

**Department of Employment, Education, Training and Youth Affairs**

# **The Changing Nature and Forms of Knowledge: A Review**

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## **Current Issues Concerning the Nature and Application of Knowledge**

The nature of knowledge, the extent and justification of its truth content, and rules for its orderly production have been the subject of epistemological inquiry since the time of Plato. This was given a fresh impetus in the first half of the twentieth century by the need to explain the extraordinary power, and limitations, of scientific knowledge. Meanwhile, those concerned with growing wealth began to look for means to organise the apparently capricious processes of knowledge generation, and to capture greater benefits from its application.

At the same time, inquiries about knowledge remained largely the province of scholars, with occasional acknowledgment as a key component of the civilised culture, and the educated professional. Universities, with their role in the generation, maintenance and transmission of knowledge, were the prime locus of both the production of, and reflection about, knowledge.

Over the past decade, however, there has been a considerable upsurge in interest in and analysis of the nature and contribution of knowledge to the modern economy and society. A number of themes can be identified.

### **1.1 Changes in the Relationship between Knowledge and Wealth Creation**

Drucker has argued that the role of knowledge in wealth creation has passed through two earlier stages, and is now emerging into a third. The first stage, in the eighteenth century, saw the emergence of the capitalist economic system based on organisation through factories and machines—what he called ‘knowledge applied to tools, processes and products’.

The second stage was based on the assumptions and insights associated with F. W. Taylor’s dissection and routinisation of the work process, described by Drucker as ‘knowledge applied to human work’. The resulting production line organisation and consequent processes of mechanisation and automation provided a further substantial impetus to productivity.

Now, Drucker maintains, a society is emerging that is dependent on the development and application of new knowledges: ‘knowledge is being applied to knowledge itself’. Productivity is becoming dependent on the development and application of new knowledge by specialist knowledge workers.

Gibbons et al (1994) have identified the intensification of international competition in business and industry as the driving force behind a markedly accelerated supply of and demand for 'marketable knowledge'. Firms that wish to compete in the international market-place are confronted with 'dynamic competition', which means that subsequent decisions and investments are strongly constrained by prior ones. One means of coping with this competition is collaboration, including with knowledge suppliers.

Faced with turbulent market environments, companies have sought to increase competitive advantage by shifting their strategic focus, at least in part, from markets and customers to organisational capabilities:

. . . ability in acquiring, assimilating, sharing and creating knowledge is the ultimate organisational capability, a meta-competence which allows an organisation to consistently outperform its rivals.

(Jordan 1997)

## **1.2 The Emergence of the 'Knowledge Economy', and Consequent Importance of 'Knowledge Management' and 'Knowledge Skills'**

An increasingly common, and strong argument (e.g. OECD; Sheehan et al 1995; Johnston 1996) is that the character of the economy, national and international, is being transformed. One major component of this, along with globalisation and electronic connectivity, is the increasing knowledge intensification of all economic activity, and the emergence of trade in knowledge as a commodity in its own right.

The two defining characteristics of the global knowledge economy are the increased knowledge intensity of the processes of creation, production and distribution of goods and services, and the fact that economic processes are becoming increasingly integrated on a global basis. Neither of these two elements is new to the world economy, but both their rising intensity and their mutual interaction are of a new order.

The new modes of production and distribution of knowledge have changed radically the role of knowledge in economic development. The industrial economy, based on goods and services, is being matched, and in some cases displaced, by the global knowledge economy, based on the production, distribution and use of knowledge. As the OECD puts it, the power of information and communication technology gives the global knowledge economy a new technological base which:

. . . fundamentally changes the conditions for producing and distributing knowledge as well as linking it to the system of production . . .

(OECD 1996, p. 13)

Since the 1970s the pace of this process has accelerated rapidly, because of the increasing availability of vastly improved processes for generating, storing and using knowledge. This increased knowledge intensity is evident in production and trade flows for both goods and services—the increasing importance, for example, of knowledge-intensive products such as aeroplanes, drugs, computers and communication systems and of services such as education, health and complex financial services—and also in both the qualifications of the employed labour force and the pattern of employment within manufacturing.

Since 1977 the knowledge intensity of trade<sup>1</sup> has increased steadily and persistently, from an index value of 0.70 in 1977 to just over 1 in 1994, rising by 44 per cent over this period. Whereas in the first half of the 1970s world manufacturing trade was concentrated in lower knowledge-intensive activities, by 1994 it was marginally more concentrated in higher intensity rather than lower intensity industries.

This has led to an emphasis on more effective accounting for knowledge assets (e.g. Sveiby 1997) and the different requirements for managing the knowledge firm effectively (e.g. Nonaka & Takeuchi 1995; Ruggles 1997). These include the fact that value to the company, and hence power, rests more on capability and reputation than position, and that long-term relationships are likely to be far more important than short-term financial objectives.

In particular, knowledge workers (Jones 1982; Drucker 1993) or ‘symbolic analysts’ (Reich 1991) possess the skills of problem identification, problem solving, and brokerage. These skills are difficult to duplicate (hence highly priced) and impossible to manage through any command-control approach.

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<sup>1</sup> The index of knowledge composition of manufactured exports is derived by weighting the exports by industry of a given country by the average knowledge intensity of that industry in the major OECD countries. It thus provides a measure of the knowledge intensity of the commodities included in that country’s exports, but in terms of the average intensity of industries in the major OECD countries. Thus this index does not assess the knowledge intensity of the processes in each country which generate the exports (e.g. the degree of value added and of technology transfer), nor does it take account of the specific within-industry composition of exports. The average knowledge intensity of an industry in the major OECD countries is measured in terms of the ratio of research and development to production in that industry for those countries.

### 1.3 Impact of Information Technology on Knowledge Acquisition and Management

Information technology offers great promise, according to its proponents, to dramatically increase the effectiveness and productivity of knowledge (in the form of information) management. Ready access to comprehensive databases of client and product information, through electronic networks, and the possibility of email and bulletin board sharing of knowledge and experience between knowledge specialists, as offered by a number of Lotus Notes-based 'knowledge systems', provides the basis for 'informating' (Zuboff 1988) the organisation.

Under these conditions the less accessible personal and tacit knowledge resources (see next section) of the individual can be replaced by encoded knowledge located in information technology systems. In addition, it is possible to locate and draw on the knowledge resources of company staff regardless of where they are physically located.

### 1.4 A New Economics of Knowledge

Drucker has emphasised the need for a new theory of the knowledge-based economy, as current assumptions about economic behaviour quite obviously do not apply. Thus, in the knowledge economy, imperfect competition is inherent, increasing returns are the rule rather than the exception (Arthur 1988), neither consumption nor investment appear to determine the level of knowledge production, and the quantity of knowledge bears no relationship to outcomes.

Scientific knowledge has been regarded as having a range of intrinsic characteristics that make it impossible for it to be treated, or managed, as just another commodity; as a consequence there is an imperfect market for this knowledge, which causes business to under-invest. This market failure provides a justification, indeed a powerful reason, for governments to act to supplement and stimulate this investment. The list of these 'intrinsic characteristics' varies, but is generally considered to include:

- **limited appropriability**
  - this claim rests on the view that it is impossible to create a market for knowledge once it is produced, because others can access the knowledge at little or no cost, so producers have a limited ability to appropriate the benefits of their investment;
- **non-rivalry**
  - knowledge is a non-rival good, in that once produced, its use by one person does not preclude its availability and use to others—an important consequence is that 'the good's production costs are fixed: once the good has been produced, there is no need for continuing investment because there are no production costs in replicating it' (Callon 1994, p. 400.);

- **uncertainty or risk**
  - knowledge outputs are not precisely predictable—it is necessary to invest in knowledge production without knowing the outcome with any accuracy;
- some commentators have added the quality of **durability**
  - the knowledge good is not destroyed or altered by its use—indeed increased use of a piece of knowledge can increase its value and applicability;
- a final characteristic commonly referred to is **indivisibility**
  - knowledge must be aggregated on a certain minimum scale to form a coherent picture before it can be applied.

Together, these characteristics provide the basis for scientific knowledge being treated, and supported, as a public good, the production of which is subject to market failure.

This market failure analysis has been widely accepted as providing a sound justification for government intervention to support research with public funds.

There are at least three major challenges to the current paradigm, and the views of research and industrial innovation upon which they are based.

The first of these is concerned with the supposed **non-rivalry** and **appropriability** of scientific knowledge. The common emphasis is on the limited extent of control of new knowledge by the research performer. However, the fact that the producer of knowledge may have limited control over who can get access to it does not necessarily imply that such knowledge is freely available.

This argument can be countered from two perspectives. One is that the sociology of scientific knowledge has demonstrated that an isolated ‘piece of knowledge’, statement, or theory, is quite literally useless—indeed has no meaning—unless it is embedded in a supporting context of well developed theory, evidence and argument. Making use of any piece of knowledge requires a considerable investment in establishing the necessary interpretive context of theory, concepts, data and tacit experience.

The other perspective is that a scientific or technical resource has no intrinsic value or use. It is only when the necessary ‘complementary assets’ of technological support systems, production capacities, and distribution networks are appropriately assembled that knowledge can be converted to a profitable use.

Thus a public good is not necessarily a free good. The extent of the public or private nature of scientific knowledge is highly variable, and context-dependent, rather than an intrinsic property of the knowledge itself:

Degrees of appropriability and of rivalry are the outcome of the strategic configurations of the relevant actors, of the investments that they have already made or are thinking of making.

(Callon, 1994, p. 407)

The second major challenge comes from the phenomenon variously referred to as **irreversibility, increasing returns, or path dependency** (Arthur 1989). In order to limit the potentially infinite number of goods that could be offered on the market place, to allow the consumer the possibility of ‘ordered, informed choice’, and to ensure the possibility of a return on the investment in new technology and new products, what Callon aptly calls ‘that strange conspiracy between technology and the marketplace’ (Callon 1994, p. 408) occurs to develop a common techno-economic trajectory. Furthermore, it is the initial decisions concerning technology and design that commonly provide the powerful and self-reinforcing determinants of that trajectory.

Under these conditions, the emergent trajectory acts as an active shaper of not only the value of knowledge items, but of the extent to which they have any meaning. The overall process can be presented as the generation of knowledge which ‘fits’ within the system, and a large range of other knowledge candidates which do not fit, at least at that time, are left to pile up in storage, some to be used at a later date, and many never to see the light of day again.

Under these conditions, what is commonly called public good science might be seen as a source of variety in knowledge, outside the confines of the accepted trajectories. It provides the mutations which are assessed via the selection criteria of the existing evolutionary systems, and which occasionally challenge successfully, and transform, the dominant paradigm, leading to the formation of completely new bodies of knowledge, new technologies, and new industries.

The third major challenge is presented by advances in the theoretical and practical understanding of **the innovation process**. This issue is treated in Section 3.

One consequence of the changing economics of the knowledge market is that the normal reliance on protection of a crucial asset, and exploitation of scarce resources, apparently does not always apply. In the information technology industry itself, the free sharing of knowledge, as through open systems, has emerged as an effective strategy for maintaining market competitiveness and share.

## 1.5 The Nature and Basis of Reliable Knowledge

In recent years, the essentially positivist view of knowledge has come under considerable challenge. Sociologists of scientific knowledge have challenged the privileged status of abstract scientific knowledge, apparently demonstrating the social and cultural situatedness of knowledge, and the social negotiation processes which are used to test and refine what is accepted as knowledge. Cognitive

anthropologists have argued that all knowledge has a context, and post-modernists have challenged the idea of fundamental truth, rewriting it as a 'story of our times'.

In summary, knowledge is apparently becoming more and less important, simultaneously. On the one hand its profound and privileged status as truth and the representation of reality has been significantly challenged. To proclaim that one is pursuing truth or knowledge is no longer an unquestioned justification; indeed, in a number of areas, such a stance is criticised as amoral, or lacking in human concern.

On the other hand, the effective production and application of knowledge is being seen as a crucial basis of economic competitiveness, and essential for the effective operation of a modern economy and society.



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## Classifications of Knowledge

Attempts to develop comprehensive classification systems for knowledge have been a regular component of epistemology, and management. Thus Russell (1912) distinguished between ‘knowledge by acquaintance’ (knowledge of someone or something on the basis of confrontation or experience) and ‘knowledge by description’ (second-hand knowledge transferred by an individual or learnt from a document). Ryle (1967) introduced another distinction between ‘knowing that’ (some proposition is true) and ‘knowing how’ (to perform some action).

As long ago as 1958, Michael Polanyi introduced the distinction between ‘explicit’ or ‘codified’ knowledge, and ‘tacit’ knowledge. The latter is knowledge that individuals possess without being aware of it, or which they cannot easily, if at all, articulate. For Polanyi, this included the realm of craft knowledge, learnable only by observation and imitation.

However, in the past thirty years, the major objective of classification has been to provide a reliable basis for accounting for, and where possible managing, knowledge production, mainly in the form of research.

The simple classification which has been in widest use in the past fifty years of the modern organised scientific research has been that between ‘basic’ or ‘fundamental’ research and ‘applied’ research. The former described research that was driven by the intellectual demands and challenges of the discipline, whereas the latter referred to the solution of technical problems by scientific means. The former was largely the province of the university, the latter of the industrial laboratory.

This distinction was enshrined in the first international attempt to provide a common basis for accounting and reporting on national expenditures on research and development, named after the Italian town in which the experts met—the Frascati convention. It continues in a modified form to this day. The modifications were the introduction of two new categories: strategic research, and experimental development, completing the linear model and explicitly introducing the development component that was supposed to link research to practical outcomes.

The category of strategic research was introduced to encompass that research which is directed to an identifiable non-disciplinary objective, but which does not have the specific problem-solving characteristics of applied research. In Australia, these categories were further refined, or conflated, to produce ‘pure basic’ and ‘strategic basic’ research.

Pure basic research is carried out without looking for long-term benefits other than the advancement of knowledge. Strategic basic research is directed into specified

broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for the solution of recognised practical problems.

Some have argued that these categories were produced in the context of growing demands for accountability for the national research budget, and the dominance of the linear model, in order to support the view that almost all research contributes directly to socioeconomic objectives, in some way.

A number of variants have also been proposed. For some time in the early 1970s, the categories of 'curiosity-oriented' and 'mission-orientated' were in favour. However, the fact that the motivation of the researcher could not be clearly established, particularly in hindsight, and that outcomes were not strongly associated with the motivation, led to this approach being dropped.

In the past few years there has emerged, largely from the sociology of scientific knowledge, some rather more sophisticated, and grounded, categories of knowledge. Based on Collin's analysis, but with a stronger awareness of organisational design and management, Blackler (1995) has proposed five categories of knowledge:

- embrained knowledge
  - abstract knowledge dependent on conceptual skills and cognitive skills, and
  - generally conflated with scientific knowledge and accorded superior status;
- embodied knowledge
  - action-oriented and likely to be only partly explicit,
  - transmission requires face to face contact, sentient and sensory information and physical cues, and
  - acquired by doing and rooted in specific contexts;
- encultured knowledge
  - related to the process of achieving shared understanding, and
  - is embedded in cultural systems, likely to depend strongly on language and hence to be clearly socially constructed and open to negotiation;
- embedded knowledge
  - resides in systematic routines,
  - relies on the interplay of relationships and material resources, and
  - may be embedded in technology, practices, or explicit routines and procedures; and

- encoded knowledge
  - knowledge recorded in signs and symbols, such as books, manuals, codes of practice, and electronic records,
  - encoding requires distilling abstract codified knowledge from other richer forms of knowledge.

Blackler develops a useful 2x2 matrix of knowledge organisation types, which provides a framework for considering what type of knowledge is most important to various organisation types.

	<b>Problem Type</b>	
<b>Effort</b>	Routine	Irregular
Individual	Expert dependent, reliant on <i>embodied</i> knowledge	Symbolic analyst dependent, reliant on <i>embrained</i> knowledge
Collective	Knowledge routinised, reliant on <i>embedded</i> knowledge	Communication intensive, reliant on <i>encultured</i> knowledge

Fleck (1997) has developed an alternative classification:

- formal knowledge—
  - embodied in codified theories, formulae,
  - usually encoded in textual or diagrammatic form, and
  - acquired through formal learning;
- instrumentalities
  - embodied in tool and instrument use,
  - requires other components (informal, tacit and contingent) for effective use, and
  - learnt through demonstration and practice;
- informal knowledge
  - embodied in verbal interaction (rules of thumb, ‘tricks of trade’),
  - held in verbal and sometimes written form (manuals, guidebooks), and
  - learnt through interaction with a specific context/milieu;

- contingent knowledge
  - embodied in the specific context,
  - distributed,
  - can appear trivial,
  - sometimes can be ‘looked up’, and
  - acquired by on-the-spot learning;
- tacit knowledge
  - embodied in people,
  - rooted in practice and experience, and
  - transmitted by apprenticeship/mentorship; and
- meta-knowledge
  - embodied in the organisation,
  - general value, cultural and philosophical assumptions,
  - can be local or cosmopolitan, and
  - acquired through socialisation.

Alternative approaches to classification of knowledge, which have emerged recently along with the interest in the knowledge economy and knowledge management, have their focus on economically useful definitions of knowledge. ‘Human capital’ and ‘intellectual capital’ have been used for some little time, but with little precise definition or quantification.

Sveiby (1997) has classified the intangible assets of a company in terms of employee competence, internal structure and external structure.

Perhaps the most encompassing approach to the present has been that of Lundvall (1994), who proposed four categories of economically relevant knowledge: know-what, know-why, know-who (when and where) and know-how. This classification avoids awarding pre-eminence to any category of knowledge, acknowledging that each can contribute significantly to achieving desired outcomes in its own appropriate context:

- know-what, or catalogue knowledge (Millar et al 1997)
  - knowledge about facts, approximating what is normally called information;
- know-why, or explanatory knowledge
  - scientific knowledge of principles and ‘laws of nature’;
- know-who, or social knowledge
  - refers to specific and social relations, not just who fills which position (know-what), but who has control of the resources needed at any particular time or situation;

- know-when and know-where
  - concrete and economically useful knowledge about markets; and
- know-how or process knowledge
  - refers to skills, the capability to organise resources to achieve desired outcomes on a practical level.

A more detailed analysis of the various components of knowledge management within an organisation has recently been developed by Johnston and Blumentritt (1998). These are:

- knowledge identification—the process of locating and recognising knowledge which is relevant to the organisation
  - this might be the result of a specific or a routine search, contact with a member of a network, or arise through serendipity, and
  - regardless, the process depends on a selection mechanism which can identify relevance;
- knowledge acquisition—the process of obtaining knowledge previously not available to the organisation in a form in which it is available for exploitation
  - this procedures could vary from simply obtaining public knowledge, as from the literature, to conducting a survey of customers, and
  - a great deal of knowledge acquisition occurs at the individual level;
- knowledge generation—the process of creating new knowledge within an organisation, whether through traditional research and development, or the linking of previously separate information (e.g. on customer needs and technology capabilities)
  - much of this occurs at the individual or team level;
- knowledge validation—the process of determining both the accuracy and the value of knowledge, from the perspective of the organisation;
- knowledge capture—the process by which the organisation gains control over particular knowledge
  - this process may involve the purchase of rights to certain proprietary knowledge from another firm, or it may be the transformation of the personal knowledge of a member of staff, or the output of a team, into an explicit organisational resource, and
  - only with capture can the knowledge become an exploitable asset of the organisation;

- knowledge diffusion—the process of spreading knowledge throughout an organisation, and to targets outside the organisation (e.g. customers or regulators)
  - this process may take place in a relatively informal manner, through conversations and discussions, or through more explicit processes designed to ensure that relevant staff and sections are informed about particular knowledge assets considered valuable for a particular objective;
- knowledge embodiment—the process of transforming knowledge within the organisation into a form in which its value becomes evident inside and outside the organisation
  - this process may involve training, establishment of new procedures, or absorption into the organisational culture, and
  - diffusion can occur without embodiment, usually resulting in the knowledge asset being less readily available or used;
- knowledge realisation—the process of identifying, or becoming aware of, knowledge assets held within an organisation (as such a subset of knowledge identification) and managing them to achieve the maximum value-added to the company and customers
  - the development and mining of technology or knowledge platforms is one approach to knowledge realisation; and
- knowledge utilisation/application—the process of deliberately and intentionally using knowledge to pursue a specific objective.

A summary of the current state of knowledge classification systems might conclude:

- Current administrative classifications (e.g. Frascati) are well-established and reasonably accurate, but there must be some doubt whether they represent a very valuable picture of knowledge stocks and flows; still less do they provide a sound basis for evaluation or strategic planning.
- Epistemological-sourced classifications (e.g. Collins, Blackler) are becoming quite sophisticated, and hold considerable promise in supporting the development of improved models of knowledge strategy and management within organisations. However, it is less clear that these classifications can readily be used in more effectively shaping the production, distribution or application of knowledge at the national level.
- Economically-oriented classifications (e.g. Lundvall) provide the basis for an improved understanding of the mechanisms, and the extent, of the contribution of knowledge to economic activity. At this stage, however, they would appear to offer limited instrumental guidance to managing the national knowledge system.

Research to draw on the insights of each approach with the objective of providing an improved information base and framework for understanding and shaping the national knowledge system may well be timely.

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## Trends in Method and Location of Knowledge Production, Distribution and Application

The most comprehensive analysis and model of the changing mechanisms and location of knowledge production and use has been developed by Gibbons et al (1994). They argue that the traditional mode of knowledge production and application, 'Mode 1', is steadily being complemented, and in some cases supplanted, by a new 'Mode 2'.

The less than elegantly named 'Mode 1' encapsulates the traditional model of knowledge generation and application, at least in Western industrialised nations.

The term Mode 1 refers to a form of knowledge production—a complex of ideas, methods, values, norms—that has grown up to control the diffusion of the Newtonian model to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice. Mode 1 is meant to summarise in a single phrase the cognitive and social norms which must be followed in the production, legitimation and diffusion of knowledge of this kind. For many, Mode 1 is identical with what is meant by science. Its cognitive and social norms determine what shall count as significant problems, who shall be allowed to practise science and what constitutes good science. Forms of practice which adhere to these rules are by definition scientific while those that violate them are not.

(Gibbons et al, pp. 2–3)

In summary, under Mode 1:

- problems are set and solved in a context governed by the largely academic interests of the relevant research community;
- problems, research agendas and accepted solutions are largely determined within a disciplinary framework;
- the community of discourse is predominantly homogeneous;
- its form of organisation is hierarchical, and there is a tendency, if not an outright commitment, to preserve existing forms of organisation; and
- it maintains a high level of internal quality control.

The logic of Mode 1 comes from its internal organisation and highly developed social control mechanisms. Its institutions tend to be centralised and stable. Their internal orientation, like other professions, tends to make the system fairly immune from changes occurring in the external environment. Its control operates through its management of entry, through training and accreditation, and its provision of what was until relatively recently a reasonably secure, high status career.

The approach of Mode 1 carries a clear distinction between what is disciplinary and internal—fundamental research—and what is shaped by external interests but necessarily draws on the theoretical core of knowledge—applied research and technology development.

The central thesis of the Gibbon's consortia is that the parallel expansion in the scale of actual or potential knowledge production on the supply side and in the requirements of specialised knowledge on the demand side has not produced a happy equilibrium. Rather, the associated tensions and pressures have created the conditions for a new mode of knowledge production, which is labelled 'Mode 2'.

The Mode 2 knowledge production system is characterised by:

- problems substantially set and solved in the context of application;
- a transdisciplinary approach and resources;
- a heterogeneous set of skills and experience directed to the knowledge production;
- weakly institutionalised, transient, and heterarchical organisational forms; and
- quality control not only through internal peer review, but also against a wider set of 'application' criteria reflecting the wider social composition of the interested audience.

In a little more detail, *the context of application* is not just the meeting of industrial needs; rather, a broad awareness, based on the involvement of a range of stakeholders, shapes the criteria for knowledge which is likely to be considered valuable.

To qualify as an identifiable form of knowledge production, the process of inquiry must be guided by a consensus as to appropriate cognitive and social practice. Under Mode 2, this requires the involvement of a *transdisciplinary* approach. This involves the context of application shaping the research effort from the outset and in a continuing dynamic manner, a recognisable contribution to knowledge, but not necessarily in its disciplinary form, and communication, and hence diffusion, of results, directly to stakeholders.

The rapidly evolving demands on knowledge production under Mode 2 requires *heterogeneous* research teams that change as requirements evolve. Accordingly there occurs an increase in the number, variety and differentiation of knowledge production sites:

. . . no longer only universities and colleges, but non-university institutes, research centres, government agencies, industrial laboratories, think-tanks, consultancies.

(Gibbons et al, p. 6)

Under Mode 2, researchers gather in *transient* teams to address a particular problem, and break up when the problem is solved or redefined. However, the communication and networks are retained, to be drawn on in new contexts. Just as the organisational form, patterns of funding are highly diverse, drawing on a wide array of sources.

The *quality control* process is more broadly based, but not necessarily any the less demanding as a consequence; indeed the reverse can be the case.

While there may be disagreements about various aspects of the Mode 2 thesis, it does appear to capture in a single model the majority of forces operating on, and changes to, national research systems. This analysis can be linked to two further distinct developments.

First, at least in certain knowledge-intensive industries, there has been a remarkable increase in the level of industry-employed researchers publishing in mainstream disciplinary journals (see, for example, Martin). This phenomenon is in apparent direct contradiction to standard economic requirements that intellectual property be concealed and protected.

The explanation appears to be twofold. First, in accord with Mode 2, private companies accept publication as one of the necessary outcomes. Second, and probably more importantly, such publications assist firms in maintaining existing research networks and entering new ones, and in recruiting high calibre staff and collaborators.

The second development is reflected in the growing emphasis on national innovation systems (NIS). Whereas under the linear model it was research that was the prime driver of economic outcome, the NIS model places the emphasis on a wide variety of structures and capacities of a nation, and particularly on the interaction between them.

Much of the recent analytical work on the relationship between technological development, innovation and economic performance has focussed on the concept of the 'national innovation system'. In this, the emphasis is not just on the constituent actors within that system—firms, universities, government research laboratories and so on—but more importantly on the relationships and linkages between them.

The concept of the national innovation system has come to prominence for several reasons. One is the growing economic importance of knowledge, with many economic activities becoming increasingly knowledge-intensive. A second and closely related reason is the widening range of institutions involved in knowledge generation. Another reason is the emerging interest in systems approaches to the study of technological development, not least because of widely recognised limitations of the traditional linear model of innovation.

It is now recognised that many important potential innovations and the emerging generic technologies likely to underpin them are characterised by the confluence of a number of component technologies. This creates the need for multi-disciplinary, multi-institutional and even, in a number of cases, multinational effort, and hence for networks, cooperation and partnerships.

Furthermore, many of the policy issues thus raised, such as intellectual property rights and the commercialisation of new ideas, require the development of effective links between science and technology, on the one hand, and the financial and legal systems, on the other. The development of such links is becoming more crucial. At the heart of the concept of the national innovation system is a belief that a better understanding of the linkages between the component actors in the system is the key to improved technological performance:

Within this complex structure of differentiated knowledges, what determines performance is not so much knowledge creation as the ‘distribution power’ of the system: the system’s capability to ensure timely access by innovators to the relevant stocks of knowledge. The distribution power of the system affects risks in knowledge creation and use, speed of access to knowledge, the amount of socially wasteful duplication, and so on.

(OECD 1994a, p. 13)

The overall innovation performance of an economy depends not so much on how specific formal institutions (firms, research institutes, universities, etc) perform, but on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, and legal frameworks).

(OECD 1994b, p. 4)

The policy implications of the national innovation system concept are far-reaching. As OECD has argued, it suggests a new rationale for government funding of research and technology based on correcting systematic failures—in other words, the lack of effective interactions between the actors in the system. It also points to the need for new types of policies to address those systematic failures; policies that develop, extend and strengthen the communication and the flows of information, and the networking, cooperation and linkages between the component organisations that make up the national innovation system.

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## Summary and Conclusions

A number of major conclusions emerge from this analysis of the changing nature and roles of knowledge in meeting the economic, social and cultural objectives of modern societies.

- The parallel expansion in both the demand for and suppliers of marketable knowledge is leading to the emergence of a knowledge industry which operates increasingly and in many respects under market conditions. This is creating the conditions for knowledge production and transmission to be organised in new ways.
- Under these conditions the dominance of the traditional knowledge suppliers—the universities and the disciplines—is open to erosion. In Australia this has long been challenged by the charter and operations of the CSIRO. However, in recent times this has been supplemented particularly by the entry of mainstream firms into the knowledge business, and the growth of specialist knowledge ‘boutique’ consulting firms. (The downsizing of the public sector and many large firms has, at the same time, reduced their knowledge capacity).
- At the same time the strengths of at least some of these university institutions in market terms (such as their acknowledged high quality staff, their international brand image, and the strengths of their relationships with major knowledge users) will provide a basis for them to maintain a strong position in the knowledge market.
- The location and form of knowledge production is being transformed, at least in part, through the emergence of a new approach or mode (‘Mode 2’). Under this mode problems are set and solved in the context of application, rely on a transdisciplinary approach and assembling an appropriate set of heterogeneous skills, and transfer results directly to application via the direct involvement of key stakeholders. This mode operates most strongly in the newer knowledge-intensive industries.
- The strong emergence of the ‘research centre’ as the dominant organisational form for research in Australian universities is in part a response to the pressures and opportunities of the knowledge economy.
- The ‘national innovation system’ approach has placed a greater emphasis on the variety of components of the infrastructure that support innovation (not just research or research and development) and in particular on the linkages between them. As a consequence there may be a need for an emphasis in government policy on strengthening the flow of knowledge throughout the economy, as much as on supporting knowledge production. The Cooperative Research Centres program can be seen to be directly addressing this issue.

- Public good science serves as a training ground for researchers, and provides the major source of variety needed to continually refresh the evolution of new knowledge outside existing trajectories. Without this variety, the richness and strength of the knowledge stream could rapidly decline.
- The relative weakness of the knowledge-intensive industries in Australia presents a considerable hurdle for Australian knowledge suppliers, regardless of globalisation. In order to operate effectively under Mode 2, Australian teams of sufficient scale will need to invest in building knowledge relationships with the key players, principally overseas.

In summary, the economic competitiveness of a nation, together with its ability to meet social and cultural objectives, rests crucially on the strength of its knowledge infrastructure and the strength of the connections between its various components. The generation and application of relevant knowledge needs to be recognised as a central economic activity.

Centres of specialist knowledge production, with a scale appropriate to compete in the global knowledge economy, are essential. But so is the linkage of these centres into the milieu of knowledge application. The growth of linkage schemes and practices in recent years would appear to have been timely. But evaluations show that in many cases these linkages are still treated as marginal, by both companies and researchers. Amplifying these linkages may be the most important policy challenge ahead.

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