette, 1990; Romer, 1990; Jones, 1998). Consistent with that literature, we choose a functional form that emphasizes the interaction among elements of national innovative capacity, namely a log-log specification between international patent production and the elements of national innovative capacity:

Table A-4: Innovation Index Regression Model

Dependent variable = L PATENTS

Coefficient (Std Error)

QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE	
L FTE R&D PERS	0.70 (0.10)
L R&D $	0.64 (0.08)
IP	0.066 (0.037)
ED SHARE	0.13 (0.02)
L GDP/POP	0.79 (0.18)
L GDP	-0.21 (0.07)
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT	
PRIVATE R&D FUNDING	0.014 (0.002)
SPECIALISATION	0.38 (0.27)
QUALITY OF LINKAGES	
UNIV R&D PERF	0.010 (0.004)
CONTROL VARIABLES	
US DUMMY	0.12 (0.09)
EMERGE DUMMY	0.027 (0.011)
YEAR EFFECTS	Significant
REGRESSION STATISTICS	
R SQUARED	0.972
NUMBER OF OBSERVATIONS	525

$$\begin{aligned}
&L\text{PATENTS}_{j,t} = \beta_0 + \beta_t \text{YEAR}_t + \beta_{USA}\text{USDUMMY}_j + \beta_{EMERGE}\text{EMERGE}_j * (\text{YEAR} - 1978) + \\
&\beta_{FTE} L\text{FTERESEARCHERS}_{j,t} + \beta_{R\&D\$}\text{LR\&D\$} + \beta_{IP}\text{IP}_{j,t} + \beta_{EDSHARE}\text{EDSHARE}_{j,t} + \\
&\beta_{GDP/POP} L\text{GDP / POP}_{j,t} + \beta_{GDP} L\text{GDP} + \beta_{SPEC}\text{SPEC}_{j,t} + \beta_{PRIVATER\&D}\text{PRIVATER\&D}_{j,t} + \\
&\beta_{UNIVR\&D}\text{UNIVR\&D}_{j,t} + \varepsilon_{j,t}
\end{aligned}$$

This specification is inspired by 4.4 of Furman et.al. (2002). It has several desirable features. First, most of the variables are in log form, allowing for natural interpretation of the estimates in terms of elasticities. This reduces the sensitivity of the results to outliers and ensures consistency with nearly all earlier empirical research (see Jones, 1998, for a simple explanation of the advantages of this framework). Note that the variables expressed as ratios are included as levels, also consistent with an elasticity interpretation. Second, under such a functional form, different elements of national innovative capacity are assumed to be complementary with one another. For example, under this specification and assuming that the coefficients on each of the coefficients is positive, the marginal productivity of increasing R&D funding will be increasing in the share of GDP devoted to higher education. Third, by using patents granted by date of application we do not need to impose a lag between the components of national innovative capacity and the measure of innovative output, international patenting.

Table A-4 reports the results from the principal regression. The coefficients on the variables are significant at the 10% level with the exception of the US DUMMY and SPECIALISATION. Consistent with prior research, the time dummies largely decline over time, suggesting a substantial "raising the bar" effect over the past 20 years (see Jones, 1998, for a discussion of declining worldwide research productivity).

Stage II: Calculating the Index

In Stage II, the Innovation Index was calculated using the results of the regression analysis in Stage I. The Index for a given country in a given year is derived from the predicted value for that country based on its regressors. This predicted value is then exponentiated (since the regression is log-log) and divided by the population of the country:

$$\text{Innovation Index}_{j,t} = \frac{\exp(\mathbf{X}'_{\mathbf{j,t}}\boldsymbol{\beta})}{\text{POP}_{j,t}}$$

To make our results comparable across countries, we included the U.S. DUMMY coefficient in the calculation. The issue of its inclusion or exclusion remains an area for closer examination in the future. We also included the SPECIALISATION and interactive EMERGE dummy variable. While refinement of these measures is an interesting area for future work, their inclusion or exclusion is not crucial for our key results concerning Australian innovative capacity.

Table A-5 provides the Index value for each country for each year. The Index, interpreted literally, is the *expected number of international patents per million persons given a country's current configuration of national policies and resource commitments*. It is important not to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process.

Stage III: Projecting the Index into the Future

The third stage of the analysis began by modelling the future evolution of each element of national innovative capacity for each country. For the policy measure of intellectual property protection, we assumed that the policy environment was maintained at its 2000 level. For the other variables, the projected value was set equal to its value for the last observed year (in most cases, 2000) plus an increment which depended on the trajectory of the variable in the country between 1991 and 2000. For the ratios such as education as a share of GDP, % of R&D performed by universities and % financed by industry we regressed each variable against a first order time term and used the resulting slope to project future changes from the last observed level. For the other variables, we regressed each variable on a first and second order time term, and then assumed that the resulting coefficients could be used to project future changes from the last observed level. This procedure can result in extreme values based on imprecise estimates, so we were careful to check our results against this possibility. Once these projected regressors were derived, the Index was recalculated following the procedure described in Stage II.

Table A-5: Historical Innovation Index 1980-2000

Year	Australia	Austria	Belgium	Canada	Czech Republic	Denmark
1980	20.6	24.4	28.5	49.5		24.5
1981	21.2	23.5	31.2	60.3		23.6
1982	20.9	21.6	31.9	57.3		23.7
1983	24.1	24.4	37.8	60.0		29.1
1984	25.4	22.3	36.1	57.1		30.6
1985	27.5	24.9	40.3	65.6		36.7
1986	27.4	27.7	42.6	59.8		40.7
1987	26.6	28.4	40.7	56.3		42.5
1988	27.6	27.5	37.4	54.2		41.5
1989	31.6	31.2	45.6	60.2		44.9
1990	29.7	27.9	41.8	53.2		46.5
1991	31.6	29.8	42.0	54.6		45.9
1992	32.5	28.9	37.0	52.2		46.8
1993	38.8	36.3	49.9	64.9	14.0	63.9
1994	45.8	42.6	56.9	73.9	18.1	72.3
1995	46.0	44.7	60.3	71.2	13.2	83.1
1996	52.8	46.9	60.7	73.7	13.4	96.1
1997	47.3	43.3	57.2	69.3	13.5	93.7
1998	43.0	48.6	60.4	65.8	15.4	103.6
1999	50.6	51.2	68.0	74.8	14.4	119.2
2000	50.9	52.4	75.1	81.4	14.5	116.3

Year	Finland	France	Germany	Greece	Hungary	Iceland
1980	28.2	50.4	74.8	0.5	31.8	10.5
1981	29.5	48.5	68.2	0.5	30.8	10.3
1982	29.5	44.9	60.9	0.6	27.1	11.1
1983	34.0	47.9	68.4	0.8	26.6	10.6
1984	36.0	44.5	64.8	0.8	23.4	11.8
1985	42.5	46.9	72.5	0.9	23.0	13.8
1986	46.5	47.7	78.7	1.0	22.2	14.9
1987	50.7	47.7	83.0	1.1	21.3	17.9
1988	53.7	46.4	77.2	1.2	17.2	19.9
1989	63.6	54.0	86.3	1.5	10.7	17.2
1990	57.0	52.9	80.5	1.6	11.2	15.5
1991	58.2	48.3	93.4	1.7	6.2	24.4
1992	51.3	53.5	88.3	2.0	5.2	19.8
1993	55.5	71.6	106.0	2.9	6.0	29.5
1994	66.3	78.2	108.3	3.9	4.8	26.6
1995	84.2	80.5	107.8	4.2	3.3	38.1
1996	98.6	82.6	105.8	5.3	3.0	57.6
1997	103.5	71.5	96.8	6.2	3.2	65.9
1998	121.2	75.3	99.2	7.0	3.3	90.1
1999	158.7	80.1	112.1	9.6	4.0	117.5
2000	173.1	77.6	109.5	12.0	5.4	130.7

* For 1980-1989, the index value is for West Germany only.

Year	Ireland	Italy	Japan	Mexico	Netherlands	New Zealand
1980	4.9	12.5	68.6		55.8	9.1
1981	4.5	13.2	92.0		48.0	9.3
1982	4.1	12.0	82.6		44.7	8.0
1983	4.7	13.7	107.8		47.4	8.3
1984	4.8	12.9	116.4		41.5	8.0
1985	6.0	16.4	132.2		48.8	8.5
1986	6.9	17.3	132.4		53.7	8.7
1987	7.5	19.0	135.1		55.7	8.8
1988	6.8	19.2	131.4		47.1	7.9
1989	8.2	19.1	134.0		49.0	8.5
1990	9.8	20.4	138.0		47.8	8.2
1991	12.1	20.0	147.2		43.4	6.6
1992	14.6	18.9	135.3		39.1	6.7
1993	17.8	19.8	182.1	0.4	48.8	11.4
1994	27.8	19.3	197.2	0.7	55.3	11.8
1995	33.4	17.1	188.1	0.5	61.5	14.3
1996	36.3	19.7	172.8	0.6	66.6	17.2
1997	42.3	19.2	161.6	0.7	57.6	19.1
1998	42.9	20.4	142.9	0.8	60.5	15.5
1999	50.4	20.2	167.4	0.9	67.1	16.8
2000	62.3	19.7	171.6	1.2	68.7	14.9

Year	Norway	Poland	Portugal	Slovak Republic	South Korea	Spain
1980	31.8		0.8		0.6	3.2
1981	32.3		0.8		0.8	2.8
1982	30.4		0.9		1.7	2.8
1983	35.2		1.0		2.3	2.9
1984	37.1		0.9		3.2	3.1
1985	45.6		1.2		4.3	3.4
1986	47.4		1.3		5.0	4.2
1987	47.0		1.5		5.9	4.6
1988	45.0		1.8		7.7	5.4
1989	44.6		2.0		10.7	6.2
1990	38.7		3.1		12.3	7.3
1991	38.9		2.4		14.3	8.5
1992	41.9		3.2		16.8	8.3
1993	51.0	2.1	3.8		22.7	9.3
1994	65.1	2.0	4.3		28.2	10.1
1995	67.6	2.4	4.9	4.4	35.9	11.1
1996	74.0	3.3	5.8	5.6	41.0	12.2
1997	71.9	3.2	5.9	5.1	36.6	11.5
1998	68.9	3.3	7.4	4.0	22.5	13.9
1999	75.4	3.9	9.5	3.6	29.9	15.3
2000	75.1	3.5	11.1	3.5	42.3	17.3

Year	Sweden	Switzerland	Turkey	United Kingdom	United States
1980	85.4	116.8	0.4	54.6	145.4
1981	87.4	106.7	0.4	56.1	157.2
1982	78.8	94.2	0.4	47.4	146.2
1983	85.6	101.9	0.5	48.0	173.9
1984	92.2	97.2	0.5	43.4	186.4
1985	103.6	103.7	0.5	45.5	205.7
1986	107.1	132.1	0.5	45.7	182.0
1987	106.5	133.2	0.5	45.0	156.8
1988	101.0	130.6	0.4	46.8	150.6
1989	106.8	152.4	0.3	45.7	154.0
1990	93.5	146.4	0.3	41.9	150.7
1991	94.3	138.6	0.4	38.0	152.0
1992	88.8	127.2	0.4	36.1	131.5
1993	107.5	159.5	0.4	44.1	170.9
1994	124.6	176.0	0.4	51.8	179.9
1995	150.0	176.9	0.4	53.5	170.5
1996	178.0	180.5	0.7	54.4	180.9
1997	153.8	154.6	1.0	57.4	180.2
1998	166.1	152.8	0.8	62.6	180.4
1999	194.3	155.4	0.9	72.7	197.5
2000	184.9	149.7	1.4	79.4	214.4

Appendix B: US Patents by Australian Organisation

	Organization	Patents Issued from 1997 to 2001
1	COMMONWEALTH SCIENTIFIC AND IND. RES. ORG.	153
2	SILVERBROOK RESEARCH PTY. LTD	127
3	CANON KABUSHIKI KAISHA	56
4	UNIVERSITY OF QUEENSLAND	42
5	EASTMAN KODAK COMPANY	36
5	UNIVERSITY OF MELBOURNE	36
7	ORBITAL ENGINE COMPANY (AUSTRALIA) PTY. LTD.	34
8	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.	31
9	UNIVERSITY OF SYDNEY	29
10	RESMED LIMITED, AN AUSTRALIAN COMPANY	28
11	AUSTRALIAN NATIONAL UNIVERSITY	19
12	CANON INFORMATION SYSTEMS RES. (AUS) PTY LTD.	18
12	TECHNOLOGICAL RESOURCES PTY, LTD.	18
14	AMRAD CORPORATION LIMITED	17
14	LUDWIG INSTITUTE FOR CANCER RESEARCH	17
16	BIOTECH AUSTRALIA PTY LIMITED	16
16	TELSTRA CORPORATION LIMITED	16
18	COMALCO ALUMINUM LIMITED	15
19	GENE SHEARS PTY. LIMITED	14
20	AUSTRALIAN MEMBRANE AND BIOTECH. RES. INST.	13
20	USF FILTRATION AND SEPARATIONS GROUP INC.	13
22	BHP STEEL (JLA) PTY. LTD.	12
22	SOLA INTERNATIONAL HOLDINGS LTD.	12
22	UNISEARCH LIMITED	12
25	COCHLEAR LIMITED	11
25	IMMULOGIC PHARMACEUTICAL CORP.	11
25	SRP 687 PTY LTD	11
25	WOMEN'S AND CHILDREN'S HOSPITAL	11

– Note: Shading indicates universities and research institutions
Source: US Patent and Trademark Office (www.uspto.gov). Author's analysis

References

Adams, James (1990). "Fundamental Stocks of Knowledge and Productivity Growth," *Journal of Political Economy,* 98: 673-702.

Ambramowitz, Moses (1956). "Resource and Output Trends in the United States since 1870," *American Economic Review,* 46: 5-23.

Ben-David, David and Michael B. Loewy (1997). "Free Trade, Growth, and Convergence," NBER Working Paper No. W6095.

Burton, Lawrence and Linda Parker (1999). *The Education and Employment of Engineering Graduates.* Arlington (VA): National Science Foundation, forthcoming.

Bush, Vannevar (1945). Science: *The Endless Frontier.* Washington (DC): Government Printing Office.

Dosi, Giovanni, Keith Pavitt and Luc Soete (1990). *The Economics of Technical Change and International Trade.* New York (NY): Columbia University Press.

Eaton, Jonathan and Samuel Kortum (1996). "Trade in Ideas: Patenting & Productivity in the OECD," *Journal of International Economics,* 40 (3-4): 251-278.

Furman, Jeffrey, Michael E. Porter and S. Stern (2002), "The Determinants of National Innovative Capacity," *Research Policy*, 31, pp.899-933.

Gans, Joshua, David Hsu and Scott Stern (2002), "When Does Start-Up Innovation Spur the Gale of Creative Destruction?" *RAND Journal of Economics* Vol.33, No.4, pp.571-586.

Gans, Joshua and Scott Stern (2002), "Managing Ideas: Commercialization Strategies for Biotechnology," *Working Paper*, IPRIA (www.ipria.org).

Gans, Joshua and Scott Stern (2003), "The Product Market and the Market for 'Ideas': Commercialization Strategies for Technology Entrepreneurs," *Research Policy*, Vol.32, No.2, pp.333-350.

Griliches, Zvi, ed (1984). *R&D, Patents and Productivity.* Chicago (IL): Chicago University Press.

Griliches, Zvi (1990). "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature,* 92: 630-53.

Griliches, Zvi (1994). "Productivity, R&D, and the Data Constraint," *American Economic Review,* 84: 1-23.

Grossman, Gene and Elhanan Helpman (1991). *Innovation and Growth in the World Economy.* Cambridge (MA): Harvard University Press.

Helpman, Elhanan. (1997) "R&D and Productivity: The International Connection," NBER Working Paper No. W6101.

Jaffe, Adam (1986). "Technological Opportunity and Spillovers from R&D: Evidence from Firms Patents, Profits and Market Value," *American Economic Review.*

Jaffe, Adam and Manuel Trajtenberg (1998). "International Knowledge Flows: Evidence from Patent Citations," NBER Working Paper 6507.

Jones, Chad (1998). *Introduction to Economic Growth.* New York (NY): W.W. Norton & Company.

Nelson, Richard, ed. (1993). *National Innovation Systems: A Comparative Analysis.* New York (NY): Oxford University Press.

Pavitt, Keith (1980), "Industrial R&D and the British Economic Problem," *R&D Management*, Vol.10.

Porter, Michael E. (1990). *The Competitive Advantage of Nations.* New York (NY): Free Press.

Porter, Michael E. (1998). "Clusters and Competition: New Agendas for Companies, Governments, and Institutions," *On Competition.* Boston (MA): Harvard Business School Press.

Porter, Michael E. and Claas van der Linde (1995). "Towards a New Conception of the Environment- Competitiveness Relationship," *The Journal of Economic Perspectives,* 9(4).

Porter, Michael E. and Scott Stern (1999). "Measuring the 'Ideas' Production Function: Evidence from International Patent Output," mimeo, MIT Sloan School.

Porter, Michael E., Scott Stern and the Council on Competitiveness (1999), *The New Challenge to America's Prosperity: Findings from the Innovation Index*, COC: Washington.

Romer, Paul (1990). "Endogenous Technological Change," *Journal of Political Economy,* 98: S71-S102.

Romer, Paul (1994). "New Goods, Old Theory, and the Welfare Costs of Trade Restrictions," *Journal of Development Economics,* 43: 5-38.

Romer, Paul (1996). "Why, Indeed, in America? Theory, History, and the Origins of Modern Economic Growth," *American Economic Review,* 86(2): 202-206.

Rosenberg, Nathan (1963). "Technological Change in the Machine Tool Industry, 1840-1910," *Journal of Economic History,* 23: 414-443.

Rosenberg, Nathan (1982). *Inside the Black Box: Technology and Economics.* Cambridge (UK): Cambridge University Press.

Rosenberg, Nathan and L.E. Birdzell, Jr. (1987). *How the West Grew Rich: The Economic Transformation of the Industrial World.* New York (NY): Basic Books.

Sakakibara, Mariko and Michael E. Porter (1998). "Competing at Home to Win Abroad: Evidence from Japanese Industry," Harvard Business School *Working Paper* 99-036.

Schmookler, Jacob (1966). *Invention and Economic Growth.* Cambridge (MA): Harvard University Press.

Schumpeter, Joseph (1943). *Capitalism, Socialism, and Democracy.* Second Edition, George Allen & Unwin, London (GB).

Solow, Robert M. (1957). "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics,* 39: 312-20.

Stern, Scott, Michael E. Porter, and Jeffrey L. Furman (1999). "Why Do Some Countries Produce So Much More Innovative Output than Others? Determinants of International Patent Production," mimeo, MIT Sloan School.

Neel, A. and J. Hii (1998). "Innovation and Business Performance: A Literature Review," *mimeo.*, Judge Institute of Management Studies, University of Cambridge.

Suarez-Villa, Luis (1990). "Invention, Inventive Learning, and Innovative Capacity," *Behavioral Science*, 35: 290-310.

Suarez-Villa, Luis (1993). "The Dynamics of Regional Invention and Innovation: Innovative Capacity and Regional Change in the Twentieth Century." *Geographical Analysis*, 25 (2): 147-164.

Trajtenberg, Manuel (1990). "Patents as Indicators of Innovation," *Economic Analysis of Product Innovation.* Cambridge (MA): Harvard University Press.

West, Jonathan (2001), "The Mystery of Innovation: Aligning the Triangle of Technology, Institutions and Organisations," *Australian Journal of Management*, Vol26, pp.21-43.

Data Sources

CHI Research, Inc. Haddon Heights, NJ.

DRI/McGraw-Hill, *World Markets Executive Overview,* 2nd quarter 1996.

IMD, *The World Competitiveness Yearbook,* Lausanne, Switzerland. 1997.

International Finance Corporation, *Emerging Markets Data Base Factbook,* Washington, DC. 1987-1996.

International Monetary Fund, *Balance of Payments Statistics Yearbook.* 1979-1996.

National Bureau of Economic Research, Penn World Tables, www.nber.org.

National Science Board, *Science & Engineering Indicators,* Washington, DC. 1987, 1991, 1993, 1996, 1998.

National Science Board, *Science Indicators,* Washington, DC. 1974, 1976, 1978, 1980, 1982, 1985.

OECD, *Educational Statistics in OECD Countries,* Paris, France. 1981.

OECD, *Health 97* database, Paris, France. 1998.

OECD, *Main Science and Technology Indicators,* Paris, France. 1998 vols 1 &2; 1997 vols 1 & 2; 1996 vol 2; 1995 vol 2; 1993 vol 2; 1992 vol 2; 1990 vol 2; 1989 vol 2; 1988 (1982-1988) vol 2; 1987 (1981-1987).

Petska-Juliussen, Karen and Egil Juliussen, T*he 8th Annual Computer Industry Almanac,* Computer Industry Almanac, Inc. 1996, Austin, TX.

UNESCO Statistical Yearbook. 1993, 1994, 1995, 1997.

United Nations, *National Accounts Statistics: Main Aggregates and Detailed Tables,* 1993--Part I.

World Bank internal sources (World Development Indicators staff).

The World Economic Forum, *The Global Competitiveness Report 1997,* Geneva, Switzerland.

The World Economic Forum and IMD, *The World Competitiveness Report,* Switzerland. 1993, 1994, 1995.