Education and Innovation Theme

Increasing Innovation Through Government Policy
February 2013

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Over the past three decades, questions related to how, when, where, and why innovation occurs in capitalist economies, and how policy might improve innovation performance, have moved to the forefront of economic research. While much remains to be confirmed in this research stream, a single finding has emerged clearly: Effective government policy is a vital underpinning for superior innovation performance, and government plays an irreplaceable role in promoting (or retarding) innovation. Innovation cannot be simply "left to markets" for two main reasons. First, successful innovation requires the creation and maintenance of complex knowledge bases and infrastructures that cannot be provided by firms acting alone. How these are constructed and accessed are vitally determined by government policy. Second, innovation is characterised by investment commitments under conditions of elevated risk and uncertainty; therefore incentive structures and risk-management processes are necessary; and in turn these are critically shaped by public policy. The purpose of this paper is to explore what we know about these two dimensions of innovation behaviour, and how effective policy may improve them.

What Is an "Innovation System" and What Does It Do?

In effect, the purpose of government policy for innovation should be to improve the performance of the "innovation system." But what exactly *is* an innovation system? Before proceeding further, we should first define the term "innovation" as it pertains to the world of industry and commerce. An influential definition of innovation is: "the processes by which firms master and get into practice product designs and manufacturing systems that are new to them" (Nelson 1993, 4). This definition can be expanded to include novel organisational practices and service delivery. Note that this definition also encompasses the commercialisation and introduction into practice of new ideas, not merely invention; that it includes the products and the processes by which they are produced; and that it does not limit innovation to the first introduction of a new idea.

A national innovation system can then be defined as the "set of institutions whose interactions determine the innovative performance, in the sense above, of national firms" (Nelson 1993, 5). These institutions go beyond 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 performs three vital social functions: it mobilises and allocates resources, it determines the appropriation and allocation of returns, and it manages the risk needed to undertake technological advances.

The term "system" does not imply that the complex interaction among the above elements need be either planned or deliberately created. Indeed, in most successful countries, centralised planning has either been deliberately avoided or abandoned. Nonetheless, all successful countries have acted to shape the factors that comprise an innovation system, and some such as Singapore or Taiwan have introduced far-reaching efforts to create favourable institutional climates (Goh 1995).

Innovation and Comparative Advantage

Looked at another way, in an economic sense the innovation system can be regarded as the social institutions through which societies shape and expand their comparative advantage, the basis of trade and economic specialisation. While the economic theory of comparative advantage offers valuable insight into how nations might raise their productivity in the short term—by trading with others and specialising in the fields in which they enjoy relative advantage—it offers little guidance as to how such advantage is constructed in the first instance. In the days of David Ricardo, the theory's originator, comparative advantage was regarded as largely determined by primary factor endowment in land and climate: a gift of God. Ricardo famously suggested that Portugal specialise in wine and England in textiles. In the centuries since Ricardo, however, it has become obvious that in the manufacturing and service industries that have driven economic growth, comparative advantage is mostly a human creation, more a result of effort, skill, and organisational and institutional effectiveness than natural endowment.

The study of the construction and evolution of national innovation systems can thus be viewed as the investigation of how comparative advantage is created over time. Unfortunately, economic theory has been of limited assistance in this research. Economics focuses on markets: interactions and transactions among individuals and organisations. Why some individuals, organisations, regions, or nations are better than others at performing the tasks that matter in market transactions has been seen by most economists as outside the scope of economic theory, more a matter for historians, business analysts, or organisation theorists. Yet, at its heart, comparative advantage is about just such economic capability, the ability to meet human wants better than competitors.

Nor has public discussion assisted much in understanding the sources of comparative advantage. Media coverage of economic issues rarely focuses on capability. It tends to dwell on headline stories of managerial blunders and power struggles, mergers, acquisitions, business cycles, currency exchange and interest rates, taxes, and fluctuations in energy prices. But none of these issues are fundamental. They are ultimately surface phenomena that contribute only to what we might term shallow capability: short-term pricing and cost issues. Separate from the dramas that surround these issues are the enduring factors that determine sustainable prosperity.

Because the media focuses on the shallow factors, so too often have political leaders. Politicians frequently ignore the deep capabilities that develop gradually over time and endure longer. These capabilities include accumulations of strategic resources and proprietary knowledge, which require organisational routines, employee commitment, and superior problem-solving to be realised. Deep capabilities are those aspects of the economy that are difficult for others to copy and that support ongoing gains in competitiveness. To develop new capabilities—comparative advantage—we need to move from a static to a dynamic perspective.

The shift to a dynamic view of economic development is the precisely the focus of research into innovation systems. The study of national innovation systems begins with recognition that innovation systems differ across nations, and that such variation is shaped by those nations' history and context. But study of national innovation systems is built also on an understanding of how advances in technological and economic-practice actually happen, the key actors and processes involved, and the demands on these actors.

Public policy for innovation faces two distinct but related strategic challenges. The first is the creation of essentially new industries and services based on radical technological changes. The second is the pervasive technological upgrade needed to retain competitiveness in the industries and services a nation already possesses.

Meeting these challenges requires that two key problems be addressed:

- The appropriate role(s) of 'knowledge infrastructure' (universities, research institutes etc) in creating and maintaining capabilities for innovation.
- The role(s) of business in the commercialisation of innovations, and the problem of innovation incentives and risk management in business creation and development.

A clear result of three decades' research into the sources of innovation is that the division of labour between the knowledge infrastructure and business (both new and existing) has often been understood in an oversimplified way. The problem is not to incentivize the knowledge infrastructure to provide commercializable knowledge. Rather, it is necessary to separate the infrastructure problems and the business-development issues.

The task of the knowledge infrastructure is to create and diffuse generic and scientific knowledge bases that support innovation problem-solving across the industrial structure. This requires a long-term integrated approach to the levels, composition, and governance of knowledge infrastructure investment, and to the interactions between infrastructure and business.

Commercialising innovations is the task of business, for which new financial mechanisms are needed to create incentives and control risk. This requires new approaches to tax policy (providing genuine incentives for innovation investment) and to risk management (including incentives and regulatory structures of capital markets).

The role of innovation in economic development

All major theories and all empirical analyses of economic development treat innovation as an important explanatory factor in long-term growth. But innovation rests on complex capabilities that extend well beyond those possessed by firms, and it requires long-term investment under conditions of pronounced risk and uncertainty. These characteristics of innovation performance imply market and system failures. This is why successful innovating economies invariably possess successful public-policy systems.

It is sometimes argued that innovation consists of the discovery of new scientific or technical principles (perhaps occurring in universities), followed by engineering development in companies, leading to commercialisation. This schematic of the innovation process, however, which underlays most innovation policy, has been superseded by empirical research. Innovation cannot be understood in terms of a discovery phase followed by a commercialisation phase. Recent innovation research has recognized that the innovation process varies considerably across industries, and follows different sequences in different technologies. Robust conclusions include the following:

- Innovation requires continuous interaction and feedback among perceptions of market opportunities, technological capabilities, and learning processes within firms. The strategic capabilities of firms are central here: the ability to perceive opportunities and to invest in realizing them is the main characteristics of an innovating firm. These strategic capabilities are not automatically present in firms and in fact seem to be very unevenly distributed among them.

- Research and Development (R&D) is often not a source of innovation but an effect of innovation decisions. Firms very often seek to innovate by exploiting their existing knowledge assets. Unforeseen problems often emerge, however, and these require R&D for their solution. From this perspective R&D should be seen not as a process of discovery that initiates innovation, but as a problem-solving activity within already-existing innovation processes.

- Solving innovation-related problems often requires recourse to knowledge and skills outside the firm. So cooperation and collaboration between innovating firms and suppliers, customers, design or engineering consultants, universities or research institutes are frequent characteristics of modern innovation processes. In general, innovating firms are collaborating firms. In this context, the role of universities and research institutes is not to generate innovations, but to solve background problems relevant to innovation processes.

- Innovation requires sustained investment under conditions of uncertainty. Firms cannot know the future and their strategic innovation choices can be very risky indeed. Nevertheless, they must invest in a wider range of innovation-related assets – human skills, new capital equipment, design capabilities, strategic marketing, engineering development programs, and more. So innovation requires corporate governance systems that both permit and encourage such investment, and that can manage the risks involved. The combinations of these assets that are required for innovation differ considerably across industries.

- A key characteristic of innovation capabilities, at the levels of both firms and countries, is that they are cumulative. They build over time, and they often depend heavily on past investments and sustained investment over long periods.

Thus, while many important technological advances are associated with advances in science, many are not. A grasp of how science operates in different countries is therefore essential for understanding innovation systems, although innovation depends also on many other inputs and factors. In addition, innovation takes place mostly through organisations, usually firms, which organise research and development activities and innovation projects, fund them, and decide which pursue to implementation and commercialisation. An understanding of characteristic forms of corporate and not-for-profit organisation, and the institutional norms governing typical patterns of interaction within and among firms and their personnel (that is financial, product, and labour markets), is therefore also essential. And finally, companies and the institutions of science and research (universities, public research institutes, and funding bodies) are structured and regulated by government.

The "high-tech" sectors that focus on R&D, however, generally account for only a small proportion of either innovation or growth. In most OECD economies high-tech manufacturing makes up less than 3 per cent of GDP. All OECD economies consist of a combination of large medium-technology and low-technology manufacturing industries (such as food and beverages, or fabricated metal products), and large-scale service activities (of which the largest are education, health, and social services). Research reveals that so-called low- and medium-technology industries include significant proportions of innovating firms that develop new products and generate significant sales from new and technologically changed products (Smith and O'Brien 2008).

Indeed, the very distinction between "high-" and "low-" technology industries is misleading, depending on an inadequate measure: essentially defined as the ratio between R&D performed internally by individual firms and sales. Industries with high sales numbers and low margins, such as for example food, might spend large amounts on R&D, but the high sales numbers mean that R&D amounts to only a small ratio. Other industries utilize large amounts of R&D, but such R&D is not undertaken internally to the firms. A more useful classification contrasts industries with internal R&D, in which innovation is driven by R&D performed by companies, from "distributed-knowledge" industries, in which innovation is developed externally and then optimised internally in firms. Some industries can be "knowledge-intensive" without a great deal of R&D performed by firms within the industry. An example of such an industry is agriculture, which in the developed nations has sustained innovation-driven productivity advance in excess of most other industries, but in which the overwhelming majority of R&D is performed by public-sector organisations and subsequently diffused to the private sector (farms).

Innovating industries and their knowledge bases

Much recent innovation policy, in Australia and the US, as elsewhere, has focused on 'high technology', 'knowledge intensive' industries, and the so-called 'frontier' technologies that support these industries. This has led in virtually all advanced countries to priority research policy areas placing a strong emphasis on ICT, biotechnology, and nanotechnology. These fields, and by extension the industries based on them, are R&D-intensive, science-based, and closely linked to university research. Industries such as ICT hardware and software, pharmaceuticals (including biopharma), and semiconducting materials, have shown rapid growth in output and trade (although not in Australia).

It is important to support these industries, and to foster business growth within them, for two main reasons. First, they appear to be areas of major technological opportunities, with unpredictable possibilities for future development. Second, they are areas of generic applicability – ICT, biotech, and nanotech have actual or potential applications as inputs across many other activities, and therefore open up the possibility of significant productivity-enhancing effects.

But the expanding data and evidence on innovation in low and medium-technology industries and services suggests that we should take a wide view of innovation and its effects, recognising that growth is generated across many sectors of the economy. Of course we should not deny the existence and importance of radical technological breakthroughs. But it is important to challenge the oversimplified idea that high-tech industries are 'leading' sectors, and that growth rests on their technologies in some simple way. Rather we should recognise that innovation and hence growth impulses are pervasive across the economic system, which would explain why many so-called ‘low-tech’ sectors and low-tech economies have been growing rapidly. In other words, growth impulses are dispersed across the system because innovation also is widely dispersed—it is not the case that innovation is confined to a small group of high-tech sectors. Growing sectors innovate in different ways, with a great deal of variety in methods, approaches and results. This diversity among industries is particularly important with respect to knowledge creation.

How does the system of knowledge creation and use relate to this picture of dispersed innovation and growth? Innovation follows different paths in different industry sectors with divergent approaches, methods, and results. Key dimensions of difference across industry sectors include the relative propensity to new company formation; product-versus-process focus; and internal-versus-external knowledge sourcing. In some industry sectors innovation primarily takes the form of new company formation (for example, software and certain fields of electronics); in others, it manifests through the activities of already-existing large companies. In some sectors innovation is primarily product-focused; in other sectors (for example, metals and energy production) it is process-focused. In yet other sectors it is science-research based (for example, pharmaceuticals); in others it is primarily marketing-focused (consumer goods).

Scientific Invention and Innovation

The relationship between science and innovation is thus complex, and varies from scientific field to field, and nation to nation. Causality is not uni-directional. In some instances, new science gives birth to new technology, and commercial innovation. This is the simplest picture, and the one that 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 in these sectors that an important emphasis of policy ought to be to encourage researchers to pursue industry-useful research and to develop mechanisms to take inventions through to commercialisation.

Just as often, however, commercial innovation gives impetus to new science, or draws upon existing science in ways its originators could not foresee. Serendipity plays a major role in the relationship between science and innovation. Innovations often spring from applications of science that are quite unexpected by their scientific discoverers. In addition, new technologies often precipitate new science aimed at a deeper understanding of what seems to work, and improving it. Often, a commercial production process is not simply a scaled-up version of lab procedures, but an entirely new process, the result of considerable scientific and engineering work. For example, a modern drug-production process especially in biotechnology, is not a scaled-up version of the vacuum flasks and reactors in which discoveries were originally made. A new process for drug production must often be invented.

An innovation system must therefore be understood as creating supply of science as well as supporting demand for science. The vehicles for science-based innovation are existing companies looking for new products and solutions as well as new companies created to commercialise discoveries. The balance between existing and new companies in this equation varies by industry, field of science, and country.

But in every field of science, innovation depends on experimentation (West and Iansiti 2003).

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 be offered, and a strategy to test the options developed so as to eliminate those that are too costly or have an unacceptably low probability of success. Seldom can commercial innovators be assured in advance that all the pieces will fall into place for the new product or process: that the projected technology will work as expected, that a market will be found, and that managerial and technical staff will be capable of meeting the challenges and obstacles encountered. Innovation is always, therefore, both "inefficient"–in that activities must be undertaken that will probably fail—and risky—in that it will possibly yield little or no value.

Indeed, risk is the defining challenge of innovation. And the locus and intensity of risk varies by industry and technology (West 2004). In some sectors, the technology is likely to function as anticipated, but finding a sufficiently large market for it will be difficult. This is true, for example, in much information technology. In other sectors, a market is known to exist, but getting the technology to operate effectively and to scale will be problematic. This is often the case in drug development.

Sustaining science and the efforts of organisations to commercialise new technology thus requires investment of considerable resources, at substantial risk, often over long periods of time. An effective national innovation system will therefore include means to mobilise these resources, allocate them to risky undertakings, evaluate the progress of innovation projects, and eliminate those with unacceptably low prospects of success.

In a general way, we might distinguish between two modes of knowledge creation and use. First, we need to distinguish between R&D-based knowledge and non-R&D forms of knowledge creation. Non-R&D inputs to innovation include, for example, market research, design skills, trial production and testing, prototyping and engineering experimentation, and software development. These non-R&D inputs are essential to innovation across all industries, but they are often a larger component of low-tech activities. Non-R&D expenditures on innovation are usually significantly larger than R&D expenditures, so they should not be neglected by innovation policymakers.

If we conceive of universities, research institutes, and so on as a knowledge infrastructure, how important is such infrastructure? In fact, a striking empirical feature of innovation in the modern era is the vital role of infrastructural organisations in developing and diffusing major technologies. It is surprising how often the fundamentals of major technologies – computing, biotechnology, mobile telephony, the GPS system, container transport etc - have been developed in government labs, publicly-owned companies, universities, military R&D programmes, etc. Given the prevalence of such infrastructural inputs to modern technology, it seems unlikely that their role is merely accidental.

How does knowledge flow between the infrastructure and firms and other organisations? There is a range of mechanisms, including the following. Knowledge can:

- Be embodied in intermediate products and capital goods.
- Flow via scientific principles used in engineering design.
- Flow via patents and licenses.
- Flow via technical and engineering consultancy services.
- Be exchanged via joint ventures.
- Be created through scientific and technological collaboration (informal or formal).

- Flow via the education system and movement of skilled personnel.
- Be created via extramural R&D and contract research.

All industries engage in more or less all of these activities, most of the time. The cumulative impact, in terms of evolving knowledge complexity, can be very great. For example, the food processing industry performs very little internal R&D, yet it uses complex processing and sensory technologies involving functions related to hygiene and safety, preservation, nutritional quality, logistics, and so on. These functions rest on such scientific fields as informatics, biochemistry, and microbiology. So by any reasonable standard, this is an innovative, knowledge-based industry with deep links to the science system.

The case of food processing can be generalised. Industries such as wine, fabricated metal products, or textiles can involve complex underlying knowledges related the performance properties of processes or products. These knowledges are often created, maintained and diffused by a network of infrastructural institutions. The technological knowledge of the Australian wine industry rests on universities (whose oenology courses were arguably the first in the world to put winemaking on a scientific basis), research institutes, producer associations, R&D funding programmes, and an active equipment supply sector.

Knowledge infrastructures and innovation

What is the appropriate role of the knowledge infrastructure in the commercialisation of technologies? It helps here to distinguish between three basic levels of knowledge in production and innovation.

First, there is the technological knowledge-base of the firm—which is focused on particular products, and therefore highly specific to the particular markets within which a firm operates. Firm knowledge bases involve localised expertise relevant to skills that have been developed over time, and that offer the firm a competitive advantage in its markets. Such detailed skills and expertise are powerful sources of strength in innovation and competition, but they also involve weaknesses. The fact that firms attempt to specialise around existing areas of competence means that there are limits to their technological capabilities and awareness. This leads to a phenomenon which Martin Fransman has described as 'bounded vision':

> "… the field of vision of for-profit corporations is determined largely by their existing activities in factor and product markets, in production and in R&D, and by their need in the short and medium term to generate satisfactory profits. The resulting bounded vision implies that new technologies emerging from neighbouring area where the corporation does not have current activities are likely to take some time to penetrate the corporation's field of vision ... The need to generate satisfactory profits in the short to medium term therefore further bounds the vision of the corporation, contributing in some cases to a degree of 'short-sightedness'. One example is the creation of technologies for 'the day after tomorrow' where the degree of commercial uncertainty is frequently great. In view of their bounded vision, corporations often tend to under-invest in the creation of such technology." (Fransman 2000)

On the one hand, such bounded vision means that the long-term strategic capabilities of firms can often be limited. On the other, it means that when firms seek to solve innovation-related problems, they must frequently look outside the boundaries of the firm for solutions: they draw in outside information, expertise, and advice.

A second level of knowledge refers not to firms but to the shared knowledge parameters of the industry in which they operate. Industries tend to have core areas of knowledge capability that are essential to any firm seeking to operate in the industry. This is a form of generic knowledge, common across many players in an industry. In referring to the wider dimension of technology, Richard Nelson has suggested that:

> "… a technology consists [in part] of a body of knowledge which I shall call generic, in the form of a number of generalisations about how things work, key variables influencing performance, the nature of currently binding constraints and approaches to pushing these back, widely applicable problem-solving heuristics etc ... generic knowledge tends to be codified in applied scientific fields like electrical engineering, or materials science, or pharmacology, which are 'about' technology." (Nelson 1993)

Finally, there is a much wider knowledge base in society as a whole, extending well beyond particular industries and relating to the broader understanding of properties of nature. By and large this is the domain of fundamental sciences. The sciences form an extremely wide set of knowledges that may in principle be applied across many industries and activities, and that are important supports across industries.

The upshot of these considerations is that the knowledge infrastructure should not be involved in the specifics of innovation at the firm level. What is needed from the knowledge infrastructure is problem-solving capabilities related to the second and third types of knowledge we have described above: that is, generic knowledges related to specific industries, and broader scientific knowledge bases. This does not mean an open-ended commitment to all fields of knowledge. Infrastructures should be relevant to the nation's specific industrial structure. The task of the knowledge infrastructure is to maintain the wider knowledge bases that – beyond the level of individual firms – are necessary to support and develop the actual or prospective industrial structure. This suggests *not* focusing exclusively on new industries. The history of the advanced economies should not be reduced to a history of creating new industries; of course, new activities have emerged, sometimes (as with the vehicle industry) on a spectacular scale. But growth has also taken the form of continuous and pervasive upgrading of already-existing industries – in most advanced economies, the largest industrial cluster is today exactly what it was two hundred years ago, namely the food sector. But the characteristics of this sector have been massively changed via innovation, and this has been a source of growth. Indeed, no other industry comes close to matching the sustained productivity improvement, over two centuries, of agriculture. So, the infrastructure has two major tasks: upgrading what exists, and fostering the new where the new can feasibly be created.

This perspective suggests that direct commercialisation of innovations should not be a function or task of the knowledge infrastructure. Commercialisation, however, defined in a recent Australian Department of Education, Science, and Technology report as 'the process of converting science and technology, new research or an invention into a marketable product or industrial processes', is very much in focus in Australian policy, which concentrates on the financial and other incentives to promote it.

By contrast, the challenge for the knowledge infrastructure ought not be to produce commercialisable results, but to create the knowledge conditions that enable new firms to emerge, and existing firms to innovate. The knowledge infrastructure—especially universities and research institutes—cannot substitute for or replace firms as the originators and bearers of innovation. Evidence from international debates suggests that attempts to transform universities and other elements of the knowledge infrastructure into commercial enterprises themselves will very likely be both ineffective and destructive to these institutions' ability to play their most important roles.

If the knowledge infrastructure is to play a dynamic role in economic development, then it is not sufficient simply to understand its proper role. An integrated policy approach is needed, resting in the first instance on an appropriate public-private forum or agency that can discuss and debate the knowledge infrastructure as a whole, and its appropriate funding levels and methods, composition and governance. The knowledge infrastructure is a whole-of-government issue. The challenges of thinking through its emphases and priorities, and its areas of continuity and change, should no longer be left to fragmented agencies.

Innovation and Business Creation

The bearers of innovation should thus continue to be businesses, both existing and new. But, if government policy is to promote innovation effectively, it must be based on a realistic understanding of the reasons businesses choose to innovate, and the actual challenges faced as they do so.

Put most simply, businesses innovate when they believe such effort will bring higher margins and/or accelerated growth. Innovation delivers these economic benefits to the extent that it gives the innovating business a privileged position (ideally, from the firm's viewpoint, a monopoly position) to satisfy a particular customer demand. When this occurs, innovation strengthens the bargaining position of firms with respect to their competitors and customers. Entrepreneurs, both within established companies and as founders of new ventures, are in reality business people seeking such privileged positions with regard to customers and competitors. New technologies and problem-solving capabilities are tools in this business and managerial process.

From the firm's perspective, then, the social benefits of innovation sought by policy makers, including higher productivity and new products or services, are by-products, or at best means to an end. Firms do not innovate in order to raise productivity or solve economic problems for the country as a whole. They innovate to increase profit and growth for themselves, on a risk-adjusted basis.

While seemingly obvious, this insight is key to understanding the policy-created parameters that shape innovative businesses' incentives and challenges. Businesses will confront the risk inherent in innovation only if two conditions prevail: the return from innovation is sufficiently greater than that from 'routine', non-innovative, alternatives, and the risk is sufficiently manageable.

Policy makers can substantially influence both these parameters. But it is essential to recognise that the best policy to encourage innovative economic activity might be quite different from that to encourage other economic goals, such as greater investment in infrastructure, more housing, or broader social equity. The key to promoting innovation is to tilt the playing field in favor of higher risk-adjusted returns to innovators.

How might this 'tilting' be achieved, without inducing dysfunctional economic behavior such as rent seeking through privileged ties to government? All nations with successful innovation policies have introduced means to raise the returns from innovation, especially in comparison to non-innovative activities, and to reduce the impact of failure, usually in specified sectors. To define which policy initiatives will realise these goals, it is necessary first to identify accurately what those barriers are, and what they are not, in the specific business context. Unfortunately, just what are these barriers is the subject of several pervasive myths in Australia and the US.

The first relates to entrepreneurship. Within Australia, one often hears that the country needs a more entrepreneurial business culture. This may be so, but this claim should not be taken to imply that Australia needs more companies, or more new-company formation. Per capita, Australians create roughly at least as many new businesses as comparable developed nations, and more than most. What Australia lacks is not start-up companies, which it has in proliferation, but successful growth of these companies into medium and then large-scale enterprises, of the type that alone can adequately manage the complex problem-solving and innovation-generating process. For an economy of its size, Australia has one of the world's lowest populations of multinational innovating companies.

This problem is endemic in the biotechnology sector. Australia enjoys one of the highest rates of new biotech company formation in the world, perhaps the highest, yet suffers one of the lowest average firm size and smallest total market capitalisation. Australia's listed biotech 'firmlets' are mostly narrowly focused on a single project, with a thin capital base, and as such offer little prospect of growing into ongoing enterprises, or even of the prospect of surviving the inevitable setbacks on the difficult path to commercialisation of a single product. Such a fragmented sector is unlikely to be sustainable as a platform for the nation's participation in a broad and far-reaching technology revolution.

The second myth relates to risk taking. Just as with entrepreneurship, one frequently hears that Australian businesses are excessively risk averse. Yet important evidence suggests the contrary. Australians are famous for their love of gambling, and Australia is a world leader in sponsoring and financing raw material exploration, one of the most risky forms of business enterprise. Why the difference? Why should Australians apparently avoid technology risk, but embrace wildcat mineral exploration? The origins of this difference need further exploration, but an answer is likely to be found in the accumulated knowledge base of Australian management, along with the structure and incentives of investment managers themselves, both of which appear to militate against technology risk.

The third myth is that Australia's economy is too small to lead in innovation. This argument comes in two forms: that Australia lacks the financial resources to experiment with new technologies and that its domestic market is insufficient, and too remote, to support innovation. Compared to other successful nations, however, Australia's economy is of ample size. Consider Sweden, it possesses at least twenty multinational enterprises that are industry leaders on a global scale – yet its population is eight million (of whom 16 percent are immigrants). By contrast Australia has more than twice the Swedish population, and indeed possesses the fourth-largest pool of privately managed investment capital in the world—mostly its superannuation retirement funds. Its domestic market is economically much larger than most small European or successful East Asian nations.

The challenge of business innovation in Australia is in reality *not* that Australians don't start enough companies, *nor* that they don't like risk, *nor* even that their economy is not large enough. It is that they too often fail to construct sustainable, complex, growth-oriented business enterprises necessary to bring a stream of innovations to market.

The wine industry provides an instructive example of what Australia's innovation system does well, and at what it fails. Over the last two decades, Australians have been responsible for a stream of world-beating innovations in the wine industry, both in viticulture and viniculture, and these have been successfully brought to market. Invention plus commercialisation: in these respects, the industry is an exemplary story – it has been a dramatic growth industry by any reckoning. Universities and research institutes have cooperated with growers and winemakers to produce new varieties and techniques, and create a vital, sustained, export industry.

Importantly, however, Australia has failed in the business dimension essential to capture value from this innovation. In spite of its success in growing tonnes of grapes and shipping litres of wine, and even in creating global brands, Australia's wine industry has manifestly failed to build world-class companies that can independently market and distribute their product, the field in which most value in the beverage industry is concentrated. With one faltering exception, all major wine export, marketing, and distribution out of Australia is now foreign-owned. The lion's share of value created by Australia's wine innovators thus flows to overseas equity holders.

Policy makers can create more favourable conditions for entrepreneurs (in-corporate as well as independent) to build the kind of business enterprises that will sponsor innovation, take ideas through to commercialisation, and, finally, capture value from it, by allowing higher returns for innovators and helping innovators bear risk.

The first aim can be achieved by discriminating between innovative and 'routine' business activity in pricing and taxes. In essence, all governments that have successfully promoted innovation allow innovators to charge more for these products or services, for a specified period of time, and then ask from them lower taxes. Such benefits can come in many forms, and the most effective will be related specifically to the needs of particular technologies. Patents are one form in which such government support—playing-field tilting—is provided.

The second aim can be achieved by supporting the diversification of risk. Innovation is much more risky than 'routine' economic activity because it intensifies each of the major forms of business risk: technical ("will the product work as hoped?"); market ("will customers buy this previously unknown item?"); and managerial ("can this team work together under unexplored conditions to bring this successfully to market?"). After firms and investors make the necessary attempts to reduce the risk to which they are exposed—by, for example, better understanding the underlying science or their consumer markets—the only known successful strategy to manage risk is to diversify it, in the hope that in a pool of 'bets' winners will more than offset losers. Sometimes such a diversified portfolio is managed within an existing company, in the form of a portfolio of projects; at other times it is managed through a portfolio of 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 system, the elements of which must be coordinated to enable innovation and creativity to function effectively. Organisations (including firms, non-profit institutions, and government-sponsored agencies) must align their activities with laws and norms regulating how organisations operate and interact, and with the inherent demands of the process of technological innovation itself. It is important to note that whilst these demands originate in the nature of the innovation process itself, each can often be met in different ways. Which exact combination is adopted by any successful national system will depend on its specific history, culture, and values.

Findings of research in innovation systems

The study of innovation reveals many ways to fail, but, perhaps more surprisingly, also more than one way to succeed. Table 1 illustrates in schematic form characteristic dimensions of the innovation systems in three successful innovating nations.

Table 1: Three national innovation systems

	US	Japan	Singapore
Investment mobilisation	Low domestic savings; capital import	High domestic savings	Very high savings; government mandated
Capital allocation and risk management	Capital markets; venture capital	Corporate retained earnings; banks	Government; government-linked corporations
Basic research location	Universities; government-sponsored labs	Large corporations	Government-sponsored labs
Commercialisation path	Start-up venture capital-Initial Public Offering	Large corporation or spin off within keiretsu	Sell to foreign-owned multinational corporation; government-linked companies
Professional labor market	Broad and deep	Narrow and shallow; lifetime employment	Developing
Primary value-capture mechanism	Equity; intellectual property	Production; corporate earnings	Wages; some taxes

As can be seen, while the tasks faced by these nations are similar, the means to meet them vary widely. Research into the nationally specific forms through which individual organisations and companies align their operations with the demands of the technology development process and these elements of their institutional context in different national settings has revealed several key conclusions.

The first is that innovation is 'systemic' in the full sense of that word. Many researchers have observed that national innovation systems are not simply lists of 'good' policies or institutional structures, in which the more enacted, the more innovation is obtained. Rather, they are coherent systems and the degree of innovation depends on the interaction within the system, not merely the presence of each element. Possession of, say, four out of five elements of an effective system, does not necessarily bring a nation 80% of the benefit, but often none. If one leg of the tripod is broken, the tripod 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 there. What works well in combination with one set of elements may not work at all with others.

A successful national innovation system may be thus be analogous to the concatenation that enables a bird to fly: each element of the "system" provides no benefit alone and may even be detrimental, and only when all elements are present is advantage gained. Flight demands 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 enormous evolutionary advantage of flight.

Second, research has shown that basic knowledge creation often takes place outside the market. This is one of the best-established results in the 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). He argued that a free market, left to its own devices, will allocate less resources for invention (which he defined 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 to supplement the predicted under-investment by private firms in research and invention. 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 large-sample statistical study appeared to confirm Arrow's prediction (Furman et al 2001). The study examined the innovation outputs of 17 industrialised 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 specialisation, and each individual country's knowledge 'stock'."

The study noted that between two-thirds and 90 per cent 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 per cent. 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 (eg by establishing and investing resources in technical universities) as well as greater competition on the basis of innovation (eg through the adoption of R&D tax credits and the gradual opening of markets to international competition)."

Third, research has highlighted that innovation is expensive and risky. It often demands sustained commitment. Many, if not most, governments will seek to minimise that risk and commitment in favor of politically easier paths. For most nations, economic growth can be achieved by building on strengths in existing industries and not attempting to innovate too much. Certainly, while innovation can drive economic growth, it is by no means synonymous with it. A more 'efficient' way to raise economic growth for many nations may be to apply well-understood technologies to existing industries. The problem with this approach, however, is that growth declines as the nation reaches the technological frontier. To enter sectors at the technological leading edge — characterised by both high growth and high value added — will likely 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 establishment of a semiconductor industry is instructive in this respect. Taiwan's semiconductor industry began late, in 1977. By any measure, the Taiwanese government's decision to enter the semiconductor industry posed great risks for the nation. In the late 1970s, the 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 United States and Japan, and rapidly closing the gap, having already surpassed Korea. The industry had driven Taiwan's productivity and living standards increases for almost two decades, growing at a cumulative rate of more than 10 per cent per year. How was this dramatic success achieved? One important factor was resource mobilisation. Taiwan's savings rate averaged about 30 per cent of GNP between 1969 and 1997, and household saving over the same period averaged more than 20 per cent (net household saving in many developed countries has been around 2 per cent, 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 per cent in 1952 to 47 per cent 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 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 demanded 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 per cent of whom were researchers and 500 of whom held doctorates. The agency was 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 (Matthews et al 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 possessed 12 semiconductor fabrication facilities, with sales of about US$3.3 billion. By 2000, that number had jumped to US$17 billion, or approximately 5 per cent of Taiwanese GNP.

This example indicates the scale of resource mobilisation 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 technical risk (Bhide 2000). They start small and remain small, although they can provide a prosperous life to an individual entrepreneur. Being relatively low risk, but with modest growth prospects, most such ventures are funded from personal resources, or from family and friends. But 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. As Bhide shows, success for these firms is often based on out-hustling others with similar ideas, though obviously their rapid development is based on distinctive ideas (Apple, Hewlett-Packard). Such firms have traditionally struggled for five or more years before they gained any competence that could attract 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 entrepreneurs to monetise their investment, and withdraw funds from it, through an Initial Public Offering.

Different national innovation systems emphasise 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 summarise 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 and Dore 1996; Dore 2000).

The fourth finding from innovation systems research is that the rewards of innovation flow mostly to those who bear the risk. Just as individual businesses seek different funding sources, depending upon their risk profile, so must innovative efforts to develop new industry segments. The larger and more risky, the broader will need to be the funding body to diversify its positions.

As noted, the majority of new businesses 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 sector).

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 greatly so. In life science, however, the majority of investments will yield no return at all. Some, however, will be enormously profitable, and that is what entices investors.

Perhaps even more important for investment allocators is the type of risk that must be managed. As noted above, all innovation projects contain three basic types of risk:

- Technical risk, that is whether the product, process, or service will actually perform the intended function.
- Market risk, that is whether a sufficiently large market can be found for the product.
- 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 early in their evaluation of 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 focus on 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 are usually well characterised. In life science, once technical feasibility is established —for example, it has been demonstrated that the drug is effective against a cancer with acceptable 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 more widely diversified, and that the total portfolio must be larger. Investing in information technology requires wider diversification than most 'me-too' investment, given the sums required per business and the success probability. Diversification must be wider still for investment in life-science technology. Entrepreneurial investment in information technology is usually within the scope of venture capital funds, or large corporations. In life sciences, with success rates as low as 1 in 20, and minimum investments becoming very large (to take a potential drug through all phases of development and registration, for example, now costs more than US$700 million) the required size and diversification of the portfolio is beyond all but the largest firms. A portfolio of only 20 projects at US$700 million each would require a commitment of US$14 billion. For the riskiest life-science enterprises — technologies based on 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 United States only approximately five venture capital funds specialise in biotechnology, and the proportion of venture capital investment in biotechnology has actually declined in recent years.

Fifth, while research has shown that innovation takes place across all sectors of the economy, it can exercise very different impacts on these 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.

Information technology promises to cut the cost of processing information and undertaking transactions. Since such costs affect virtually every industry, information technology will probably eventually raise productivity in many industries. Biotechnology, however, promises substitute products for many traditional strengths. The impact of biotechnology is not restricted to the development of 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 of these technologies will risk its industries being undermined.

Six, research has revealed that value from innovation is increasingly captured by equity owners rather than wage earners. In the past, nations could capture substantial value from innovations in the form of wages and taxes, by ensuring that production activities employing these innovations took place within their borders. In the knowledge-based industries that drive contemporary industrial innovation, however, typically little value is captured as wages. This is because replication of a product design — that is, manufacturing and service delivery — is increasingly trivial in key industries, 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 the owner of the intellectual property or the 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 utilises little labor. More and more industries are looking like software: intellectual property is where the value is concentrated. Table 2 shows the proportion of added value that is captured by wages in several representative industries.

Table 2: Value added by function (%)

	Wages	Net operating surplus
Precision engineering	67	6
Specialty chemicals	67	9
Disk drives	24	58
Computers	11	89
Life sciences	7	91

Source: Commerce Department

The implication of this is that for many nations 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 through wages from the presence of foreign investment. But that is less and less true. 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.

An Example: The Semiconductor Industry

My own work on the dynamics of innovation in the global semiconductor industry provides an example of many of these findings and of the necessarily integrated nature of innovation systems. 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 (West 2000, 2001, 2002, 2004). Similar results have been found by other researchers in a range of industries (Dore 1994; Clark and Fujimoto 1991 and several of the studies in Imai and Komiya 1994). The differences I observed are summarised in Table 3:

Table 3: Semiconductor industry R&D organisational practice: US and Japan

	Japan	*US*

Skills acquisition and retention	Experience-based	Education-based
Program scope and leadership	Loose	Tight
Program guidelines and timing	Implicit	Explicit
Task partitioning	Distributed	Focused
Resource allocation	Decentralised	Centralised
Experimentation capability and practice	Low–Medium	High

The two key factors in the semiconductor industry that underpinned these differences in practice were the structure of markets for university-trained labor, 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 labor in Japan remains thin and shallow. Japanese firms typically induct university-trained personnel only upon graduation from university or college (Westney and 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 twenty-first century. By contrast, a vigorous labor market exists for such personnel in the United States. 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 United States and Japan. The US higher education system produces considerably more PhD-level graduates than does the Japanese system (Lynn et al 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 et al 1993). In turn, the relative underdevelopment of the graduate-level higher education system obliges them to do so.

These differences imply that, in Japan, managers can select organisational strategies that assume continuity of employment; they cannot adopt approaches that require recruitment of pre-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.

These contextual factors seem to explain the observed differences in practice. Why, for example, do Japanese organisations distribute personnel and experimentation resources more evenly among multiple sub-units, and not emphasise formal project-specific teams, with employees dedicated to a single process generation? The answer appears to lie 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 socialisation in Japanese firms, enhancing communication and co-ordination.

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 transfer of knowledge. 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 socialisation 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 and doctoral education system, especially at the PhD 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 managers work within a different set of institutionally shaped constraints and opportunities. Confronted by the need to improve their innovation capability 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 labor market. In the US context, with fluid markets for highly skilled labor 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 favoring professional over organisational socialisation. 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 in 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 dedicated project-based teams in the 1990s, described in my studies, 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 could hire well-educated scientists and engineers relatively easily, either directly from the strong US graduate-school Masters and PhD 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 effort of process development, and were allocated a greater proportion of problem-solving responsibility and finance, personnel, and experimental resources. Thus, key elements of the US organisational mode – its focus on experimentation, tight project teams, and centralised resource allocation and task partitioning – were all ultimately encouraged by the labor 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 other's system simply be grafted on.

As a pooler of risk, government enjoys three potential advantages over the private sector: it can diversify across a wider base (in essence, the entire citizenry); it can take its returns in non-financial forms (increased productivity, improved health, more jobs, etc); and it can invest more for the long term. These advantages potentially allow government to act as a risk-bearing partner with private firms, and to enhance their own risk-bearing capabilities.

Three distinct forms of economic vehicle have been employed by governments around the world to assist private firms diversify innovation risk. The first is subsidised loans from commercial banks, in which default risk is borne partially by government and partially by the banks themselves. Such subsidies increase the willingness of commercial banks to lend to innovators, but do not substitute government officials for the due diligence process of private investors.

The second is greater support for venture capital, especially through reduced capital gains tax for technology innovators. In this respect, it is worth noting that even at half the marginal tax rate, Australia's capital gains tax is close to double that of the US. Many governments also joint-venture with private investment firms to increase venture-capital funds under management.

And the third is a system of pooled income-related loans. The European Union in effect employs this approach to finance the highly successful Airbus enterprise. In this case, EU Member States provide government loans at commercial rates, to cover 33 per cent of development costs for each aircraft project. These are not repayable if the project fails, but are fully repayable with additional royalties if the project succeeds; in the event, European taxpayers have made substantial profits from these royalties. Australia has pioneered pooled income-related loans to finance higher education; it is fully familiar with the principle. But it has not yet deployed this instrument in support of innovation.

For any of these vehicles to support diversification of risk successfully without inducing undesirable economic behavior, however, certain conditions would need to be met. The first is that private investors, not government officials, select investments, and that they do so based on commercial criteria, not on, for example, the basis of political ideals, or worse, "who is a crony of the Minister". This proviso is essential to ensure that innovation does not become a game of government-relations prowess, or indeed corruption.

The second criterion ought to be that private investors themselves bear at a substantial portion of the risk. This proviso is needed to guard against behavior in which entrepreneurs deliberately take the only the greatest risks, which when borne by someone else (the taxpayer) can encourage adventurism in the hope of occasional major pay-offs.

The final criterion should be that government-subsided investments gain a return which can replenish the pool, even if not a venture-capital-level return. In all cases, innovators should be required to return taxpayers' money when successful, not be simply the passive recipients of non-repayable grants.

Implications

Discussion of the origin, functions, and differences among national innovation systems suggests important messages for organisational practice in innovation and the role of governments in shaping national comparative advantage.

The following discussion focuses on policy implications. The single most important outcome from the research reviewed here is that government can exercise a major influence over the evolution of a nation's innovation system. But considerable care must be exercised to ensure that influence strengthens, rather than undermines that system.

First, government should complement, not attempt to substitute for or compete with, the activities of private companies. Government should aim to strengthen the market position and capabilities of private firms. The first principle is that government policy should "do no harm": it should not distort market incentives by attempting to substitute public-sector activity for those of the private sector. It should limit its domain to fields in which infrastructure, capability, and resources are both demonstrably required to support innovation and in which it is not feasible for private companies or markets to undertake the specified activity.

Second, government policy should aim to exercise influence on industry sectors of sufficient weight and potential to matter. Innovation policy should address the needs of relatively large sectors. This implies that an innovation policy cannot be limited to "research-intensive" industries such as information technology, biotechnology, or nanotechnology.

In a modern economy, especially a small one, many of the goods and services citizens want can be obtained only from abroad; generating the income to pay for these imports depends on what the nation can sell to the world. The economic fate of nations can thus rest on a surprisingly narrow base of capability in a very few fields. Ensuring the long-term strength of these sectors ought to be a high priority for any community and its government.

Third, government should address the needs of these high-leverage industrial sectors based on an analytical understanding of their actual innovation systems and processes. As noted above, innovation follows different paths in different sectors. The distinctive innovation patterns across sectors must be understood if effective policy is to be developed and applied successfully.

These three policy implications suggest a final conclusion: the construction of comparative advantage through a national innovation system implies geographic and sectoral decentralisation. To promote capability and comparative advantage effectively, government policy ought to focus on sectors in which the economy specialises and be specific about where to locate and support facilities, institutions, and resources to support these key sectors. Perhaps the final message from this discussion of research findings about national innovation systems is there can be no effective one-size-fits-all, "best" economic policy for the design and development of a national innovation system.

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