The Mystery of Innovation:
Aligning the Triangle of Technology,
Institutions and Organisation

by
Jonathan West
1. Introduction

In this paper I want to draw together some insights from researchers investigating the sources of firm-level innovation, to provide a basis for understanding the strengths and weaknesses of Australia’s national innovation system as it has developed over the last century. I will do this by synthesizing seven key conclusions from the rapidly growing body of studies of the drivers of innovation, which together offer the potential to ground policy-making in the experience of successful innovating nations. I will emphasize findings that have been well established by multiple empirical studies, rather than those that are interesting anomalies with little generalizability, or only those that accord with established theory, and then make some observations about Australia’s innovation system in light of these statements, taking that system’s capacity to support commercial innovation in the life sciences as a reference point.

I will focus on what we know about how to do it (how, that is, to promote business innovation), and will not rehearse the by now tired arguments about whether technological innovation is desirable or necessary at all, or whether it is legitimate for government to ‘intervene in the market’ to promote innovation. Suffice it to note that the economic history of the last 10 years has shown quite convincingly that nations that succeed in promoting innovation have dramatically outperformed those that don’t, achieving superior wealth creation, productivity increase, and living-standard improvement.

The ability of economic researchers to offer any such insights at all is actually quite new. Until recently, academic economists could suggest disappointingly little to policy makers when asked for advice about how to build an effective national innovation system. They usually mumbled something about ‘investing in education’ (which always carried with it an unfortunate smack of the self-serving when coming from academics) and ‘getting the prices right.’ Economic theory focused on the mechanisms that enable an economy to achieve equilibrium, and on how the price system can make economy-wide resource allocation efficient. Empirical research looked overwhelming outside the firm, at the behaviour of markets, and most policy advice simply assumed that if the market-based incentives could just be ‘gotten right’, then firms—usually pictured as black boxes responding more or less automatically to external stimuli—would become innovative. By their very nature, these approaches looked more to issues of stability and optimisation within existing technological and resource parameters, than to the deliberate shifting of those parameters. Yet the latter activity could be taken almost as a definition of innovation (Lazonick & West 1998).

Over the last two decades, however, significant new academic research has accumulated on the issues involved with national innovation systems, and several important conclusions can now be drawn. Fortunately for the researchers, not all of these conclusions are obvious, and insights from this work might therefore help guide policy makers in otherwise unsuspected directions, or at least provide a more productive context within which discussion about action proposals can take place.

1. I use the phrase ‘well established’, rather than, for example, ‘proven’ or ‘demonstrated’, since the inherently non-repeatable nature of historical experience means that little in social science—indeed very little beyond tautologies—can be certain to apply to the future policy-making.

2. What is a ‘National Innovation System’?

To begin with, it is necessary to make clear the sense in which I will employ the term ‘innovation’. A workable definition for the present purposes is: ‘the processes by which firms master and get into practice product designs and manufacturing systems that are new to them’ (Nelson 1993). Note that this definition looks beyond ‘invention’, to the full commercialisation and market introduction of new ideas, that it includes both products and the processes that produce them, and that it does not limit innovation to being the very first to bring a new idea into the world.

A national innovation system can, in turn, be described as the ‘set of institutions whose interactions determine the innovative performance, in the sense above, of national firms’ (Nelson 1993). These institutions go well beyond the behaviour of factor and product markets—essentially the determinants of price—to include political and social institutions, labour training and employment norms, laws governing financial markets and taxation, education, patent law, publicly sponsored research, as well as culture, history, and values (North 1990). In essence, a national innovation system mobilizes and allocates resources, and manages the risk needed to undertake technological advance.

Use of the term ‘system’ should not be taken to imply that the complex interaction among these elements is either planned or has been created deliberately by anyone. Indeed, in most successful countries, such overall planning has either been deliberately eschewed or proven infeasible in practical terms. Nonetheless, all successful countries have acted to shape these factors, and some (Singapore, Taiwan) have implemented far-reaching efforts to create favourable institutional climates (Swee 1995).

Any characterization of national innovation systems must be built on an understanding of how technical advance actually happens in the modern world, the key actors and processes involved, and the demands technological advance places on these actors. Most important technological advances are nowadays associated with various fields of science, which train the personnel involved, structure their ongoing interactions, and provide critical inputs of new ideas. Thus, understanding how science works in various countries is an essential underpinning. Second, innovation, in the form discussed here, takes place mostly through firms, which organise the innovation projects, fund them, and decide which ones to pursue, and which not to. Thus, understanding characteristic forms of corporate organisation, and the norms governing interaction among firms and between firms and their personnel (i.e. financial, product, and labour markets), is also essential. And both the institutions of science (universities, public research facilities, and national funding bodies) and firms are regulated and structured by government. Hence, understanding the roles played by government is vital.

But the processes these actors employ to innovate are structured by the demands of the innovation process itself. Technological advance (as distinct from commercial innovation) today proceeds primarily through dedicated R&D facilities, staffed by university-trained scientists and engineers, and funded by firms, universities, or government agencies. The creation and maintenance of these facilities, and their personnel, is thus a central consideration in any national innovation system.

The relations between science and innovation are complex, however, and vary not only from field to field, but from nation to nation. In the first place, the
direction of causality is not linear. In some instances, new science gives birth to new technology, and commercial innovation. This is the simplest picture, and the one advocates of more spending on science and education usually have in mind. Here, innovation is seen as the commercialisation of inventions made in scientific labs, and it follows that an important emphasis of policy ought to be to encourage researchers to pursue ‘relevant’ research and to develop mechanisms to take inventions through to commercialisation. Failure in this series is often seen as a key problem in Australia, including by the last Labour government, which placed great emphasis on making science more commercially relevant. Just as often, however, commercial innovation gives impetus to new science, or draws upon existing science in ways its originators had no way to foresee.

Serendipity thus plays an irreducible role in the relations between science and innovation. Innovations often spring from applications of science that are quite unexpected by their original scientific discoverers. In addition, rather than originating from science, new technologies often themselves precipitate new science, aimed at understanding more deeply what has been observed to work, and improving it. Often, a real production process is not simply a scaled up version of lab procedures, but an entirely new process, itself the result of considerable scientific and engineering work. A modern drug production process, for example, especially in biotechnology, is not a scaled-up version of the laboratory glass tubes and reactors in which discoveries were originally made. Such scaling up is neither technically nor economically feasible. A new process must be invented.

An innovation system must therefore be as much about supporting demand for science, as creating supply of it. The vehicles for science-based innovation will as often be existing companies looking for solutions to their product or production problems, as new companies created to commercialise discoveries. The degree to which one or other side of this equation dominates varies by industry, field of science, and country.

But no matter how strong the science, innovation always demands experimentation. Once problems have been identified and defined, whether on the supply side by engineers or scientists or on the demand side by marketers, a set of potential solution options must then be assembled, and some means must be brought to bear to test the options, eliminating those with less likelihood of success. Almost never can commercial innovators be assured in advance that all the elements will fall into place: that the projected technology will work as expected, a market will be found for it, and the managerial and technical personnel involved in attempting to bring it to market will prove capable of meeting the myriad challenges likely to be experienced in the attempt. Innovation is always, therefore, both ‘inefficient’ (activities must be undertaken that will probably fail, and yield little or no value) and risky.

The intensity and location of risk varies by industry and technology. In some sectors, the technology is very likely to work as expected, but finding a sufficiently large market for it will be the problem. This is true, for example, in much of the internet. In others, a market will probably be found, but whether the technology will work, or can be feasibly scaled up, is problematic. This is often the case in drug development.

Sustaining both the science and the efforts of organisations to commercialise new technology thus demands the concentration of considerable resources, at
substantial risk, over often lengthy periods of time. A national innovation system must therefore include some means to mobilize these resources, some means to allocate them to risky undertakings, and some means to assess the progress of the innovation projects, and cut those with unacceptably low prospects of success.

Critical to management of risk is almost always diversification. Once all possible efforts have been made to reduce risk by careful option consideration and management selection, the only known way to manage intense risk is to diversify it: to pursue a basket of multiple undertakings, of different kinds, in the hope that the successes will more than offset the inevitable failures. Sometimes such a diversified portfolio is managed within an existing company, in the form of a portfolio of projects; other times it is managed through a portfolio new companies, as in the case of venture capital firms. However much careful attention these organisations pay to selection, ultimately, they must rely on diversification.

The result of these considerations is a triangle, the elements of which must be aligned to build an effective national innovation system. Organisations (firms, not-for-profits, government-sponsored agencies) must align their activities with institutions (including laws and norms regulating how the business game is played), and with the inherent process of technological innovation itself. Thus, all successful national innovation systems include some way to mobilize and sustain risk investment, some means to manage that risk, usually through diversification, some means to create science-based options, and some means to conduct experimentation, whether through public agencies, existing firms, or the creation of new ones. These demands are created by the nature of the innovation process itself, but each demand of innovation can be met in different ways. Many choices are possible. Which exact combination is adopted by any successful national system will depend on its specific history, culture, and values.

Table 1
Three National Innovation Systems: The United States, Japan, Singapore

<table>
<thead>
<tr>
<th>Investment Mobilization</th>
<th>US</th>
<th>Japan</th>
<th>Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low domestic savings; capital import</td>
<td>High domestic savings</td>
<td>Very high savings; government forced</td>
<td></td>
</tr>
<tr>
<td>Capital Allocation &amp; Risk Management</td>
<td>Capital markets; venture capital</td>
<td>Corporate retained earnings; banks</td>
<td>Government; government-linked corporations</td>
</tr>
<tr>
<td>Basic Research Location</td>
<td>Universities; government-sponsored labs</td>
<td>Large corporations</td>
<td>Government-sponsored labs</td>
</tr>
<tr>
<td>Commercialisation Path</td>
<td>Start-up-venture capital-IPO</td>
<td>Large corporation or spin off within keiretsu</td>
<td>Sell to foreign-owned MNC; government-linked companies</td>
</tr>
<tr>
<td>Professional Labour Market</td>
<td>Broad and deep</td>
<td>Narrow and shallow; lifetime employment</td>
<td>Developing</td>
</tr>
<tr>
<td>Primary Value-Capture Mechanism</td>
<td>Equity; intellectual property</td>
<td>Production; Corporate earnings</td>
<td>Wages; some taxes</td>
</tr>
</tbody>
</table>
The study of innovation reveals many ways to fail, but, more surprisingly, also more than one way to succeed. Table 1 above, illustrating in schematic form characteristic dimensions of the innovation systems of three successful nations, shows some of the combinations that are possible.

3. **Seven Key Findings: How Successful National Innovation Systems are Built**

Investigation of how individual companies align their operations with the demands of the technology development process and these elements of their institutional context, in different national settings, can help us understand the demands of successful national innovation system construction. Without burdening the reader with voluminous references to what is now a substantial literature, we can draw the following seven significant conclusions:

3.1 **All elements of the system must be present, and structured to complement one another, or little benefit may be gained.**

Many researchers have observed that a national innovation system is not simply a list of ‘good’ policies or institutional structures, the more of which are enacted, the more innovation is obtained. Rather, they are coherent systems in the full sense of that word. With, say, four out of five elements of an effective system, a nation does not gain 80% of the benefit, but, often, none. If one leg of the tripod is broken, it falls. Moreover, it is not feasible to mix and match elements more or less at random, combining the best from here with the best from over there. What works well in combination with one set of elements may not work at all with others.

A successful national innovation system is more like the concatenation that enables birds to fly, each part of which provides no benefit alone, or even a detriment, and which gains advantage only when all elements are present. In order to fly, birds need wings, feathers, light bones, broad tails, and rapid metabolism. Taken alone, any element of this system would disadvantage the creature possessed of it. But together, they bring the magic of flight.

My own work on the dynamics of innovation in the global semiconductor industry provides an example of this, which is worth outlining in a little depth. I found that characteristic business organisation in Japan and the US had evolved along divergent paths, with each element of technology, institutions, and organisational form supporting each other, to form very different systems. The differences I observed are summarized in table 2:

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The two key factors in the semiconductor industry that underpinned these differences in practice appeared to be the structure of markets for university-trained labour and the operation of national research systems.

As many researchers have noted, Japanese enterprises frequently extend ‘permanent employment’ rights beyond management and shareholders to technical and shop-floor workers. As a consequence, the market for professional labour in Japan remains thin and shallow. Japanese firms typically induct university-trained personnel only upon graduation from university or college (Westney & Sakakibara 1986), and, for all practical purposes, do not recruit such personnel later in their careers. Only in unusual circumstances would university-trained personnel later in their careers find themselves available to join another firm, nor, typically, would any of the Japanese firms I interviewed seek to hire such personnel. While some erosion of this system has been reported in recent years, and Western firms in Japan have hired professional employees mid-career, this system remained largely intact in the opening years of the 21st century. By contrast, a vigorous labour market exists for such personnel in the US. US firms not only enjoy the opportunity to recruit already trained and experienced personnel, but such personnel increasingly anticipate that career mobility will form an essential part of their professional development.

Allied with this contrast in employment norms are important differences in the skill-formation systems of the US and Japan. The US higher education system produces considerably more Ph.D.-level graduates than does the Japanese system (Lynn, Piehler & Zahray 1988). Japanese firms expect to train employees themselves, or to sponsor external training; US firms assume that skills acquisition is mostly an individual responsibility. Japanese firms can afford to invest in the skills of employees because they can be more confident of retaining those skills over time, and thus gaining the benefit of their investments (Lynn, Piehler & Kieler 1993). In turn, the relative underdevelopment of the graduate-level higher education system obliges them to do so.

These differences mean that, in Japan, managers can select organisational strategies that assume continuity of employment; they cannot adopt approaches that require recruitment of already-skilled employees. US organisations face an inverse choice set. They cannot assume continuity of employment, especially of manufacturing employees; they can recruit already highly trained engineers and scientists.

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### Table 2

**US and Japanese Development Organisational Practice**

<table>
<thead>
<tr>
<th>Skills Acquisition and Retention</th>
<th>Japan</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Scope and Leadership</td>
<td>Loose</td>
<td>Tight</td>
</tr>
<tr>
<td>Program Guidelines and Timing</td>
<td>Implicit</td>
<td>Explicit</td>
</tr>
<tr>
<td>Task Partitioning</td>
<td>Distributed</td>
<td>Focused</td>
</tr>
<tr>
<td>Resource Allocation</td>
<td>Decentralized</td>
<td>Centralized</td>
</tr>
<tr>
<td>Experimentation Capability and Practice</td>
<td>Low-Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
These contextual factors seem to explain the observed differences in practice. Why do Japanese organisations, for example, distribute personnel and experimentation resources more evenly among multiple subunits, and not emphasize formal project-specific teams, with employees dedicated to a single process generation? I think the answer lies in guaranteed employment continuity, which allows Japanese firms to pursue an experience-based approach to knowledge creation and problem-solving. Employment continuity also facilitates deeper organisational socialization in Japanese firms, enhancing communication and coordination. Japanese employees report that they develop strong relations with other employees of the same firm over many years, and are deeply familiar with each other’s work style. This understanding improves communication and reduces problems of inter-functional and inter-discipline knowledge transfer. Both these effects were claimed to be stronger when the engineers had worked together as a group for longer. Paradoxically, therefore, it may be that stronger organisation-specific integration and socialization make teamwork easier, but formal team structures less necessary. The result would be that Japanese organisations experience less need for project-team-type organisation, and less need to bring resources and personnel together under a single organisational roof.

While characteristic Japanese employment practices may bring these advantages, however, they also constrain the options available to Japanese organisation builders. Japanese managers reported that it would be difficult for Japanese organisations to introduce new personnel from outside, even if such personnel were available, discouraging reliance on externally sourced skills. The relative weakness of the Japanese graduate-education system, especially at the Ph.D. level in physics and electrical engineering (in contrast to its strength at the high school level) further encouraged Japanese firms to pursue an experience-based strategy.

US organisation builders work within a different set of institutionally shaped constraints and opportunities. Confronted by the need to improve their capabilities in the mid-1980s, many US firms opted in the late 1980s to move away from their former functionally and discipline-divided mode of organisation. This mode had produced cost overruns, time delays, and lower-quality products. But the US firms were simultaneously less able to build experience-based strategies and more able to access high-quality personnel in the labour market. In the US context, with fluid markets for highly skilled labour and strong professional bonds, most firms could not assume that they would maintain a deep experience base over the long term. Even the strongest firms, such as Intel and IBM, risked loss of key personnel in the event of a dip in the company's fortunes.

This context creates an environment favouring professional socialization over organisational socialization. US employees in the semiconductor industry are often more integrated into their professions as electrical engineers, solid-state physicists, or semiconductor specialists, than into their current employers. Shallower organisational integration compounds communication difficulties. US organisations commonly report problems building communication across internal organisational boundaries, functional and discipline-based, problems which were widely believed to have precipitated the delays and cost overruns that damaged the US firms' competitive position in the mid-1980s.
The shift to project-based dedicated teams in the 1990s, described in my study, helped the US firms solve these problems. This dynamic was encouraged by the ease with which US firms could recruit already highly trained personnel. The successful firms, especially, could relatively easily hire well-educated scientists and engineers, either directly from the strong US graduate-school Masters and Ph.D. programs or from other firms. These personnel were well trained in designing and executing experiments and possessed strong knowledge of scientific fundamentals in relevant fields, but often lacked on-the-job experience. These teams became increasingly central to the process-development effort, and were allocated a greater proportion of both problem-solving responsibility and resources, personnel and experimental. Thus, key elements of the US organisational mode—its focus on experimentation, tight project teams, and centralized resource allocation and task partitioning—were all ultimately encouraged by the labour market constraints and opportunities within which US managers made their choices.

In sum, institutional context incentives and constraints can explain the observed differences between Japanese and US organisational practice, especially those related to skills acquisition, project-team organisation, task partitioning, resource distribution, and experimental capability concentration, and each element of the system dovetailed with the others. In neither country could pieces of the others’ system simply be grafted on.

3.2 Non-profit making institutions must sponsor factor creation in knowledge.

This is one of the best-established results in this field. As long ago as 1962, economics Nobel Prize winner Kenneth Arrow showed that a ‘competitive system’ (by which Arrow meant a freely functioning market) will fail to achieve ‘an optimal resource allocation in the case of invention’ (Arrow 1962). Arrow showed that a free market, left to its own devices, will allocate less resources for invention (which he defines as the production of knowledge; importantly, not the commercialisation of invention) than would be desirable. The essential reason is that individual participants in a fully competitive market cannot capture sufficient returns to justify bearing the risk. Arrow concluded that:

‘…for an optimal allocation to invention it would be necessary for the government or some other agency not governed by profit-and-loss criteria to finance research and invention. In fact, of course, this has always happened to a certain extent. The bulk of basic research has been carried on outside the industrial system, in universities, in the government and by private individuals…’

‘One could go further. There is really no need for the firm to be the fundamental unit of organisation in invention; there is plenty of reason to suppose that individual talents count for a good deal more than the firm as an organisation. If provision is made for the rental of necessary equipment, a much wider variety of research contracts with individuals as well as firms and with varying modes of payment, including incentives, could be arranged. Still other forms of organisation, such as research institutes financed by industries, the government and private philanthropy, could be made to play an even livelier role than they do now.’

And, indeed, all successful innovating nations have found some mechanism for supplementing the predicted under-investment by private firms in research and
Many, of course, provide generous funding to universities; Japan and other East Asian countries have created mechanisms, such as the keiretsu and lifetime employment, that do allow firms to capture the benefits of riskier basic research. Even this may not be enough, however, and a weakness of the Japanese system may well turn out to be its reliance on US and European basic research.

A recent large-sample statistical study appeared to confirm Arrow’s prediction (Furman, Porter & Stern 2001). The study examined the innovation outputs of 17 industrialized countries, and related these to a variety of resource and contextual factors. The results were unambiguous, government resource commitment, especially to education and research, as well as policy, mattered a great deal:

“We find that while a great deal of variation across countries is due to differences in the level of inputs devoted to innovation (R&D manpower and spending), an extremely important role is played by factors associated with differences in R&D productivity (policy choices such as the extent of IP protection and openness to international trade, the share of research performed by the academic sector and funded by the private sector, the degree of technological specialization, and each individual country’s knowledge ‘stock’).”

The study noted that between two-thirds and 90% of the overall variation in innovation (measured by patent output) was explicable by measures of R&D expenditure and total economy size, and a 1 percentage point increase in the share of resources going to higher education increased the output of innovation by 11%. Significantly, the study found that “countries with a higher share of their R&D performance in the educational sector (as opposed to the private sector or in intramural government programs) have been able to achieve significantly higher patenting productivity.” This was especially true of those countries that had increased their performance most:

“Each of the countries that have increased their estimated level of innovative capacity over the last quarter century—Japan, Sweden, Finland, Germany—have implemented policies that encourage human capital investment in science and engineering (e.g. by establishing and investing resources in technical universities) as well as greater competition on the basis of innovation (e.g. through the adoption of R&D tax credits and the gradual opening of markets to international competition).”

3.3 To make these investments, and to support new innovative sectors, the economy must mobilize substantial investment resources, and devote these to inherently risky undertakings in preference to other potential investments.

While innovation can certainly drive economic growth, it is by no means synonymous with it. A more ‘efficient’ way to raise economic growth may be to apply known and well-understood technologies to existing industries. The problem with this approach, however, may be that growth then tapers off when the nation reaches the technological frontier. To enter sectors at the technological leading edge—characterized by both high growth and high value added—may require that investment be directed deliberately into areas of considerable risk, at least during the industry’s early years.

The example provided by Taiwan’s construction of a semiconductor industry is instructive. Taiwan’s semiconductor industry began late, in 1977. By any measure, Taiwan’s decision to enter semiconductors seemed risky. In the late
1970s, the semiconductor industry was already dominated by powerful global companies, based in the United States and Japan, and seemed headed for a battle between these two for survival. Most industrial research was concentrated in these two countries, as was education in the technology, and markets. The prospects for successful entry by a relatively distant, much poorer, entrant did not look good.

By 2000, however, Taiwan’s industry had emerged as the world’s third largest, in production behind only the US and Japan, but ahead of Korea, and rapidly closing the gap. The industry had driven Taiwan’s productivity and living standards increases for almost two decades, growing at a cumulative average over 10% per year. How was this dramatic success achieved? One important factor was resource mobilization. Taiwan’s savings rate averaged about 30% of GNP between 1969 and 1997, and household saving over the same period averaged more than 20% (net household saving in Australia has been around 2%, and in recent years has actually turned negative). To gain such high savings rates, something had to give. And indeed it did. To marshal these resources, the Taiwanese government had to push down private consumption. Consumption as a share of Taiwanese GDP dropped from 74% in 1952 to 47% in 1987 (Scott 2000).

But not only were savings and investment high, they were deliberately encouraged to focus on this risky, but potentially highly lucrative, sector, at least until Taiwan’s firms in the sector could stand on their own feet. The Taiwanese government established a focused venue for the industry, Hsinchu Science-based Industry Park, and encouraged firms to move there. Although the small firms were privately owned, they received many inducements to enter the semiconductor industry: attractive terms for setting up a business, taxation allowances, low interest loans, matching R&D funds, and special exemptions from tariffs, commodity and business taxes. All this cost substantial sums of money, and ate up the country’s savings. But the government went much further. It also established the Industrial Research Institute, with a 1996 budget of US$1 billion and 6000 employees, 75% of whom were researchers and 500 of whom were Ph.D.s. The agency is charged with importing and developing relevant technology, and then licensing it to private firms.

The Taiwanese government also provided venture capital for the first semiconductor firms, United Microelectronics Corporation and Taiwan Semiconductor Manufacturing Corporation (TSMC), and went into joint venture to ensure TSMC was sustained (Mathews, Cho & Cho 2000). Only after 15 years of government absorption of risk and government input of resources did the first substantial private capital enter the industry. Significantly, this public sector support came direct from the government; there was no protective tariff to force customers to finance it. By 1995, Taiwan had 12 semiconductor fabs, with sales of about US$3.3 billion. By 2000, that number had jumped to US$17 billion, or approximately 5% of Taiwanese GNP.

3.4 When entering new industries, some means must be found to diversify away risk, often over very long time frames.

The example above indicates the scale of resource mobilization and commitment required to enter entirely new innovation-based industries. Risk must be assumed, and managed. Every successful national innovation system has developed a broad and effective risk management approach. All involve a mechanism for diversifying
risk, but at least three different approaches have been shown to be successful at the national level, in different contexts.

Most new businesses create a ‘me-too’ product or service, incurring little risk (Bhide 2000). They start small and remain small, although they can provide a prosperous life to an individual entrepreneur. Table 3 shows the most common new businesses by industry in the United States:

**Table 3**

**Most Popular Start-Ups in the US, 1996**

<table>
<thead>
<tr>
<th>Type of Business</th>
<th>Number of Start-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>24,787</td>
</tr>
<tr>
<td>Restaurant</td>
<td>22,781</td>
</tr>
<tr>
<td>Retail Store</td>
<td>21,081</td>
</tr>
<tr>
<td>Cleaning Services (residential, commercial)</td>
<td>19,642</td>
</tr>
<tr>
<td>Real Estate</td>
<td>17,549</td>
</tr>
<tr>
<td>Automotive Services &amp; Repair</td>
<td>16,158</td>
</tr>
<tr>
<td>Consultant</td>
<td>13,835</td>
</tr>
<tr>
<td>Beauty Salon</td>
<td>11,762</td>
</tr>
<tr>
<td>Computer Service &amp; Repair</td>
<td>11,111</td>
</tr>
<tr>
<td>Designer</td>
<td>10,676</td>
</tr>
<tr>
<td>Management &amp; Business Consulting</td>
<td>9,665</td>
</tr>
<tr>
<td>Arts &amp; Crafts</td>
<td>9,412</td>
</tr>
<tr>
<td>Painter</td>
<td>9,156</td>
</tr>
<tr>
<td>Lawn Maintenance</td>
<td>8,498</td>
</tr>
<tr>
<td>Marketing Programs &amp; Services</td>
<td>8,314</td>
</tr>
<tr>
<td>Landscape Contractor</td>
<td>8,268</td>
</tr>
<tr>
<td>Investment Broker</td>
<td>8,206</td>
</tr>
<tr>
<td>General Contractor</td>
<td>8,137</td>
</tr>
<tr>
<td>Communications Consultant</td>
<td>8,022</td>
</tr>
<tr>
<td>Building Contractor (remodelling, repair)</td>
<td>7,998</td>
</tr>
</tbody>
</table>

Note: Sourced from County Data Corporation, cited in Bhide, p. 50.

Being relatively low risk, but with modest growth prospects, most such ventures are funded from personal resources, or from family and friends, Figure 1 below shows the sources of funding for start up companies in the US:
While small, ‘me-too’ firms are numerous, they often have a relatively short average life span, and contribute little to the growth of a modern capitalist economy. The typical entrepreneurial firm that grows into a large-scale, and sustainably successful, firm, is somewhat more risky, though not initially larger scale. Most such firms take several years to define a niche in which they might be considered to have a distinctive competence, and during that period their customers are implicitly agreeing to share the risks involved. Most such companies succeed based upon out-hustling others with similar ideas, though obviously develop rapidly based on distinctive ideas (Apple, Hewlett-Packard). Such firms have traditionally had to live for 5-8 years or more before they would have any competence that would merit formal venture funding, and are also often financed with a combination of personal assets and aggregated friends-and-family assets.

For larger and riskier undertakings, sources of capital that appear small in the overall picture gain much greater importance. Such ventures usually require funding beyond the resources of almost all individuals, almost certainly beyond those of the individuals who come up with the novel ideas, are much more risky, and frequently require much longer time frames before ideas come to fruition. To cope with such demands, entrepreneurs must turn to investors who can diversify risk.

The three main vehicles for such investment are venture capital and private investors, large corporations, including banks, and government. At the early stage, formal equity and debt markets—the stock and bond markets—play a negligible
role. Such markets primarily serve the function of enabling the entrepreneur to monetize their investment, and withdraw funds from it, through an Initial Public Offering.

Different national innovation systems emphasize one or other of these vehicles for entrepreneurial risk diversification. While all approaches are employed in most countries, the particular mix and emphasis chosen for performing this role is one of the defining characteristics of different national innovation systems. To summarize a large body of literature: US and ‘Anglo-Saxon capitalism’ typically relies more on venture capital; European ‘welfare-capitalism’ relies more on government and banks; and Japanese ‘keiretsu-capitalism’ relies more on large corporations (Berger & Dore 1996; Dore 2000).

3.5 The structure of risk and reward will influence which risk management system is optimal.

Just as individual businesses seek different funding sources, depending upon their risk profile, so must efforts to develop new industry segments. The larger and more risky, the broader will the funding body have to be able to diversify its positions. Figure 2 characterizes four types of new business entrants according to their initial and potential scale, on the horizontal axis, and their initial risk, on the vertical axis, with arrows indicating their desired growth trajectories.

**Figure 2**

**Risk and Scale in New Business Development**

![Figure 2](image-url)  

**Note:** Adapted from Amar Bhide, The Origin and Evolution of New Business.

The majority of new businesses fall into a category in the lower left hand corner: they involve relatively low risk, but offer the potential for only little growth. They require only small-scale funding, with a fairly predictable return. Some ‘me-too’ businesses begin at similar scale but involve a new way of doing business (suggesting somewhat more risk) and grow to become substantial enterprises. Information-technology businesses nowadays begin somewhat larger, that is, they
require more initial funding, and are more risky than ‘me-too’ businesses. Life science businesses often require substantial funding over more years than either information-technology or ‘me-too’ businesses, and are much riskier. They can, however, potentially deliver the greatest returns (the pharmaceutical industry, for example, is regularly listed as the world’s most profitable business).

Important, however, is not only the average probability (or improbability) of success, and the potential payoff, but also the profile of risk. Almost all ‘me-too’ businesses will make at least some return for investors, even if the average return is modest. Most information-technology businesses will yield at least some revenue, and many will be at least marginally profitable, even if few are enormously so. In life science, however, the overwhelming majority of investments will yield no return at all. Some, however, will be enormously profitable, driving the average beyond any other industry.

Perhaps even more important for investment allocators is the type of risk that must be managed. All innovation project contain three basic types of risk: technical risk (whether the product, process, or service will actually perform the intended function), market risk (whether a sufficiently large market can be found for the product), and managerial risk (whether the organisation attempting to innovate either has or can assemble the leadership team required to bring the innovation to fruition). Most venture capitalists attempt to remove, or substantially reduce, technological risk before undertaking an investment. Discussions between technological entrepreneurs and venture capitalists usually begin with ‘proof of concept’: evidence that the device, software program, or service actually works.

Venture capitalists are experts at managing market and managerial risk; they are rarely qualified to understand or deal with technical risk. In the fields in which venture capital has flourished, information technology, software, and telecommunications, it is usually possible to demonstrate at the outset that the proposed concept is feasible and practical, at least in principle. The underlying physics and engineering is usually well characterized. In life science, once technical feasibility is established—once it is established, for example, that the molecule cures cancer with no undesirable side effects—commercial success is virtually assured. Most life science projects and life science start-ups come into being precisely to determine whether the concept will work technically. The underlying science is not well understood, and must be established through experimentation. Thus, in life science, potential investors confront irreducible risk of all three kinds.

The implication is that to manage risk in different sectors, particularly life sciences, investments must be diversified wider, and the total portfolio must be larger. Information-technology investing requires a wider diversification than most ‘me-too’ investing, given the sums required per investment and the success probability, but not as wide as life-science investing. Information-technology entrepreneurial investing is usually within the scope of venture capital funds, or large corporations. In life sciences, with ‘hit rates’ as low as 1 in 20, and minimum investments becoming very large (to take a potential drug through all phases of development, for example, now costs more than US$400 million) the required size and diversification of portfolio is beyond all but the largest firms. A portfolio of only 20 projects at US$400 million each would require a commitment of US$8 billion. For the riskiest end of life sciences—technologies based on brand new genetic discoveries—investment is usually beyond the reach of all but the very
largest firms, or government. It is not surprising, then, that even in the US, only approximately five venture capital funds specialize in biotechnology, and the proportion of venture capital investment in biotechnology has actually declined over the last 10 years.

3.6 While innovations typically improve an economy’s overall productivity, they can do this by either enhancing or destroying existing industries.

A key conceptual insight in recent study of innovation has been that while most innovations do eventually succeed in raising economy-wide productivity, this outcome can be achieved in distinctly different ways. Innovations can be classed as either sustaining or disruptive (Christensen 1997). Sustaining innovations add to the productivity and competitiveness of existing companies and industries; disruptive technologies undermine existing companies and their industries.

Viewed from the perspective of national economies, this distinction can be critically important. For large and diversified national economies, such as that of the United States, the distinction is important for incumbents in particular industries, but for the economy as a whole it presents mainly problems of adjustment (which of course can be painful), from declining sectors to a growing ones.

For small nations such as Australia, the distinction might be much more important. With an economy concentrated in particular sectors, and especially a concentrated export portfolio, it is vital to understand whether potential technological innovations will be sustaining or disruptive. The two great technological revolutions transforming global industry, and which make up the epicentre of innovation, will impact Australia’s industry quite differently. While information technology holds the promise of raising productivity in a wide range of industries—although a live debate continues as to whether it has actually done so yet—biotechnology will likely be a powerful industry destroyer.

Information technology promises to cut the costs of processing information and undertaking transactions. Since such costs affect virtually every industry, information technology will probably eventually raise productivity in many of those in which Australia concentrates, especially if Australia can continue to afford to adopt it.

Biotechnology, however, promises substitute products for many of Australia’s strengths. A common misunderstanding is that biotechnology is essentially about new drugs. While it is true that these techniques will help deliver new medicines, they also will likely transform the basis of several other industries: industrial materials, energy, agriculture and food, and defense. Gene manipulation offers the potential to develop biologically derived substitutes for the raw materials and intermediates that feed the production processes of these industries.

This being so, any nation that limits itself to the role of consumer will be marginalized—and impoverished—within the global economy.

3.7 In non-replication intensive industries, most of the value is captured by equity owners, not wage earners.

In the past, nations could capture the value of most innovations in the form of wages and taxes, by ensuring that production activities took place within their
borders. In the knowledge-based industries that drive contemporary industrial innovation, however, little value is captured as wages. This is because in several key technologies replication of a product design—that is, manufacturing and service delivery—is increasingly trivial, and unskilled. Value is concentrated in the original design. Once one copy is perfected, making millions more poses little challenge, and merely captures value for the design owner, either intellectual property owner or equity owner.

Consider computer software. Developing the first version of a computer program is highly skilled work, time consuming, and usually well paid. Once the ‘design’—that is, the code—is perfected, replicating it is trivial. Copying the program to disks or distributing it over the Internet utilizes little labour. More and more industries are looking like software: intellectual property is where the value is concentrated. Table 4 shows the proportion of value added captured by wages in several representative industries:

<table>
<thead>
<tr>
<th></th>
<th>Wages</th>
<th>Net operating surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Economy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precision Engineering</td>
<td>67%</td>
<td>6%</td>
</tr>
<tr>
<td>Specialty Chemicals</td>
<td>67%</td>
<td>9%</td>
</tr>
<tr>
<td>New Economy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk Drives</td>
<td>24%</td>
<td>58%</td>
</tr>
<tr>
<td>Computers</td>
<td>11%</td>
<td>89%</td>
</tr>
<tr>
<td>Life Sciences</td>
<td>7%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Note: Sourced from Commerce Department.

The implication of this chart is that in the technologies in which innovation is concentrated, and which drive global economic growth and productivity advance, it is not sufficient to rely upon serving as an attractive base for the operations of foreign-owned corporations. In the past, a strategy of this type could assume that much value would be captured locally from the presence of foreign investment through wages. But that is less and less the case. These numbers are reflected in figures for value added per employee, which show that in precision engineering valued added was US$53,000 per employee; in electronics US$112,000 per employee; and in financial services US$159,000 per employee.

Unless a national innovation system is capable of developing local entrepreneurship (equity ownership) and intellectual property control, the vast majority of value created by investment in innovation will flow out of the economy. Moreover, the substantial social investments in education and infrastructure required to attract foreign investment in technologically sophisticated industry will not be recouped by wages and taxes alone, as they might have been in a past economy dominated by replication-based industries like precision engineering, automobiles, and specialty chemicals. In the absence of a capability to capture
equity and intellectual property value locally, such investments will become less and less rewarding, and more and more difficult to justify, seducing the country to fall further behind.

4. Implications for Australia’s National Innovation System and a Proposal for Promoting Australia’s Life Science Industry

These seven conclusions suggest far-reaching for Australia’s national innovation system as it enters its second century. Australia’s system grew up in a very different context than it now faces, and it seems ill prepared for the new challenges. Consideration of how Australia’s system is positioned with respect to each of the conclusions shows significant lacunae in key elements.

1. All elements of the system must be present, and complement one another.

Australia’s resource mobilization is poor, and its capital allocation and risk management systems show bias against technological innovation. Large corporations invest little in R&D, and few technologically innovative companies are formed or grow to substantial size. The result is a broken national innovation system. Exploration of the remaining six elements will illustrate in what ways.

2. Non-profit making institutions must sponsor factor creation.

Australia is one of the very few nations worldwide, and perhaps the only developed country, that appears actually to have reduced its commitment to higher education and publicly sponsored research over the last decade. It is estimated that Australia stripped A$5 billion from its government spending on innovation and education in the second half of the 1990s, far more than the A$2.9 billion that is promised to be returned under the current federal innovation strategy. Australia has little or no tradition of non-government, not-for-profit sponsorship of research, particularly outside of medicine. If Australia is to rely on a market-oriented, entrepreneurship-based model of technological innovation, as it espouses, then the majority of academic studies and theory suggest that basic research and education must receive higher not lower priority.

Only in national systems in which private companies can capture the rewards of education and investment—that is, in which there are not free markets for technically sophisticated labour and intellectual property—can investment by public agencies be reduced. Australia is much closer to the US in this respect than it is to Japan, yet it does not even match, let alone surpass (as it should if it is in ‘catch up’ mode) US investment in education and research.

3. The economy’s institutions must mobilize substantial resources for investment in innovation, and must ensure that those investments are sustained over substantial periods of time.

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Australia has one of the lowest personal savings rates in the world, saves little or nothing through government, and yet also maintains one of the highest corporate pay-out ratios in the world (i.e. its corporations save and invest relatively little through retained earnings). To substitute for these deficiencies, Australia relies upon imported capital to meet its investment needs, paying the long-term price in terms of its declining exchange rate, foreign debt ratios, and surrender of asset control.

4. Some means must be found to diversify away risk in new industries. Australia’s large corporations are not structured to support long-term highly risky investments because they are not sheltered (as are many East Asian corporations) from shareholder demands for payout. Government in Australia is unwilling to bear risk by ‘socializing’ it, that is, diversifying it across the entire community. Australia espouses a free-market-oriented model, which suggests a reliance on venture capital—securities markets can never undertake this kind of investment activity.

Yet venture capital in Australia is both small and notably averse to technological risk. Of the A$4.9 billion in total venture capital in Australia as of 30 June 2000, only 5% was invested in the country’s strongest technological sector, biotechnology. This total venture capital for the entire Australian economy amounts to less than is invested in the American suburb in which I live, Cambridge, Massachusetts.

5. The structure of risk and reward will influence which risk management system is optimal.

In spite of the weaknesses in its macro structure, Australia does not have a problem with too little entrepreneurship overall. Its rates of new business formation are roughly in line with those of other developed, Anglo-Saxon capitalist type economies, and sufficient financial resources seem able to be mobilized to keep this rate going. But most of these new businesses, like those in all the developed world, are small, low-growth potential, ‘me-too’ start-ups. These will not bring the kind of growth, innovation, and productivity improvement Australia will need to remain in the forefront of the global economy.

Australia’s difficulties arise in those few, but vitally important, new enterprises that must begin larger, and assume more risk. Australia’s weaknesses in capital allocation and entrepreneurial risk management constrain these ventures, often forcing them off shore.

6. Innovations can be sustaining or disruptive.

Australia’s leadership appears to have been assuming that it can prosper by being a world-class consumer of technology. This approach rests on the assumption that technological advance will be productivity enhancing in existing industries, that is, will be sustaining. But experience in the United States has shown that about one-half of economy-wide productivity advance is actually located in the computer and information technology industries themselves, and that there has been as yet little overall flow-on to other sectors. Some speculate that information technology may stimulate more

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demand for information than it satisfies, thus not raising productivity, in the same way that computers did not lead to the predicted ‘paperless’ office, but in fact stimulated demand for paper, by making it easy to use.

Equally as disturbing for Australia, many of the sectors in which its industry, especially its exports, are concentrated are vulnerable to the development of substitute products from biotechnology. The world’s largest chemical company, Du Pont, for example, has an internal slogan: ‘From Hydro-Carbons to Carbohydrates’. The company aims ultimately to replace its vast line of petrochemical-based materials and fibres with alternatives grown by microbes, animals, and plants. Much of the innovation likely to come in the next decades will be disruptive, and Australia is ill prepared to meet it.

7. In non-replication industries, value is captured through equity and intellectual property ownership.

Australia’s assumption that it can rely on the import of technology, as an attractive place for multinationals to do business, ignores the issue of equity and intellectual-property ownership. Yet the trends indicate that non-replication industries will dominate growth.

What can be done to stimulate a more effective national innovation system for Australia’s second century? I will conclude this discussion with a modest proposal for augmenting existing arrangements, in line with Australia’s unique history, culture, and challenges. I will not make yet another plea for more factor creation and investment in education and research. While that is certainly necessary, I will address primarily the resource allocation and risk management issue, without which all other elements of an otherwise effective system would fall.

As noted, Australia does not have a problem of lack of entrepreneurship or shortage of start-up companies. Its rate of new business formation is, on average, about on par with that of other developed countries. Nor does it lack resources. By any measure, Australia remains a wealthy country with ample latent capital to support technology and new business formation.

Australia’s problem lies in the system for mobilizing and allocating resources to inherently risky technological innovation, and in managing the ensuing risk. These problems are intertwined: it is more difficult to mobilize and allocate resources when risk cannot be managed, and returns ensured with a reasonable probability. Let’s examine the kind of national institutional system that would be required to finance the three types of firm identified earlier: ‘me-too ++’ firms (firms with potential to develop a distinctive approach and grow to become large, over about 5-8 years); information-technology firms; and life science firms. In all three instances, I propose strategies to reduce the real risk faced by investors by using government to socialize (diversify) risk, without thereby incurring the problems of direct government allocation of risk capital or management of firms.

Australia is well on the way to developing the capability to finance the ‘me-too ++’ firms. Venture capital concentrates on these firms, and significant support is available through government agencies. Perhaps this sector could be further encouraged by promoting the availability of subsidized loans through commercial banks. It would be desirable to require 51% Australian ownership, and limit the scale of such loans to, say, A$50 million. A government agency could take, say, half of any losses from default, thus limiting the downside risk of the lenders, while
allowing investors to keep the upside winnings. Such as scheme is unlikely to have substantial impact on start-up information technology or life science ventures, however, since the risks are probably still too high for them to justify fixed rate loans.

I have outlined below a second line of financing, based upon promoting venture capital as contrasted to bank lending (fig. 3). In this scheme, the venture capitalist shares in the upside, and can accept greater risk, hoping for perhaps one real hit in 10. Venture capitalists are rewarded differently than lending officers at banks, and attract different people. In my suggested scheme, government would make loans to specific designated venture capital investment funds (not directly to firms), accepting a single digit rate of return on these funds, thus allowing private investors to keep more than their proportionate share of any upside gains. Fund managers then pick which small firms to back, subject to the fact that they would have to be 51% Australian owned, and be part of the knowledge-based economy, however that may be defined for this purpose. Individual start-ups might thus be expected to look for backing from more than one VC fund, as shown in the chart. Each such fund would have to keep a designated minimum fraction of its investments in Australian firms, with the remainder diversified as it sees fit. These percentages might be adjusted by the authorities from time to time as conditions indicate (i.e. the percentage invested in Australia might be expected to rise as Australia establishes more of a private technological innovation culture).

**Figure 3**

A Possible Risk Management Framework for the IT Sector

The life sciences would seem to require a different scheme. Here the risks are so high, and of such a type, that there is little private venture capital involved even in the US. At the same time any such ventures are likely to require substantial sums of money. This seems to me to be a case in which private markets are very unlikely to accept the risks involved, and government must take the lead if Australia is to capture any of the returns to ownership. Australia has already launched a number of modest supporting investment programs at universities, and several state governments are actively promoting factor creation in the sector.
All of this makes sense, but the economy-wide capital allocation and risk management system is a crippling gap. A state-owned enterprise, such as that created by the Taiwanese government to kick-start its semiconductor sector, may be the only way to get such an activity underway in the foreseeable future. Most important is that it should be managed as a firm, not a bureaucracy. It should be able to take risks, and accept some inevitable project failures, if it is to succeed. It should be operated to build an effective business enterprise, not to advantage consumers (a practice which apparently cripples Telstra, for example). The eventual aim would be to take it private, as a world-class life-science firm.

Australia already has some precedents for such an undertaking, as do Europe and several of the most successful East Asian innovators, including Singapore and Taiwan. The novelty of this proposal is not in the corporate structure or in the lead role of government, it is in the risks involved and the time frame of the potential payoff. These risks need to be made explicit, and carefully considered. Surely, any such venture would need to be prepared for some ‘bumps’ along the way; it will be a long time before it could be expected to fund its project portfolio in large measure from its own cash flow. As with any ‘adolescent’, there would need to be expected standards of performance, and some accountability to others.

In summary, Australia’s national innovation system, as it has developed in the century since Federation, is characterized by critical gaps: in its ability to mobilize resources, its system for allocating investment to innovation, and—most significantly—its institutions for managing the risk of science-based innovation. To build a position as a knowledge-based economy, Australia needs to innovate in value capture as well as value creation. Australia has the skills, organisational capabilities, and financial resources to do so. With sufficient commitment, it could build an institutional system capable of turning those resources into sustained innovation, and into the prosperity and work satisfaction that.

References


