1. Introduction

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AN OLD QUESTION . . .

Innovation is vital to meeting the national challenges of the twenty-first century. As the economist William Baumol put it: ‘Under capitalism, innovative activity – which in other types of economy is fortuitous and optional – becomes mandatory, a life-and-death matter’ (Baumol 2002: 1). It lies at the heart of discussion of the concept of the ‘knowledge economy’, that is, the theory that advanced economies are increasingly based on the production, distribution and use of knowledge, and that their future competitive advantage lies in how efficiently and effectively they are able to engage in these activities (Baumol 2002; DTI 2003; NESTA 2006).

Every year the UK spends around £21 billion of public and private sector money creating knowledge – an impressive figure but only a drop in the global ocean of R&D spending, which the OECD estimates at around £500 billion (\$720 bn in 2004). Even this is likely to be an underestimate because we don’t really know how much some of the major new players like India and China are spending. As we move from the eras of labour and of capital intensity, so knowledge is increasingly recognized as the next major source of international competitiveness. No enterprise – and at aggregate level, no nation – wants to see itself left behind in this race, and so we see the rise of the ‘knowledge economy’ as the next step in economic evolution.

Small trading nations like Denmark and Ireland see their future as depending not on owning or running large factories but in contributing the design and service elements of a globally distributed manufacturing value network. And larger players like Germany and France wrestle with the difficult choices of supporting domestic industries or following the trend towards ‘outsourcing’ much of the downstream manufacturing activity and concentrating on the high-value aspects. Even giant economies like the USA are facing the challenge of lower-cost manufacturing and looking to regroup around their core strengths in knowledge-based work. The result is a race to invest more and more in creating new knowledge to put the clear blue water between the different national ships in the competitive race.

Faced with such widening gaps, most advanced economies have adopted some version of the 'knowledge economy' as an 'escape route' – climbing up the value-added ladder for goods and services. For example, in 2003 the UK Department of Trade and Industry stated that the government wanted 'the UK to be a key knowledge hub in the global economy . . . In terms of business R&D and patenting we will aim to be the leading major country in Europe within ten years' (DTI 2003: 1). It went on to make a number of general recommendations, including the development of a national Technology Strategy. Across the European Union (EU) since the mid-1990s a succession of measures to increase R&D spend have been introduced, including a series of Research and Technological Development (RTD) framework programmes. In March 2000, the Lisbon Council committed the EU to the objective of becoming the 'most competitive and dynamic knowledge-based economy in the world' by 2010. To achieve this it established (in 2002) the goal of increasing its R&D expenditure to 3 per cent of GDP by 2010.

Services account for 75 per cent or more of these economies, but here too the chilly winds of international competition are being felt. With infrastructures such as the Internet, the traditional problems of local production and distribution have given way to many services being globally traded – and to the same kinds of shift towards lower-cost providers. To counter this, service industry firms are increasingly committing to knowledge-based competition, investing in R&D and putting in place structures to support a much more innovation-led kind of business.

The result is a huge push down on the accelerator pedal of knowledge creation. Any way you look at it, there's a great deal of knowledge being generated. But investing on that scale inevitably prompts the question – not least from the taxpayers and shareholders whose money is being spent – is it worth it? Do we get the maximum return for our dollar, pound or yen – does the R&D goose really lay golden eggs? We can certainly find examples of spectacular gains which follow good research – it's the rationale, for example, behind the pharmaceutical industry's continuing to spend 15–20 per cent of its turnover on fuelling the discovery cycle through frontier research. When they get it right – as with blockbuster drugs such as Zantac or Viagra – the returns run into millions of pounds per day. The relentless pursuit of progress along the pathways laid down by Moore's law in electronics (that performance doubles every 18 months) is driven by a huge research investment on the part of firms such as Intel and AMD and their extended equipment supply chains.

And public sector projects do pay off – not just via the occasional spin-off like Teflon coatings for non-stick pans, but in the deep and wide-ranging creation of opportunities – for example, much of the information and

communications technology (ICT) revolution has its roots in public sector programmes, primarily around defence activities.

But although there are returns on R&D investment, the question remains whether these are sufficient to justify the huge input. Does new knowledge create wealth or social value – and does the system do it as ‘efficiently’ as it might? The UK, for example, is often typecast as being good at inventing and weak at capitalizing on those initial inventions. The usual suspects are wheeled out in evidence – the first computer, whose roots go back to wartime experiences at the code-breaking centre in Bletchley Park. Or the body scanner (which has become ‘the photocopier of the medical sector’ but whose later (and profitable) exploitation was not carried through by EMI but by GE, Siemens and Philips). But this negative view ignores innovation success stories in areas such as pharmaceuticals and aerospace – and it underlines the need for patience. Lead times between initial knowledge production and later commercialization in sectors such as these routinely exceed 10–15 years but their impact is none the less significant when they do finally come through as widely diffused innovations.

INVENTION ISN’T ENOUGH

The reality is that investing in creating knowledge *does* create value – through new products and services which can satisfy existing markets and create new ones, and through improvements in productivity brought about by improved or radically new and more effective processes. But we also need to recognize that innovation is a *process* – an extended set of activities that translate new knowledge into something of value. It isn’t – despite the persistence of images such as Archimedes in his bath or cartoon characters with light bulbs flashing above their heads – simply a matter of a ‘Eureka!’ moment, but rather a long and painstaking process of translating the initial idea into something useful – and used.

The UK DTI’s definition of innovation as ‘the successful application of new ideas’ sums this up quite well. Most people would accept that there’s more to innovation than the invention stage – for example: ‘Industrial innovation includes the technical, design, manufacturing, management and commercial activities involved in the marketing of a new (or improved) product or the first commercial use of a new (or improved) process or equipment’ (Freeman and Soete 1997: 3), or ‘Innovation does not necessarily imply the commercialization of only a major advance in the technological state of the art (a radical innovation) but it includes also the utilization of even small-scale changes in technological know-how (an

improvement or incremental innovation) . . .’ (Rothwell and Gardiner 1985: 168).

Moreover, innovation involves two different strands being woven together – a ‘supply’ strand of knowledge about possible means and another ‘demand’ strand of knowledge about needs. Innovation results from the intertwining of these two – as Chris Freeman, one of the pioneer economists who worked in industrial innovation put it, ‘necessity may be the Mother of invention but procreation still needs a partner!’

That takes us to the core of the problem – getting value from knowledge depends on understanding and organizing this innovation *process*. And whether at the firm or the national level, we need to recognize that this is a complex *system* of interacting players – innovation is emphatically not a solo act. If we wish to increase the effectiveness of that system, we should do more than simply call for more money to be thrown in at the start, and instead try to understand and improve the workings of the system itself. What are the mental models that underpin our thinking about how innovation works? Do we know who the relevant actors are and what ‘good practice’ might be in terms of getting them to work better together? Are some innovation systems – whether across a particular sector, in a region or around a major transnational firm – more effective than others – and if so, why?

These are not trivial questions – take the idea of mental models as an example. If we believe innovation works in a particular way, then we will organize and structure the system around that model and exclude alternative views. But this carries the risk that we work with simplistic or inappropriate models and create less than effective systems as a result. If we believe that innovation is, like the cartoon characters with the light bulb flashing on at the ‘Eureka!’ moment, then we’ll build innovation systems that are great at invention. But coming up with new ideas is no guarantee of successful innovation – as many originators of good ideas know to their cost. (For example, Elias Howe invented the sewing machine, but it was Singer who actually made the money from promoting the diffusion of the idea.) If we believe innovation is a linear process, a logical sequence of activity in which the R&D front end creates a knowledge push and innovations happen as a result of this momentum, then we’ll create structures and mechanisms that assume ideas will be taken up – despite the clear evidence that the world does *not* beat a path to the doors of every mousetrap salesman with a novel idea.

In similar vein, if we believe that the main contribution of universities to innovation is to incubate entrepreneurial ideas which then spin off, then we’ll invest in structures and mechanisms to support this activity. Yet the evidence is that – while the model works spectacularly well for a few high-tech firms in sectors such as electronics and biotechnology – the reality is

that very few firms are born out of universities, even in the USA, where this model is widely thought to work best (Hughes 2007).

The issue is not about debunking models that are too simplistic, but rather to develop richer, more accurate understanding of where and how innovation works – and then to use that as a template for policy and practice. We need to experiment around emergent good practices and to evolve more appropriate local, regional and national innovation *systems*. Indeed, in such a globalized and technically interconnected world we may need to look at developing an international or globally networked innovation system.

So the challenge in getting value from knowledge involves rethinking our innovation systems and making sure that their design is fit for purpose and their operation is effective. The trouble is that we are not dealing with simple cuckoo-clock mechanisms but with complex, dynamic and multi-player systems. As if that weren't hard enough, we also need to recognize that the innovation game itself is changing and being played by a different set of emergent rules in the twenty-first century.

NEW RULES OF THE GAME

Whilst it is clear that the 'exploitation/exploration' question is not new and has led to the development of firm-specific approaches to resolving the tension between them, we would argue that this old question is now challenged by a significantly different context within which firms operate. Changes along several core environmental dimensions mean that the incidence of discontinuities is likely to rise – for example in response to a massive increase in the rate of knowledge production and the consequent increase in the potential for technology-linked instabilities. But there is also a higher level of interactivity among these environmental elements – a complexity that leads to unpredictable emergence. For example, the rapidly growing field of VoIP (voice over Internet protocol) communications is not developing along established trajectories towards a well-defined end-point. Instead it is a process of *emergence*. The broad parameters are visible – the rise of demand for global communication, increasing availability of broadband, multiple peer-to-peer networking models, growing technological literacy among users – and the stakes are high, both for established fixed-line players (who have much to lose) and new entrants (such as Skype, recently bought by eBay for \$2.6 bn). The dominant design isn't visible yet – instead there is a rich fermenting soup of technological possibilities, business models and potential players from which it will gradually emerge.

Table 1.1 summarizes some of the key changes in the context within which search behaviour is located. Arguably these require firms to pay more

Table 1.1 *Changing context for search behaviour*

Context change	Indicative examples
Acceleration of knowledge production	OECD estimates that close to \$1 trillion is spent each year (public and private sector) in creating new knowledge – and hence extending the frontier along which ‘breakthrough’ technological developments may happen
Global distribution of knowledge production	Knowledge production is increasingly involving new players, especially in emerging market fields such as the BRIC nations (Brazil, Russia, India and China) – so the need for search routines to cover a much wider search space increases
Market fragmentation	Globalization has massively increased the range of markets and segments so that these are now widely dispersed and locally varied – putting pressure on search routines to cover much more territory, often far from ‘traditional’ experiences – such as the ‘bottom of the pyramid’ conditions in many emerging markets (Prahalad 2006)
Market virtualization	Increasing use of the Internet as marketing channel means different approaches need to be developed. At the same time emergence of large-scale social networks in cyberspace poses challenges in market research approaches – for example, My Space currently has over 80 million subscribers. Further challenges arise in the emergence of parallel world communities as a research opportunity – for example, Second Life now has over 6 million ‘residents’
Rise of active users	Although von Hippel long ago identified the active role that users can play in innovation, there has been an acceleration in the ways in which this is now taking place – for example, the growth of Linux has been a user-led open community Development (Von Hippel 2005). In sectors such as media the line between consumers and creators is increasingly blurred – for example, You Tube has around 100 million videos viewed each day but also has over 70 000 new videos uploaded every day from its user base

Table 1.1 (continued)

Context change	Indicative examples
Development of technological and social infrastructure	Increasing linkages enabled by ICTs around the Internet and broadband have enabled and reinforced alternative social networking possibilities. At the same time the increasing availability of simulation and prototyping tools has reduced the separation between users and producers (Schrage 2000; Gann 2004)

attention to the limits of their current models and add an element of urgency to the need to extend and develop new routines.

TOWARDS A 'FIFTH-GENERATION' MODEL OF INNOVATION

The question of mental models of innovation is a powerful one, since what we think about shapes what we pay attention to and what we create as an innovation system. One of the key thinkers on innovation for many years was Roy Rothwell, professor at SPRU who worked on Project SAPHO, an influential piece of research on how organizations manage the innovation process (Rothwell 1992). In this important paper he mapped out the changing landscape of our thinking around innovation models, grouping them into five generations – essentially dominant modes of thinking about the process. Over time we move from simplistic understanding to a richer and more complex one – reflected in the innovation systems we built and managed. Table 1.2 illustrates this evolution, and Figure 1.1 shows the process.

Arguably Rothwell's predicted 'fifth-generation' model reflects the emergent picture in the twenty-first century and gives us some clues as to the design rules for our complex innovation system. Elements of this will include:

From	Towards
Knowledge creation emphasis	Knowledge flows and their management
Knowledge ownership and use	Knowledge trading and use
Closed innovation models	Open innovation models
Linear models of knowledge flow within innovation	'Spaghetti' models with inside and outside connections
Passive users as consumers	Active users, co-creators

Table 1.2 Rothwell’s five generations of innovation models

Generation	Key features
First and second	Simple linear models – need pull, technology push
Third	Coupling model, recognizing interaction between different elements and feedback loops between them
Fourth	Parallel model, integration within the firm, upstream with key suppliers and downstream with demanding and active customers, emphasis on linkages and alliances
Fifth	Systems integration and extensive networking, flexible and customized response, continuous innovation

Figure 1.1 Fifth-generation innovation process

WEALTH FROM KNOWLEDGE

An early and influential innovation study back in the 1970s took this heading as its title – and it remains an important challenge (Langrish et al. 1972). Innovation can create value – not just financial wealth but also social value – but only if the system is well tuned and appropriate. So what is an appropriate model, deploying the principles outlined in the preceding section? And how far away from this model are we? For that matter, who are the ‘we’ who might share a concern for exploring these issues? There are certainly a number of interested players:

- Entrepreneurs trying to create new start-up businesses that deploy knowledge in new ways

- Managers in established businesses trying to improve productivity through the effective application of new knowledge, and who are also concerned with the ‘re-invention’ of the business through a form of corporate entrepreneurship
- R&D managers in the public and private sectors trying to improve the take-up of knowledge created in their groups
- Knowledge-intensive business service providers trying to build a business through enabling connections and flows within the knowledge system
- Government policy agents at local, regional and national level charged with improving the efficiency and effectiveness of the innovation system
- Supply chain ‘owners’ concerned to upgrade the system-level efficiency and effectiveness of their networks through innovation.

This book tries to bring together some of the thinking and research around the questions we have outlined above. It draws particularly on a large-scale research programme funded by the UK’s Engineering and Physical Sciences Research Council (EPSRC) and involving five universities (Cambridge, Cranfield, Liverpool, Loughborough and Imperial College London), together with the Advanced Institute for Management Research (AIM). The ‘Grand Challenge’ this group is addressing is that of innovation and productivity in the UK context, and we are trying to understand the system-level questions and how they might be addressed by focusing on four core themes:

- What’s going on at the moment? What is the context within which innovation happens in the UK system – who are the actors, what are the linkages, where are the strengths and weaknesses?
- How do new firms form on the basis of knowledge and its deployment? How can such entrepreneurial behaviour be understood and best enabled?
- How do established firms access and use knowledge to improve their current activities and generate new directions?
- What is the enabling infrastructure, both technological and organizational? What opportunities and challenges exist in mobilizing this infrastructure to underpin an effective innovation system?

Within each of these areas we have a number of direct research activities going on and we are – in keeping with a fifth-generation approach – trying to establish links and connections with other researchers and their knowledge to help populate the emerging map.

Although we focus primarily on the UK experience, we would argue that this is a problem of concern to a much wider audience and that the challenges posed are broadly similar. The book represents some of the early map-making and also highlights key research questions that need further exploration. It is organized as follows.

Part I looks at the context question. What is the current pattern in terms of knowledge production and does this translate into an enhanced competitive position? In their chapter on the UK Science Census Pablo D'Este and Andy Neely look at some of the statistical evidence and draw out some comforting but also some disturbing trends. Perhaps the most significant theme that emerges is that the game itself may be shifting away from concerns about relative amounts of expenditure and success in different R&D domains towards a global game where the ability to trade with other knowledge-producing partners becomes critical.

Linus Dahlander and David Gann look at the key question of 'open innovation' and explore the extent to which this is a new phenomenon as distinct from a rediscovery of an old and important innovation principle. They look at some of the forces shaping firms' search behaviour and the growing need for taking a more 'open' and proactive perspective on exploration activity.

Alan Hughes looks again at the evidence for the effectiveness of one of the persuasive models for capitalizing on our knowledge production investment – the university spin-off. Although this is a popular view, he suggests that the reality is that relatively little direct productivity growth arises from such activities and that simply pumping in more money to either knowledge creation or to fund the spin-off infrastructure may be misdirected. He shows, for example, that US productivity growth owes much more to Wal-Mart than to high-tech firms and their growth (although there have been some spectacular exceptions to this). Instead he argues that we might need to look at alternative views of universities as knowledge centres that create 'public space' within which a diverse set of network-based knowledge flows can happen.

Although much of the book focuses on UK experience, the chapter by Mark Dodgson and John Steen offers a different perspective – that of Australia. Significantly, although the economy has a very different shape, dominated by primary industries and operating in a different geographical zone, the challenges have a marked similarity. Future economic growth is likely to require a much higher level of knowledge intensity, based on increasing the rate of innovation. Despite its huge physical size, the economy is relatively small and cannot sustain a huge R&D investment; instead future growth will need to depend on a policy much more aligned with the principles of 'open innovation', trading knowledge in and out and

using it to enhance added value of primary resource exports. The chapter looks particularly at *how* open innovation can be configured, focusing on the issue of broking and intermediary services which can facilitate connections across a national and out into an international knowledge market.

Whilst innovation happens at the level of the individual enterprise, the rapidly rising stakes in the international competitiveness game make a persuasive case for looking at what governments might do to help. Whilst heavy hands-on intervention is often clumsy and ineffective – and increasingly outlawed under the emerging world trade regime – there are many ways in which state and regional development agencies can help improve the conditions within which innovation can thrive. But what are the effective modes of intervention and how can they be fine-tuned to support a vibrant open innovation system? In his chapter on UK government policy Tim Minshall looks at the historical evolution of innovation support and explores new directions for the future.

In Part II we shift our attention to the enterprise level and how knowledge can create and grow new business opportunities, for both established firms and new start-ups. Here the question of entrepreneurial firms and how they are formed and grow assumes particular relevance – and one of the places where this has happened in the context of a region famous for knowledge production *and* exploitation is Cambridge. In their chapter, Erik Stam and Elizabeth Garnsey look in detail at this experience, reviewing the literature on knowledge as a source of entrepreneurial opportunities, with evidence at both the regional and organizational levels. In addition they explore the causal mechanisms of new firm growth, discussing longitudinal case study research on problem solving and competence creation in such firms.

The other side of this coin concerns the question of how established firms can continue to innovate through the use of new knowledge. What stops them from doing so and what might facilitate greater use of such knowledge? What channels are more or less effective in enabling knowledge flow? When should they use established networks and when does it make sense to look for new and different connections to enable wider exploration of new options as well as more efficient exploitation of established fields?

In Part III these themes are explored in the chapters by Simone Ferriani, Elizabeth Garnsey and David Probert, and by John Bessant and Bettina von Stamm, which look at the phenomenon of radical or ‘discontinuous’ innovation. Under certain circumstances firms are forced to extend their repertoire of search strategies in order to deal with significant shifts in their operating environments – emergence of new market constituencies, of radically different technologies, of shifts in the regulatory context, etc. How do they do this – and what implications does this shift in search behaviour have

for the design and operation of effective innovation models that emphasize knowledge flows?

At the other end of the spectrum Richard Adams and John Bessant explore the question of slow take-up of well-established knowledge. Productivity gains can emerge as much from the faster adoption of proven knowledge among the mainstream population of firms as from deploying breakthrough innovations at the frontier. Using the example of advanced manufacturing techniques, they use the lens of diffusion theory to try and throw some light on why firms are slow and often resistant adopters – and what might be done to reverse this trend. Resistance to change is also a theme taken up by Sue Morton and Neil Burns in their chapter on the sources of resistance at a psychological and organizational level.

Part IV looks at the ways in which connections between knowledge-based institutions like universities and research institutes can be made. What types of infrastructures can help – or hinder – the knowledge flows that underpin effective innovation? What role do factors such as geographical proximity or technological channels (including the rapidly increasing Web-enabled options) play in facilitating rich and multidirectional flows? How can social systems and networks play a role in the innovation process? And what is – or could be – the role of intermediaries and brokers (individuals and agencies) in a high-performing innovation system?

Much depends on the nature of the relationship established between different actors in the knowledge flow process. Part of the difficulty with earlier models of innovation has been the use of terms such as ‘technology transfer’, which imply a somewhat serial and static process whereas – as Markus Perkmann and Kathryn Walsh argue in their chapter – the reality is that successful innovation results from strong *relationships* rather than short-term contracting behaviours.

At the heart of the knowledge flow question is, of course, the individual motivation to engage in this kind of activity, and in their chapter Pablo D’Este and Andy Neely look more closely at this. In particular they examine two key issues – *who* in the academic world interacts with industry and *why* do they do so? This assumes considerable relevance when we consider that, over the past two decades, there has been a significant increase in the perception that knowledge transfer/interaction is an important mission of universities alongside their more traditional roles in teaching and fundamental research.

In their chapter on geographical proximity Kate Bishop, Toke Reichstein and Ammon Salter look at the evidence for the argument that being close to universities helps facilitate innovation. Their conclusions are that, despite the significant advances in communications technology, innovation still depends heavily on proximity factors. But they also suggest that the impact

of geographic proximity on university–industry links is not always positive, stressing the importance of agency in making the most of physical location.

This theme is picked up in the chapter by Hossein Sharifi, Weisheng Liu, Brian McCaul and Dennis Kehoe, who look at the role and experience of technology transfer offices (TTOs) in the UK. Recent years have seen significant expansion in this kind of agency – in Britain alone 71 new agencies were established during the 1990s according to the Lambert Review. And these are not small operations – the average staff level in Europe is eight people in a TTO. But throwing resources at the problem does not necessarily solve it, and the chapter looks at where, when and how effective TTOs work – and the messages for developing agencies of this kind to contribute to improved knowledge flow in the wider innovation system.

One of the key developments in the twenty-first-century innovation model is, of course, the increasingly significant role that technology can play as an enabler of knowledge flow. Developments, particularly in information and communications technology (ICT) allow for massively greater interaction on a global scale – indeed the Internet itself was originally developed by Tim Berners-Lee and colleagues as an aid to their collaboration and knowledge sharing. In their chapter on the enabling technological infrastructures Roula Michaelides and Dennis Kehoe look in depth at the opportunities but also the challenges posed by such developments and their implications for improving the innovation system.

A GRAND CHALLENGE?

There is little argument about the importance of innovation in the early twenty-first century – whether at the level of the firm, in universities and research institutes or among policy actors at regional and national level. The challenge is to make it happen more effectively – getting more leverage from existing investments as well as increasing the overall rate and scale of knowledge production.

Our argument in this book is for a rethink by all the players around their mental models – and operational structures resulting from those models – of innovation. Are they really using a ‘fifth-generation’ model – highly networked, technologically and socially enabled and predominantly ‘open’ in character, or are they still trying to force-fit the ‘spaghetti’ reality of knowledge flows into outdated and limited linear models from an earlier generation?

This isn’t an easy transition, but we hope that some of the ideas presented in this book give some indications of the new directions that such fifth-generation thinking might take.

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