THE ECONOMICS OF THE KNOWLEDGE DRIVEN ECONOMY

Papers presented at a conference
jointly organised by the
Department of Trade and Industry and the
Centre for Economic Policy Research[1]
London, 27 January 1999

[1] The views expressed in the papers in this volume are the authors' own and do not necessarily reflect the views of either DTI or CEPR. CEPR takes no institutional policy positions.

Foreword

Lord Sainsbury
Parliamentary Under Secretary of State for Science, Department of Trade and Industry

I was delighted to participate earlier this year in a conference held at the Department of Trade and Industry on the economics of the knowledge driven economy. I was pleased to welcome to the conference many distinguished academics and economic commentators, including Joe Stiglitz, whose work on the economics of knowledge is world renowned. The conference was jointly organised with the Centre for Economic Policy Research whose assistance in staging this event I gratefully acknowledge.

Since the conference was held as part of the follow-up to last year's Competitiveness White Paper, *Our Competitive Future: Building the Knowledge Driven Economy*, I would like to set the scene by saying a little about the background to the White Paper, and what we are doing to take forward the agenda it sets out.

We live in a period of rapid economic change. Innovative products, processes and services spread more rapidly across the globe. The Internet is changing the way that business meets customer demands. Scientific and technical knowledge is developing at a startling pace. These forces are making knowledge an increasingly important generator of wealth. New technologies and markets bring new competitors, but also new opportunities.

The new environment challenges business. But it challenges government too. When Labour took office and asked business how we could best help them improve performance, it was clear we had to create a new way of thinking about how to foster industrial success.

The new economic policy we have been following since the election has two strands. First and foremost, we are creating a **stable macroeconomic environment**. By giving the Bank of England operational independence and establishing clear rules for the conduct of fiscal policy, the Chancellor has taken major steps to deliver stability in an unstable world. These steps are designed to replace the economics of boom and bust with the economic stability that business requires.

The second strand is the **modernisation of the supply side** of the economy. We must promote competition and stimulate enterprise, flexibility and innovation. I think John Kay - one of the contributors to this volume - put it best when he said that policy should focus "not on what we do worse than other people, but on what we do better." In other words, a successful corporate sector and a successful industrial policy should be based not on doing what others already do well but in developing our own distinctive capabilities.

This approach to modernising the supply side of the economy underpins the Competitiveness White Paper with its themes of investing in business capabilities, catalysing greater collaboration and promoting competition, and its strong focus on increasing enterprise, innovation and the exploitation of science.

The Government has to take a lead in building up the UK's capabilities in areas where the market may under-provide. As a result of the White Paper, the DTI is increasing the support it gives to innovation by fostering the development of an entrepreneurial culture through a commitment of £150m to the Enterprise Fund to support SMEs with growth potential. In my own role as Under Secretary of State for Science, I was delighted that the Government's Comprehensive Spending Review reversed years of under-investment in our science and engineering base. An extra £1.4 billion is being made available to UK science to support cutting-edge research. Government must encourage the development of skills and expertise at all levels so that the benefits of the knowledge economy may be shared as widely as possible

The DTI must also help businesses to work together more effectively and the White Paper puts in place policies to do this. The extension of the successful Teaching Company Scheme is helping businesses to innovate and exploit the latest technology. We want to encourage the sharing of best practice across industry, whether through formal research links such as the Society of Motor Manufacturers & Traders industry forum or through other more informal networks.

We also want industry to develop closer links with Universities so that it can benefit from the knowledge accumulated by our world class science base. Clusters of scientific and business excellence can be encouraged by Government. I recently led a team to tackle the barriers to the growth of nationally significant clusters in the biotechnology sector. Other initiatives to facilitate the growth of clusters are under consideration.

Finally, successful businesses need to compete aggressively. We have already passed the new Competition Act which strengthens the power of the OFT. And we are considering the responses to a consultation on the case for merger policy reform to ensure that all corners of the economy are exposed to the rigours of competition.

The task of implementing the commitments outlined in the White Paper and delivering improvements in economic performance is already under way. A detailed implementation plan has been drawn up and over half of the milestones identified in March 1999 towards delivering the commitments have now been achieved.

The conference itself was part of the implementation process. In the same way that industry must develop links into the knowledge and expertise in our universities and research institutes, Government also needs to tap the knowledge of academics and other researchers in order to make policy more effective.

The papers presented in this volume, and the discussions they provoked, have helped inform our work on the role of knowledge in the economy and the implications for policy. They have, for example, deepened our understanding of the role of technology in driving productivity growth, the importance of a sophisticated consumer base as a spur to innovation, and the contribution of clusters to economic development.

I hope the publication of the papers in this volume will help bring fresh insights and encourage further research on the issues raised, which are of crucial importance to understanding the foundations of economic success.

Lord Sainsbury of Turville
November 1999

Overview: The Economics of the Knowledge Driven Economy

Romesh Vaitilingam
Royal Economic Society and CEPR

This publication brings together papers presented at a conference jointly organised by the Centre for Economic Policy Research (CEPR) and the Department of Trade and Industry (DTI) on 27 January 1999 on the economics of the knowledge driven economy. The starting point for the discussion was the UK Government's Competitiveness White Paper published at the end of 1998, *Our Competitive Future: Building the Knowledge Driven Economy*. The conference was opened by the Parliamentary Under Secretary of State for Science, **Lord Sainsbury**; and the central messages of the White Paper were presented by senior DTI economists **David Coates** and **Ken Warwick**.

The papers in this volume explore the meaning of the knowledge driven economy; what the growing importance of knowledge implies for industrial structure, for national economic performance, and for the sources of competitive advantage for both firms and nations; and how government policy should be directed towards building UK capabilities, facilitating collaboration within and between businesses, and encouraging competition.

What is the Knowledge Driven Economy?

The Competitiveness White Paper defines the knowledge driven economy as

"*....one in which the generation and the exploitation of knowledge has come to play the predominant part in the creation of wealth. It is not simply about pushing back the frontiers of knowledge; it is also about the more effective use and exploitation of all types of knowledge in all manner of economic activity*."

The document goes on to describe four structural forces driving economic transformation: revolutionary changes in information and communications technology (ICT); rapid scientific and technological advance; increasingly global competition; and shifting consumer demand.

So how does the knowledge driven economy differ from its predecessors? The conference's keynote speaker, **Joseph Stiglitz** argues in his paper that knowledge has fundamentally different characteristics from ordinary commodities and these differences have crucial implications for the way a knowledge economy must be organised. Most importantly, knowledge is a global public good: it is "infinitely expansible" or "non-rival in consumption". Stiglitz notes that Thomas Jefferson captured this idea best when he wrote:

"*He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me*."

What Stiglitz calls "the scarcity-defying expansiveness of knowledge" is the root of its other important defining features. Once knowledge is discovered and made public, there is essentially zero marginal cost to adding more users; ideas and innovations have extensive externalities, their benefits typically extending well beyond those who first put them forward; and it can be difficult to exclude other potential users of knowledge through intellectual property rights. What is more, there is an inherent "unknowability" in knowledge: it is like an experience good, which consumers find hard to value unless they have used it before.

Danny Quah, London School of Economics and CEPR, outlines what he sees as different in the knowledge driven economy or, as he prefers to call it, the weightless economy. First, there is a proliferation of knowledge products that share the infinite expansibility and related characteristics of knowledge. Of particular importance are ICT, including the Internet; intellectual property, including not only patents and copyright, but also branding, development of images, advertising, trademarks and logos; and libraries and data-bases, both silicon-based electronic compilations of information and bio-technology or carbon-based forms.

What is central about the new technology, Quah suggests, is that it brings consumers ever closer to the chalk face of technological development. In the traditional industrial economy, knowledge is the first point in a chain running through intellectual property protection in the form of patents and then into machinery and manufacturing for producing goods for consumers. In the knowledge economy, the chain disappears and consumers and knowledge producers interact directly with each other. This is the real "death of distance": not in the sense that ICT reduces the importance of physical geography but as a closing of the gap between knowledge producers and consumers.

The Implications for Industrial Structure and Economic Performance

So what is the impact of the new technologies on industrial structure? **John Kay**, London Economics, points out some fallacies in much contemporary analysis. For example, it is feared that with a strong system of intellectual property rights, the characteristics of knowledge imply "winner-takes-all" markets and hence concentration into a relatively small number of global players, the "superstars". In addition, many believe that market dominance and commercial success will be based on those who control standards and/or the delivery processes.

Making a comparison with the impact of the printing press on the dominant position of the Roman Catholic Church, Kay contends that, on the contrary, the expansion of the knowledge driven economy will create a proliferation of material, firms and activities at all points and at all levels, suggesting that no one can expect to enjoy continued control of these markets. There may be temporary monopolies but they cannot last. And it is misconceived to think that the key lies in being at the point of delivery of the product: the low cost and ease of access to the delivery mechanism mean that rents are driven down at the delivery level and instead migrate back up the value chain to those with genuinely scarce factors and competitive advantages.

Kay explores the changing nature of competitive advantage during the 20th century. He notes that there has been a shift from competitive advantage based on market position, size and power to competitive advantage based on the incorporation of knowledge into no longer important raw materials. Knowledge based competitive advantages derive from the power of brands as signals of reputation; from standards like Microsoft's operating systems or the English language; from innovations protected through patents, copyrights or secrecy as with Merck or Coca Cola; or simply from a reputation for innovation as Sony enjoys. Equally important as sources of knowledge based competitive advantage are what Kay calls the internal and external architecture of firms: the networks of trust, knowledge-sharing and information processing both within and between organisations.

Networks and geographical clusters of firms are a particularly important feature of the knowledge driven economy. **John Cantwell** of Reading University claims that firms are finding it more and more necessary to work with other firms in technology-based alliances. The costs of research and development (R&D) are rising and firms often find it beneficial to spread costs among themselves. Meanwhile, as consumers become more sophisticated and the goods they demand more complex, R&D is having to draw on a wider range of technologies and a broad array of inputs. Many larger multinational firms are becoming "multi-technology corporations", locating themselves around centres of excellence in different countries.

But why are clusters important if ICT supposedly diminishes the role of physical geography? The answer seems to be that while the Internet is certainly effective at spreading information around the world, it is not so effective at spreading understanding. Firms "co-locate" because it is a better way of sharing such understanding. One key activity that is dependent on face-to-face contact is hiring new people. Firms in a cluster benefit from a vibrant labour market and repeated contact helps build up relationships of trust with potential collaborators. These considerations seem to be particularly important for high-tech smaller firms, as **Alan Hughes** of the University of Cambridge demonstrates.

Of course, given the nature of knowledge, not all the benefits of a new idea flow to the company whose research department has developed it. It is difficult to protect new ideas, particularly basic research, which is often unpatentable, and the researchers involved may move to a competitor. This is where the justification for government involvement in the knowledge economy begins: left to their own devices, businesses will not invest as much in R&D as might be beneficial for the country as a whole. **Stiglitz** argues that there needs to be real recognition of the fact that knowledge is a global public good. If everybody is doing applied research, taking ideas out of the basic knowledge pool and converting them into patentable innovations, there must be more co-operation in enhancing the supply of basic research.

Stiglitz suggests that governments should not be engaged in picking winners but in trying to identify important externality-generating research projects. In his view, governments have had a remarkable record of doing this successfully and in ways that have had really profound effects on the economy. For the United States, these include support of agricultural research in the 19th century economy, which led to huge productivity increases; construction of the first telegraph line in 1842, which

encouraged businesses to invest in expanding the network; and the development of the Internet. In each case, there was a large difference between the initial benefits to the private sector of such work and to the economy and society as a whole.

Paul Stoneman of Warwick Business School emphasises the value of government support for basic research in giving a country the advantages of technological leadership. Despite the fact that others can ultimately make use of the knowledge developed, the first use of knowledge or the temporarily exclusive use of knowledge can yield great benefits. An individual country may, in fact, be much more prosperous than other countries either because it uses more knowledge or uses knowledge more quickly than others. But as other countries use that knowledge, the leader's advantage tends to get whittled away.

The Role for Government Policy

So what should government actually be doing in the knowledge driven economy? Having demonstrated that firms should see competitive strategy as the business of establishing a match between their distinctive irreproducible capabilities and the competitive environment in which they operate, **Kay** argues that industrial policy should be thought of in the same way. The contribution of government is to recognise, understand and develop the distinctive capabilities of a national economy and match these to the competitive environment that a country faces.

As **Stiglitz** and **Stoneman** indicate, an important part of developing a country's capabilities is the support of universities and graduate education in basic science and technology. Investing in R&D does not just lead to new ideas; it develops the expertise to understand what researchers have been doing in other countries. Furthermore, spending on a research budget creates the kind of technical skills in the work-force that enable effective use of other people's results. It is difficult for a country to access the global pool of knowledge without its own R&D experience.

But what about the broader role of education and training? **Stephen Nickell** of the London School of Economics and CEPR presents a skills profile of the UK: broadly level with the Germans and Americans on the numbers of people with higher level skills; comparable with the United States but well below Germany on the numbers who have attained at least lower level skills; but behind both on the numbers with middle level skills. Nickell suggests that it is at this skill level, corresponding to further education, that the need for improvement in the UK is greatest. He added that while US and UK numbers are comparable for lower level skills, a great advantage of the United States is that a far higher percentage of businesses operate at "best practice", the most efficient way of doing any task.

Stiglitz emphasises the value to the knowledge driven economy of vibrant financial markets, suggesting that one key to the success of Silicon Valley is the large number of venture capital firms, which provide not only capital but know-how and managerial skills. Other conference participants focused on the potential advantages of capital markets encouraged to focus more on the long term and tax measures that might achieve such an aim. The goal of providing a stable environment for investment for

investment was also raised, including the benefits of macroeconomic stability. And **Quah** stresses the importance of consumers, noting that according to some economic historians, 14th century China was an industrial revolution waiting to happen with the supply side of technology fully in place. Yet tight control by the state prevented the emergence of a sophisticated demand base and dramatically stifled growth.

The issue of competition policy, particularly in relation to intellectual property rights, looms large in the knowledge economy. Quah describes the basic trade-off for society: *ex post* social efficiency outcome, where everyone enjoys access to the benefits of new ideas, versus *ex ante* incentives for firms to produce knowledge and new knowledge products. If firms are unable to appropriate a significant part of the rents from their research efforts, Quah asks why should they conduct research in the first place. Yet a strong intellectual property rights system offers the potential for monopoly power, which even if temporary, may not be desirable for society.

Stiglitz expresses some concern that collaboration and co-operation between firms hold out the danger of collusion, where firms can work together to raise prices and reduce effective competition. He views the need to develop safeguards that encourage constructive knowledge-creating co-operation without tacit or explicit collusion as one of the real challenges for government in the knowledge driven economy. Stiglitz also warns about the potential for new technology to undermine competition through increasing returns to scale, "winner-takes-all" and "lock-in" effects.

Others are less concerned. On the dangers of collusion, **Hughes** reports survey results showing that the forms of collaboration undertaken by high-tech firms are much more likely to involve sharing R&D, knowledge and information systems rather than entering into arrangements to keep current customers. **Kay** points out that past concerns about monopoly have turned out to be unfounded. For example, in the 1930s, there were many worries about monopoly capitalism and what the new industrial economy was going to do to competition. As it turned out, technology changed, the scale of operations went down, transport costs lowered, markets became global and the number of monopolies probably decreased rather than increased. However, **Stiglitz** argues that it is possible that today's powerful corporations may have learned from the past, seen how monopolies were destroyed and, in response, put in place artificially created barriers which may slow the pace of innovation.

Paul Seabright of Cambridge University and CEPR raises the question of whether there is a case for systematically favourable treatment by regulators of mergers and/or joint ventures in high-tech industries on the basis of the scale economies in information-intensive processes and the weak character of many intellectual property rights. He concludes that while such an idea has some sense analytically, there would be a danger of strategic manipulation of information by firms. For example, firms might exaggerate the character of an alliance, making it seem more high-tech than it really is. Seabright adds that competition authorities need to develop an understanding of the benefits and dangers that can come from a joint venture as opposed to a merger since the former is becoming an increasingly important organisational form.

Finally, in terms of policy for both government and industry, many emphasise the importance of establishing a culture of creativity. Pluralism, openness, competition

and a willingness to experiment are vital to the generation and creative use of knowledge. And as **Stiglitz** concludes, the government has an important role in facilitating these changes: for example through the provision of education, by encouraging creativity and risk-taking, and by helping to develop institutions, including introducing the appropriate regulatory and tax environment.

The Knowledge Driven Economy: Analysis and Background

David Coates
Chief Economic Adviser, Department of Trade and Industry
Ken Warwick
Senior Economic Adviser, Department of Trade and Industry

Introduction

The increasing importance of knowledge, creativity and skills is changing the way firms compete and the sources of comparative advantage between nations. This was recognised in the Government's Competitiveness White Paper, *Building the Knowledge Driven Economy,* published towards the end of last year (DTI, 1998a).

The theoretical underpinnings for the White Paper were set out in a separate report, published at the same time, entitled *Analysis and Background* (DTI, 1998b). In what follows, we offer a summary of that report. We examine why knowledge is increasingly important in modern economies, consider the consequences, benchmark the UK's performance and discuss appropriate policy responses.

The Growing Importance of Knowledge

There can be little question about the increasing importance of knowledge in the economy, or about its consequences for the way economic activity is organised or for the way policy-makers think about economic and industrial policy. This has attracted comment in recent analyses by both the World Bank and the OECD:

> "For countries in the vanguard of the world economy, the balance between knowledge and resources has shifted so far towards the former that knowledge has become perhaps the most important factor determining the standard of living..... Today's most technologically advanced economies are truly knowledge based." (World Bank, 1998)

> ".... the emergence of knowledge based economies....has profound implications for the determinants of growth, the organisation of production and its effect on employment and skill requirements and may call for new orientations in industry-related policies." (OECD, 1998)

Reflecting the growing importance of knowledge in the economy, the DTI *Analysis and Background* document sought to:

- define knowledge and the knowledge driven economy;
- analyse the forces behind the knowledge driven economy;
- assess the UK's relative performance;
- consider policy implications; and
- identify areas for further work.

Defining Knowledge

Knowledge does not simply consist of information or ideas that can be written down and transmitted in one medium or another, so called "codified" knowledge. It also incorporates understanding of a more tacit nature, which is more difficult to acquire and slower to diffuse. By its very nature, tacit knowledge is often the basis of competitive advantage.

Nor are we talking simply about economic activity based on extending the frontiers of knowledge, important though that is, but also about using existing knowledge to improve current practice. The diffusion and exploitation of existing knowledge may be just as important as the creation of new knowledge.

A tangible example of the way tacit knowledge is diffused and applied is provided by the experience with one of DTI's business support programmes. The Department helps bring Japanese production engineers to the UK to advise automobile components manufacturers about best-practice techniques. The proprietor of one of the UK firms had read extensively on lean production and already made many significant changes to his techniques. But with great candour he observed that his visitors showed him how little he had really understood. He noted that "I didn't know what I didn't know". Only through face-to-face contact was he able to benefit in full from the understanding and application of their tacit knowledge.

The definition of a knowledge driven economy in the *Analysis and Background* report follows from an understanding of knowledge itself. It is an economy in which the generation and the exploitation of knowledge have come to play the predominant part in the creation of wealth. It is not simply about pushing back the frontiers of knowledge; it is also about the more effective use and exploitation of all types of knowledge in all manner of economic activity.

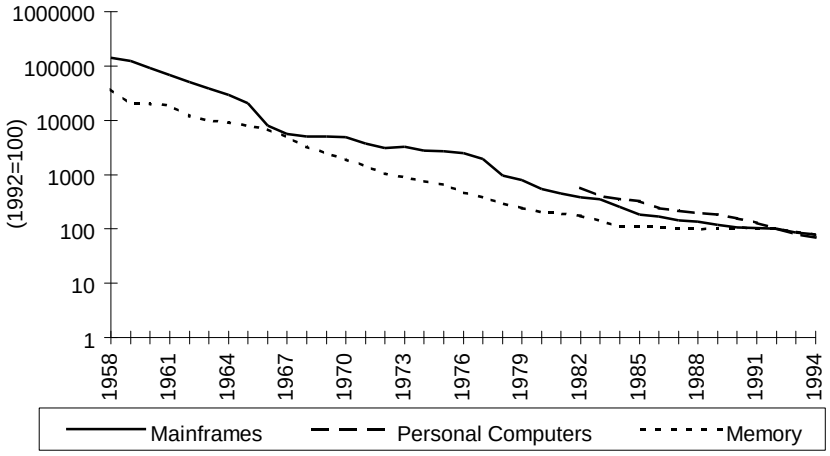
Why is Knowledge More Important?

Economies throughout the world have been moving in the direction of being more knowledge based for a long time. However four important influences can be identified which are acting to increase the pace of change: new information and communications technology, rapid scientific progress, global competition and changes in tastes, lifestyle and leisure that go with increased incomes.

Revolutionary Changes in Information and Communications Technology

The pace of change in ICT in recent years has been extraordinary. Prices of computer equipment have fallen to a fraction of their level a generation ago (Chart 1). Falling prices and rapid technological advance and innovation have led to the emergence of a whole new range of products and services. This revolution in ICT allows companies to transform the way they do business, creating and accessing new markets and changing the way they relate to their customers, suppliers and competitors.

Chart 1: Price of computer equipment in the US (adjusted for quality)

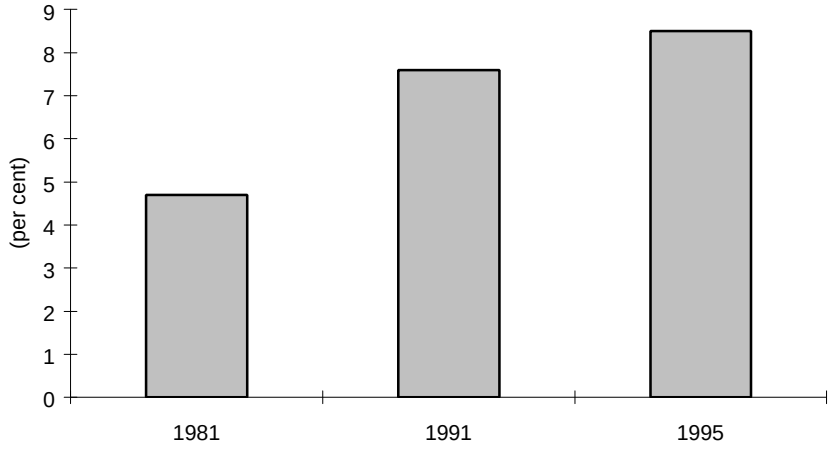


Source: Triplett Note: Log scale

More Rapid Scientific and Technological Advance

Recent years have seen large increases in the resources devoted to basic scientific research and R&D. In the OECD countries, spending on R&D in the business sector has almost doubled in real terms since 1981. Not only has the stock of scientific knowledge expanded, but the pace of dissemination has also increased. This has been partly driven by improved ICT, but firms are also spreading knowledge by diversifying their R&D effort internationally, leading to an increase in the share of R&D financed from abroad (Chart 2).

Chart 2: Proportion of R&D in EU countries financed from abroad

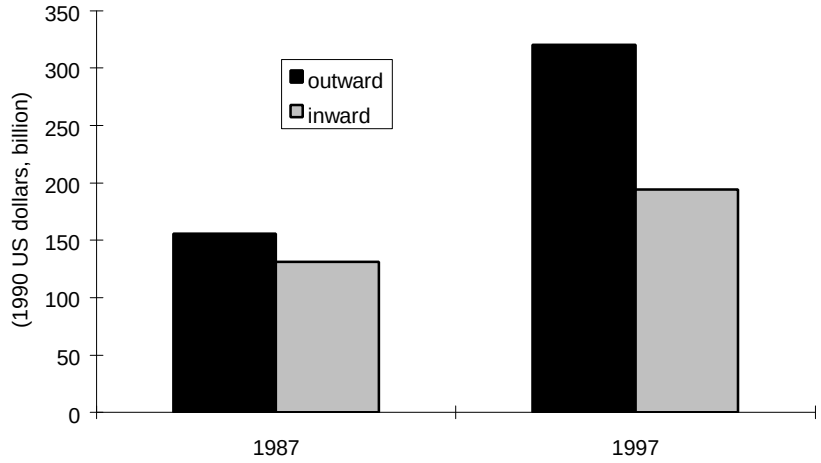


Source: OECD

Competition Becoming More Global

Globalisation has quickened considerably as a result of falling tariffs, the liberalisation of capital controls and lower transportation and transactions costs. World trade has increased twice as fast as GDP over the last two decades. Moreover, there has been a rapid increase in flows of international investment (Chart 3). This offers opportunities for specialisation, spillovers from research and development, and all kinds of learning through example, emulation, and the movement of people spreading improved methods of management, organisation and supply.

Chart 3: Outward and inward direct investment flows in the OECD



Source: OECD

Note: Current price figures deflated by GDP deflator

Changes in Income, Tastes and Lifestyle

The changing demands which go with increased income are a potentially important driver of the knowledge economy. Rising incomes and changing tastes have led to greater emphasis on quality and design, on convenience services and on cultural and recreational activities, and a shift in attitudes to sustainable development. This in itself is changing the opportunities for profitable production.

In addition, businesses which produce innovative products are more likely to succeed where they have access to sophisticated and demanding business and retail customers who are themselves willing to embrace technological change. For example, the spread of e-commerce depends on the willingness of consumers to acquire the necessary skills and change their purchasing habits just as much as it depends on the capacity of firms to invest in new technology and change their ways of doing business.

Implications

All these changes have made knowledge even more important as a driver of competitive advantage and a source of economic growth. In turn this has consequences for:

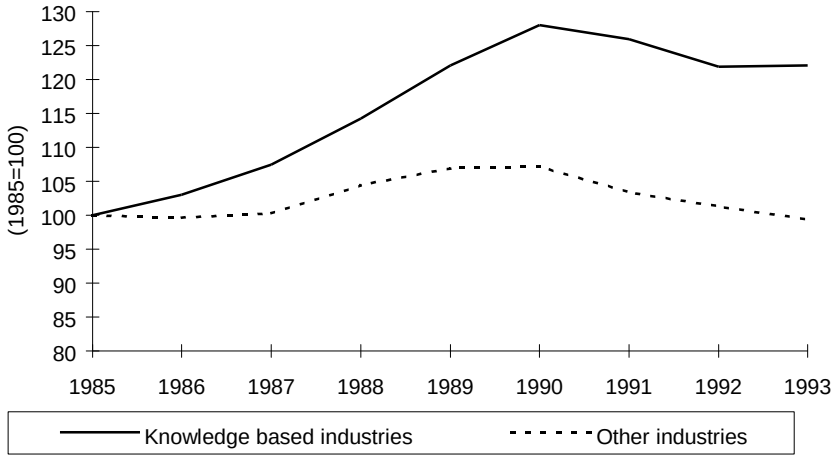
- managers - who have to think far more about realising advantage through knowledge and about developing attributes of their company or product that are distinct and difficult to copy;
- employees - who need the basic skills to learn and to adjust to change;
- investors and financiers - who need to recognise, assess and communicate the value of intangible assets and their potential for commercial exploitation;
- policy makers - who must create a climate conducive to success; and
- regulators - who need to reflect the changing nature of competition; the challenges created by new technologies, including the protection of intellectual property; and the trade-offs between protection and the wider exploitation of new products and processes.

The UK in the Knowledge Driven Economy

Since knowledge is increasingly the key to economic success, it is important to attempt to benchmark UK performance.[2]

Turning the spotlight on to the UK, there has been a shift in employment (Chart 4) into industries that the OECD classifies as knowledge based, including services like finance and telecommunications, and manufactures such as pharmaceuticals and aerospace.

Chart 4: Employment in the UK



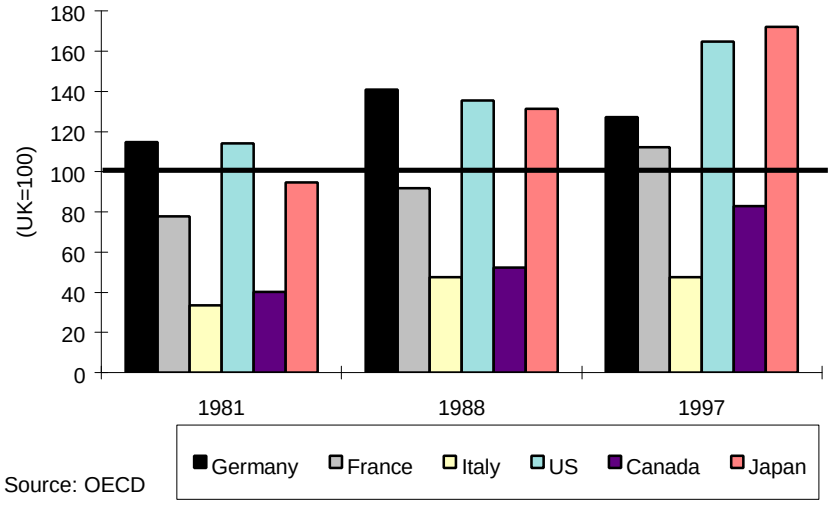
Source: OECD

[2] A much fuller analysis of the competitiveness of the UK as a knowledge driven economy is contained in *UK Competitiveness Indicators 1999* (DTI, 1999).

This structural shift is reflected in the pattern of UK trade. Trade statistics show that the proportion of high-tech exports in total exports of goods has grown more rapidly than that of our main European competitors.

However, in terms of R&D spend, UK performance has been disappointing (Chart 5). The growth of R&D spending between 1981 and 1997 lagged behind other G7

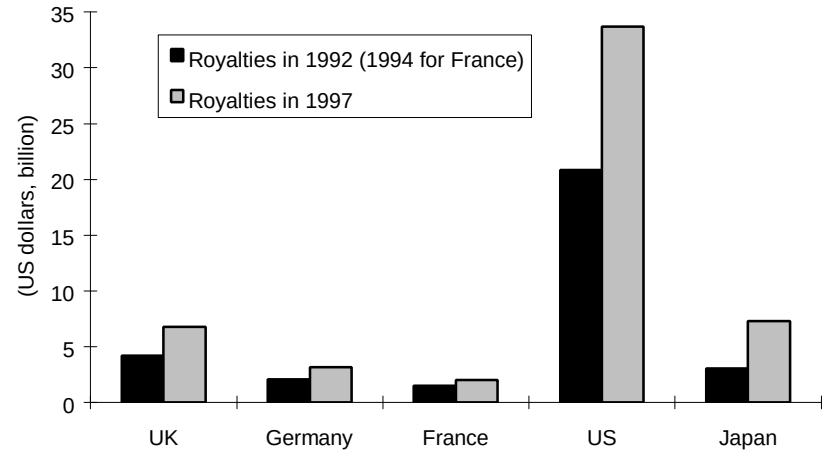
Chart 5: Business enterprise R&D as a proportion of GDP



Source: OECD

countries. France and Japan overtook the UK during this period and Italy and Canada narrowed the gap. On the other hand, the relative scale and growth of our earnings from royalties suggests an unusual degree of exploitation of British ideas overseas (Chart 6).

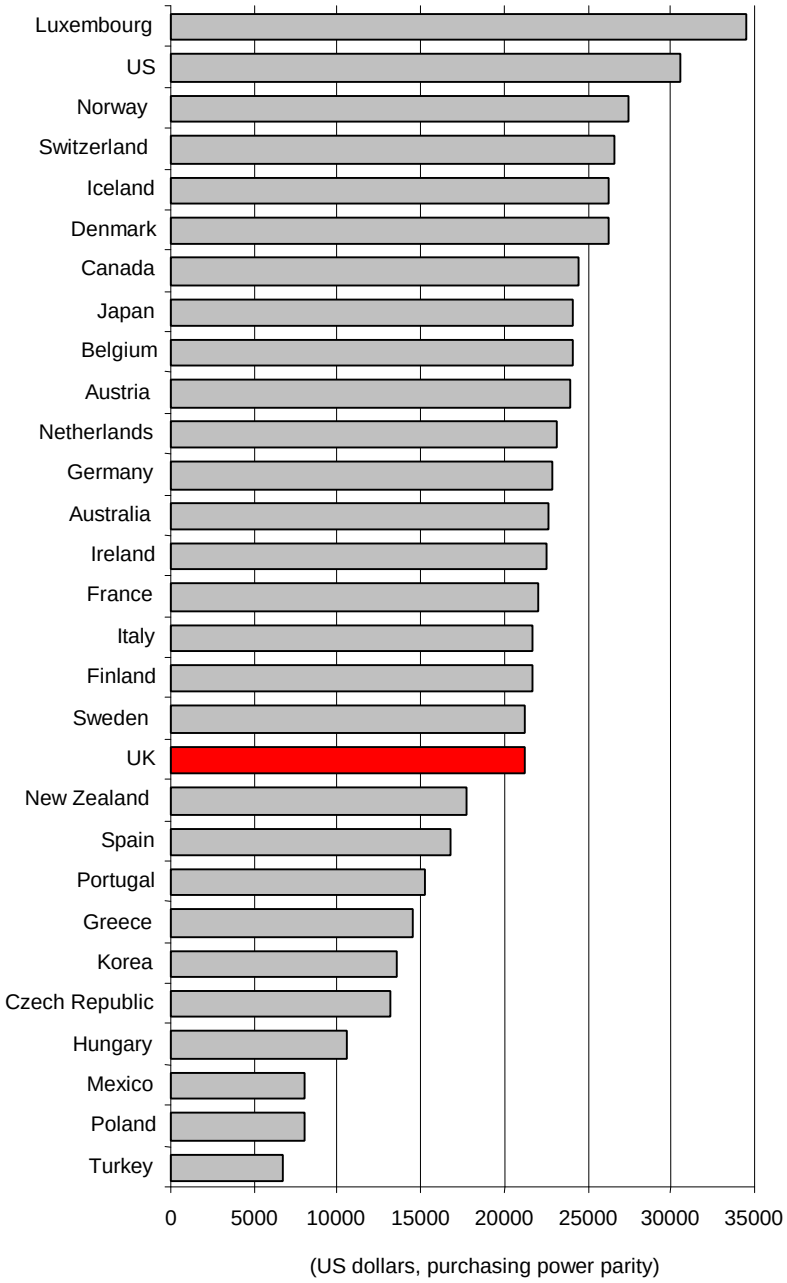
Chart 6: Overseas earnings from royalties and license fees



Source: IMF, ONS

While the record on measures of the progress of the knowledge driven economy is mixed, it is clear that in terms of overall output per head and living standards, the UK still lags behind. Productivity, whether measured per worker or per hour worked, falls below the G7 average across a wide range of industries and firm sizes. That there is clearly much scope for improvement can be seen in the comparison of GDP per head, the most commonly used measure of relative standards of living (Chart 7).

Chart 7: GDP per head in 1998



Source: OECD

Progress in closing this gap will only be possible if British business can take advantage of the tremendous opportunities of a world which is changing rapidly, with knowledge and its exploitation playing an ever greater role. Government too must play its part in responding to this challenge.

Policy Issues

The Competitiveness White Paper (DTI, 1998a) identified three broad themes for policy action:

- investing in capabilities;
- catalysing collaboration; and
- promoting competition

Capabilities

The analysis in the White Paper suggests the following areas where UK performance needs improvement:

- the capacity to create and exploit scientific knowledge and technology;
- improved enterprise and innovation;
- well functioning capital markets; and
- access to skilled workers and the ability to make the best use of their knowledge.

Our capacity to create and exploit scientific knowledge and technology is a basic determinant of success in the knowledge driven economy. As Chart 5 showed, R&D performance has weakened relative to other G7 countries. Moreover, Michael Porter's recent Innovation Index showed UK performance, as measured by international patenting data, to be very weak.[3] On the other hand, there is evidence that foreign firms from abroad seem to find that the UK is a good environment in which to undertake R&D. It seems paradoxical that the UK has such a poor overall performance on business expenditure on R&D and commercial exploitation given our revealed comparative advantage in R&D.

Securing an improvement in scientific exploitation requires enterprise and innovation. There are sound reasons for thinking that entrepreneurship plays a central role in determining success in a knowledge driven economy. Indeed, it is more important than ever because of the shortening of product cycles, new opportunities for small firms and the consequent need for adaptation and rapid change. If this is the case, then how can the Government foster a more entrepreneurial economy?

Finance for enterprise depends in turn on well functioning capital markets. Much has been written on the extent to which finance hinders investment and growth. There is concern that any structural problems in financial markets may be exacerbated by the rapid pace of change. Fledgling firms need finance to grow but have no track record.

[3] Porter and Stern (1999).

In addition, the increased importance of intangible assets makes it more difficult for analysts and financiers to assess companies' value and long-term prospects.

If these interpretations are correct, then firms may become more cash-constrained in their investment plans as the pace of change accelerates and the potential for very rapid growth (through network effects and global markets) increases. Information problems are likely to increase as intangibles become more important. This poses questions for current corporate governance arrangements and may increase the associated principal-agent problems.

Firms also need access to skilled workers, and the successful organisations will be those who make the best use of their people and skills. Skill-biased technological change is shifting the demand for labour, raising important economic and social questions. Flexibility in the labour market will be increasingly important.

However, the training externality problem may worsen in the knowledge economy since firms may have less incentive to train their staff because specific skills become obsolete more quickly and the need for general skills grows. Mechanisms such as paying lower wages to employees in training grades can help resolve this problem but firms in the knowledge driven economy may also need to consider other ways of aligning employee interests more closely with those of the firm.

Collaboration

The White Paper states that to compete more effectively, companies have to collaborate more intelligently. Collaboration can be viewed in two ways.

The first is collaboration or partnership within the firm. John Kay, Michael Earl and others have written extensively about the importance of harnessing knowledge at all levels within the firm.[4] This includes the "customer capital" embodied in statistical data-bases and in personal contacts, the tacit knowledge of workers on the production line and the creativity of staff at all levels. This may imply a need for new management systems and flatter management hierarchies.

Associated with this is the increased need for incentives which tie in key employees to the firm. The benefits of loyalty and commitment to the firm are even greater when knowledge of the workers is a key asset. Firms face the challenge of how to create appropriate structures to motivate and retain workers and make the most of their knowledge.

The second area of collaboration is between firms, and between firms and other institutions. Collaboration is more important because interdependence is increased by spillovers in research and the growing complexity of technology. New business forms may emerge, such as more contracting out or virtual firms, facilitated by ICT, but with close collaboration between the units. However, the development of a knowledge driven economy has ambiguous effects on the incentives to increase or reduce vertical

[4] See, for example, Earl and Scott (1999), Kay (1993) and Davenport and Prusak (1998).

integration. On the one hand, management of knowledge, especially tacit knowledge, may be easier in centralised firms; working in the other direction, contracting out and decentralisation may be easier to manage with improvements in ICT.

It may seem paradoxical that ICT developments are taken by some to imply the death of distance, yet localised clustering is a strong theme in the work of writers such as Krugman (1991) and Porter (1998). It is argued that this is because the benefits from clustering are likely to be greater in the knowledge economy as tacit knowledge is more easily transferred by face-to-face contact. In Porter's terms, anything that can be sourced from a distance no longer confers a competitive advantage, because others can do the same.

The analysis also points to increased networking as an effective way of spreading best practice or the results of R&D. Of course, clustering by itself is no guarantee of continued economic success and there is a need for greater understanding of the conditions driving cluster performance. The Government is currently considering how policy can foster the development of clusters and networks.[5]

Competition

The knowledge economy is both a result of increased competition through international trade and investment liberalisation and a contributor to heightened competition as a result of lower communication costs.

The Internet and other forces contributing to globalisation allow SMEs access to wider markets and facilitate rapid growth. This is particularly the case in the "dot com" sector where start-ups such as Amazon have experienced phenomenal growth. Competition from cyberspace challenges the position of incumbents, as existing barriers to entry, such as extensive high street distribution networks, dissolve.

However, one characteristic of the knowledge driven economy is the preponderance of "information goods" or "knowledge goods" such as films, pharmaceuticals and software. Stiglitz notes that these goods have large fixed costs, but low or zero marginal costs and they may have some of the properties of public goods, such as non rivalry in consumption. Unless the knowledge embedded in the good is protected by copyright or patent, competitors can quickly copy the idea. This undermines the ability of the innovator to recoup the cost of his investment and damages the incentive to produce knowledge. The obvious solution of increased patent protection may well improve the incentives to produce knowledge, but by restricting the flow of knowledge, society as a whole may be worse off. A balance has to be struck between the desire to incentivise the *ex ante* production of knowledge and the *ex post* maximisation of economic welfare.

[5] An outline of the latest approach is given in HM Treasury (1999).

Conclusion

The development of the knowledge economy is profoundly affecting the goods and services produced, the way firms behave, how they are organised and their relations with their employees and with other firms. The pace of change poses new challenges for managers, employees, investors, policy-makers and regulators.

Many of the features of the knowledge economy have only recently risen to prominence in the economics and business literature. Further research is required in many areas, for example: the valuation of tangible assets; the benefits of clusters and networks; the role played by consumer demand; the role of intellectual property rights and competition policy in promoting innovation; and the implications of the growing importance of industries producing knowledge and information goods.

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Growth and Increasingly Weightless Economies

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Introduction

One aspect of the knowledge driven economy that has attracted much comment and analysis is the increasing weightlessness of production.[6] The growing knowledge intensity and weightlessness of output carries implications for how we view the growth process. In particular, it raises questions about the role of consumer demand, the extent to which the technological advances associated with the knowledge economy are apparent in national accounts statistics, and the implications for growth theory.

This paper has three aims. The *first* is to provide a macroeconomic perspective on a number of issues discussed in the DTI White Paper. These include the impact of changes in technology on the distribution of income, the impact of changes in overall industrial structure, and the role of consumer demand. The role of consumers is stressed in order to move away from the supply side of products - the DTI's traditional remit - to put more emphasis on the demand side. This is done not just because it serves as a useful supplement but because, for a variety of analytical, theoretical and historical reasons, understanding the demand side and the role of consumers in technical change is crucial.

The *second* aim of the paper is to argue that, in the short run, the knowledge driven economy, or focus on knowledge, might not yet be apparent in statistics that measure overall economic performance. Those who are sceptical of the promise that knowledge will deliver advantages to the economy often point to the lack of evidence of any impact in the macroeconomic statistics.

The *third* goal is to say why it would be wrong to be sceptical on the basis of the evidence available, and then to discuss what is new about this knowledge based, technology driven economy.

Technology and Growth Models

Economists have long argued that technology - and its input, knowledge - is the engine of growth. There is no ambiguity about this, whether one reads the neoclassical growth theorists, the neoclassical growth empiricists, or the new endogenous growth theory. The emphasis varies and the economic mechanisms may be different, but there is without doubt a large body of literature concerned with how technology drives economic growth and why it is important for economic performance.

For example, Robert Solow, one of the pioneers of growth accounting, described economic growth in the United States in the early part of the 20th century as being

[6] See, for example, Coyle (1997), Leadbeater (1999) and Quah (1997).

driven in the main - by over 85 per cent - by technology. By comparison, the accumulation of physical capital contributed a minuscule amount.

One doesn't have to confine oneself to the early part of 20th century, of course, when thinking about knowledge as a factor input, or about technology and its importance. Going back to the industrial revolution, the new technologies - in forms such as the spinning jenny or the steam engine - were direct drivers of growth in that period.

And, while this is an old view, a neoclassical view, new growth theorists also emphasise the contribution of technology to economic growth. While it might be argued that new growth theory still needs to be developed further, it is clear that most views of the economic growth process ascribe a central role to developments in knowledge and new technology.

Productivity Paradoxes

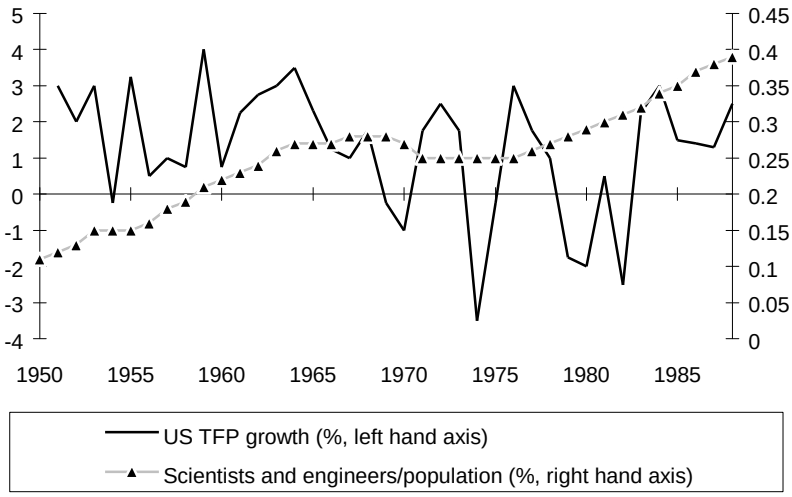
If there is a convergence of views on the importance of technology, why then is there scepticism about the magnitude of its contribution to economic growth? One set of sceptical evidence goes under the heading of productivity paradoxes, of which there are several variants. Perhaps the best known is that articulated by, once again, Robert Solow (1987) in his quip that you see computers everywhere, except in the productivity statistics.

If one takes the view that computer hardware and software, information technology and systems for managing knowledge are critical factor inputs in production, then the increasing penetration of computers in working life ought to show up in how productive economies are.

Increased penetration is evident in the investment data. Private business investment in information technology-related goods rose from 7 per cent of total private business investment in the 20 years before 1973, to six times as much - over 40 per cent of total private business investment - in the 20 years after 1973.

What happened to productivity growth as a result of this investment in systems for managing knowledge? Chart 8 shows that over the last 40-50 years in the United States, the rate of growth of total factor productivity (TFP) has shown no clear upward trend. Productivity growth fluctuated, at times dramatically, but, at least until the early 1990s, it did not show any dramatic improvement. In fact, if anything, the opposite seems to have been true. In the 20 years before the 1970s, TFP growth averaged 2½-3 per cent per annum. In the 20 years subsequently, TFP growth averaged about 0.8 per cent per year, up until the early 1990s. Where is the impact of these wonderful systems for managing technology? This is Solow's productivity paradox, applied to information technology.

Chart 8: Scientists/engineers and productivity in the United States



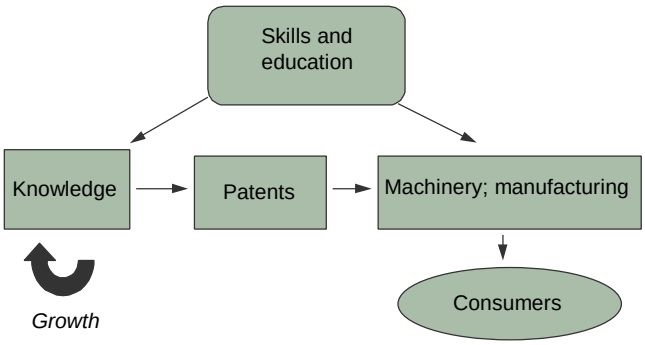
Solow's paradox applies just as well to other measures of knowledge input in the aggregate economy. Chart 8 shows the growth in the number of scientists and engineers employed in research and development in the United States as a fraction of the total US population. The figure has increased fourfold from about 0.1 per cent to 0.4 per cent since the 1950s. Once again, nothing has happened to total factor productivity growth despite the fact that all these knowledge inputs were growing at the gallop.

The Nature of Growth in the Weightless Economy

Why is there this productivity paradox? Why is it that early measures of the importance of technology were close to unanimous about the dominant contribution of technological progress to economic growth whereas the productivity paradox evidence suggests the opposite conclusion?

In part, the answer lies in understanding the nature of growth in a knowledge or weightless economy. The model in Chart 9 may be helpful in addressing these questions. In the diagram, knowledge - in the box on the left-hand side of this picture - is the ultimate source of growth. It feeds on itself and is what drives economic growth. It is an input into a structure of intellectual property, called here for shorthand "patents". Patents in turn are taken as an input to an industrial sector: for example machine tools. A machine can be considered as heavy metal wrapped around an idea, to produce goods for consumers. Growth, as described in this picture, derives from taking human capital (the skills and education of the labour force, managers and other skilled personnel) as a direct input into both the production of knowledge and the running of the machinery.

Chart 9: Technology and growth, old and new



The dynamic described in the diagram is what drives growth, both in the sophisticated, neoclassical growth perspective, as well as in the views of new economic growth theorists such as Paul Romer and others.[7] It is a picture that applies just as well for the early part of the 20th century as it does during the 18th century industrial revolution, when James Watt and Matthew Bolton were racing between Manchester and the Patent Office in London to get their ideas into heavy metal wrapped around the locomotive.

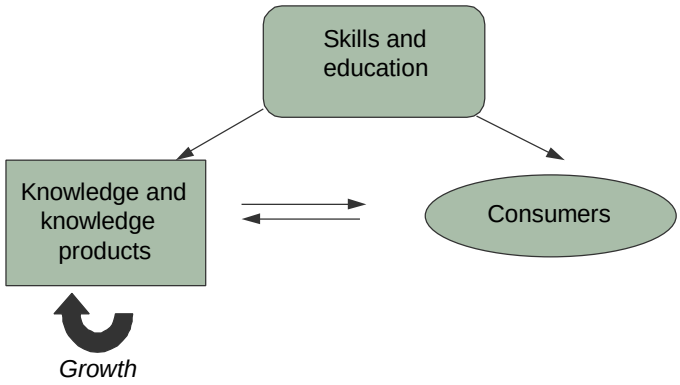
In this picture, monopoly power from the patent structure, and from inappropriable machinery and manufacturing, provides positive rents which, in turn, support and finance the creation of knowledge. To emphasise, those components - the patents and machinery and manufacturing - are the key in the economic mechanism that drives both old and new theories of economic growth.

The DTI's White Paper focuses on what is going on in the left-hand side of this picture. However, in considering the most recent wave of technology, more attention needs to be paid to the right-hand side. What's happening in the newest, most recent technology is not just that there is more and better technology. That there is more and better technology is well described by a picture like this. However, it would, if it were right, not be helpful in understanding the productivity paradox.

The crucial difference about the new technology is that it brings consumers ever closer to the chalk face of technological development. It brings consumers closer to the producers of knowledge in the way illustrated in the following picture:

[7] See, for example, Romer (1990).

Chart 10: Growth in the weightless economy



In Chart 10, the chain that links an intellectual property rights scheme through machinery and manufacturing to consumers has been removed. Instead, consumers and knowledge producers directly interact with each other.

Consider some examples. In surfing the Internet for information, the ultimate consumers are at the chalk face of technological development. When consumers walk into a supermarket and confront advanced genetically modified foodstuffs, they are at the chalk face of technology. When, in turn, supermarkets use a loyalty programme to obtain information and provide better service to customers, that too brings knowledge producers and consumers ever closer together. And there are other examples: the way in which each of us uses computer software, and the role of branding in the knowledge driven economy. All of these are manifestations of the weightless economy, an incarnation of the knowledge driven economy that brings consumers and producers ever closer together.

Characteristics of Knowledge Products in the Weightless Economy

The weightless economy can be thought of as comprising four main elements:

- *information and communications technology*, including in particular the Internet;
- *intellectual property*, not just in the typical economic market form of patents and copyright, but also in branding, images, advertising, trademarks and logos;
- *libraries and data-bases* in the form of electronic compilations of information; and
- *bio-technology*, including carbon-based libraries and data-bases, which are after all just carbon encasings of strings of information.

Thinking about the new or most recent technological developments in this way helps us understand a number of policy debates. The weightless economy is not just about the shift from manufacturing to services that can be seen in all advanced economies. Knowledge can play a bigger role in traditional sectors as well as new sectors and may be of relatively minor importance in some service sectors. Nor is the weightless

economy just about technological change, which has been ever-present. And it is certainly not the case that the weightless economy is a destroyer of jobs. It provides new sources of employment and new opportunities for enhanced prosperity.

What is different about this new way of thinking, about the knowledge driven economy? What is the special significance of this reduction of distance, not in the Frances Cairncross (1997) sense of the death of geographical distance, but in the sense of the death of distance between knowledge producers and consumers? What are the implications for the distribution of income, for industrial performance, for economic performance overall?

One point to note is that many of the products of a weightless economy would not constitute knowledge in the view of a scientist, an academic or research engineer. A piece of computer software or a new pharmaceutical product is very different from a theorem, or a piece of machinery or a new industrial process, the traditional embodiments of knowledge. What is key is that these new forms show a high concentration of knowledge in the final product and, more important, the products themselves behave like knowledge. Stiglitz and Dasgupta (1980) and others have thought a lot about the implications of these developments for industrial performance and industrial structure. In the ongoing rush of technology, it is important to think about what these developments mean for consumers too.

Knowledge and Knowledge Products

There are a number of ways in which the knowledge products of the weightless economy behave like knowledge:

Infinite expansibility. I have described this elsewhere as the chocolate hobnob problem. When one person eats a chocolate hobnob, it is no longer available for other people to consume. Knowledge is different. When a consumer uses an item of knowledge, that knowledge remains and is still as good. When a consumer in London downloads a piece of software by satellite from a server and uses it in London, another consumer living in California can be doing the same thing at exactly the same time and not suffer any degradation in his or her enjoyment of the product. That is the first sense in which these consumer products behave like knowledge.

New geography. From the above description, it is also apparent that these products are severely disrespectful of physical geography, hence Cairncross's (1997) book on the death of distance.

Inherent unknowability. Knowledge goods have some of the properties of experience goods for the consumer - unless one has used them before, one does not know how useful they are.

Ranking priority. Since there is a disrespect for geography, it is also easy to understand why there are spillovers - although in the short run these still tend to be regionally concentrated. Ranking priority refers to how, as a consequence, only the first creator of an item of knowledge really owns that product and is able, other things

being equal, to service the entire market. There is a winner-takes-all, or economics of superstars, character to many knowledge products.[8]

Non-additivity. The supply side of many knowledge products is characterised by non-additivity in input. The production of knowledge may often take one computer programmer working intensely for a period of time. You do not necessarily get a better product or faster product by throwing more computer programmers, more software designers, more graphic artists at the particular project. Non-additivity may be illustrated by the fact that, for instance, to make a baby you cannot make nine women pregnant for a month each. Similar arguments apply to the production of knowledge products too.

One consequence of these characteristics of knowledge products is that the institutional structure that societies choose will determine the outcome in terms of the distribution of income across producers. A strong system of intellectual property rights will lead, by the nature of these products, to winner-takes-all dynamic monopolies. They might be transient but they are, nevertheless, winner-takes-all monopolies. On the other hand, fully exploiting the near-zero marginal cost of production of knowledge products would lead to an *ex post* flooding of the market. If property rights are very weak, making a knowledge product available to one consumer could lead to it being available to all.

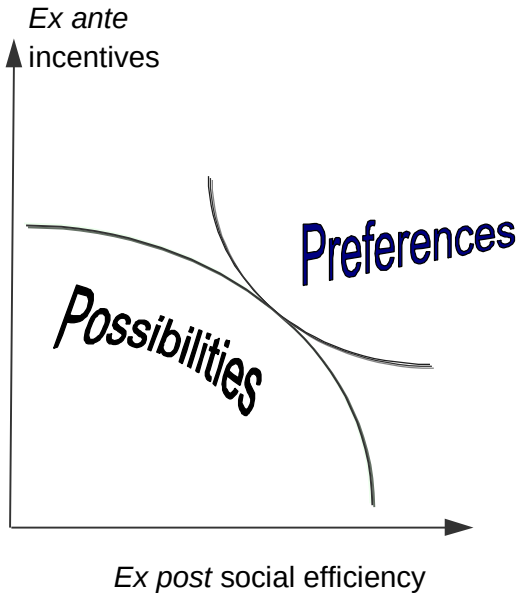
Of course, the trick is to find a "third way" between the extremes of winner-takes-all monopolies and *ex post* flooding. This is the main challenge facing regulators and economic policy-makers. Among the lessons that need to be considered about some commonly used business models are the following:

- Marginal cost pricing is not a particularly useful way to think about running businesses in the knowledge driven economy.
- Because knowledge products are taken directly to consumers, the demand side takes on enhanced importance in shaping the development of knowledge products and the technology behind them.
- Industrial structures are likely to evolve dynamically in a way that creates more superstars and winner-takes-all markets.
- Rather than thinking locally, the knowledge economy requires thinking about the global implications of developments.

The trade-offs society faces in the knowledge economy can be described in a simple diagram (Chart 11).

[8] See, for example, Rosen (1981).

Chart 11: Trade-offs for society



In the chart, the horizontal axis describes the *ex post* social efficiency outcome - the *ex post* flooding of a market stemming from a single copy of, say, a software product. Moving rightwards along the horizontal axis describes a move to a more socially efficient outcome. Doing that, however, destroys the incentives for software producers to continue to make these wonderful products in the first place. So on the vertical axis there are *ex ante* incentives. Societies confront a "possibilities frontier", along which there is a trade-off between *ex ante* incentives and *ex post* social efficiency. Finding the appropriate balance between *ex ante* incentives and *ex post* social efficiency is one of the key issues that policy-makers need to confront in the knowledge driven economy.

Concluding remarks

Significant social changes are being driven by the knowledge economy. There is the possibility for economic growth which is potentially unbounded and of a nature that is different from that in sophisticated neoclassical growth or post-neoclassical new endogenous growth theories. The institutions for the production and distribution of knowledge products and knowledge more generally will determine the outcomes in terms of *ex ante* incentives and *ex post* social efficiency, the dynamics of change in industrial structure, and the possibilities for income distribution and mobility.

As an illustration of some of the messages of this paper, consider the example of 14th century China and the industrial revolution that failed to happen. China in the 14th century was, by many economic historians' account, 400-500 years ahead of the West in technical development. Paper had been developed 1000 years ahead of the West, and movable printing type 200-500 years before Gutenberg. There were methods for harnessing power from water wheels and more sophisticated methods for refining iron than was available in the West. Many technical developments were present at the end

of the Sung dynasty in China. According to some economic historians, 14th century China was an industrial revolution waiting to happen. It was a society and economy where the supply side of technology was fully in place.

What was missing in 14th century China was a consumer base. Technology was tightly controlled by State bureaucrats. This tight control of demand prevented a sophisticated demand base from developing and stifled growth in 14th century China, and an industrial revolution that should have occurred there did not.

So, while the knowledge or weightless economy brings great opportunities and large social changes, it also brings pitfalls and challenges to regulators and economic policy-makers. Given the right institutional framework, the knowledge economy brings with it huge potential including the possibility of virtually unbounded economic growth, even if this is yet to show clearly in national accounts statistics.

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Business Strategy in the Knowledge Driven Economy

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Introduction

Researchers at Oxford's Bodleian Library have recently unearthed one of the earliest business school cases. It is concerned with the strategic response of large multinational enterprises to the advent of the knowledge driven economy.

In 1476 Pius III, Chief Executive of the Roman Catholic Corporation, had a problem. The Roman Catholic Corporation was then the world's leading audio-visual products manufacturer. Through its extensive investment in retail distribution by building cathedrals throughout Europe and by its weekly performance of multi media experiences, known as masses, in these retail outlets, the Roman Catholic Corporation reinforced its dominance in its established market while engaged in global competition, known as crusades, with its main rival, IslamiCorp.

However, Pius III was faced with some difficult strategic choices summarised in a report from the Cardinal for Strategic Planning entitled *Business Strategies in the New Knowledge Driven Economy*. What had prompted this was the disturbing reports that were coming in from England and from Germany about the invention of printing, and it was clear that the invention of printing had major implications for the business strategies of both IslamiCorp and the Roman Catholic Corporation.

The Cardinal for strategic planning had pointed out that this new technology involved massive scale economies. Historically, the only way in which books could be produced was by having them copied and re-copied one by one by individual monks. With the invention of the printing press, however, a single investment in establishing printing enabled the production of a very large number of volumes of any particular kind. It was obvious that this created massive scale economies and that the existence of these scale economies would reinforce the market dominance of Roman Catholic Corporation and IslamiCorp. More than that, they were going to reduce the number of available products as well. If you could produce one book at virtually zero marginal cost, it was very unlikely that in future people would want either to produce or to read the number of books which had been around historically. So the evolution both of the market itself and the firm structure was going to be driven by the scale economies.

Secondly, one had to look at what this implied for standards in the market. The key to dominance was control of the language standards. So it was clear that Latin would become the dominant world language by 1526. Control of the new industrial structures depended on having control of the new technology and there was a firm warning that unless the Roman Catholic Corporation integrated rapidly into printing, the Englishman Caxton was likely to become Pope within 10 years.

Now, with hindsight, these prescriptions look ludicrous. However, they correspond more or less exactly to what people are saying today about the impact of new technologies on industrial structure. It implies:

- concentration into a relatively small number of global players;
- that market dominance will be held by those who control standards and established standards will be reinforced; and
- that control of and integration into the delivery processes is essential for commercial success in the new knowledge economy.

The archive also contained a note written 100 years later by a young Scots scholar called Johannes Kay which explained why the Cardinal's predictions had been so badly wrong. In each case the outcome was essentially the opposite of what had been predicted. Printing did not reinforce the dominance of the Roman Catholic Corporation and may even have been a key element in the decline of the Roman Catholic Corporation and the fragmentation of its particular market.

Secondly, printing did not reinforce established or new standards. It created an explosion of material in vernacular languages and the result was that Latin disappeared quite rapidly as a common medium of communication. Although printing became big business, people who controlled the printing presses were not the people who controlled the new audio-visual markets. The key misunderstanding was that, while the new technologies were characterised by economies of scale, it was more important that these new technologies were cheap, in contrast to the expensive scarce delivery mechanisms which had existed up to then. It was this reduction in cost which drove the changes in market structure and which turned all the processes of origination, publication and delivery into competitive businesses. It destroyed rather than reinforced the vertical integration which had been characteristic of the market up to then.

Moreover, this is equally true of the new advances in information delivery and information technology: more important than the scale economies associated with them is the simple fact that they are cheap. They will turn the whole basis of electronic transmission into a competitive business in much the same way as printing did in relation to the delivery of older kinds of audio-visual material. Indeed the monopoly of the Roman Catholic Corporation over the distribution of audio-visual material was broken by the cheapness of that particular product.

Implications for Strategy in a Knowledge Driven Economy

We must start by avoiding two of the commonest fallacies in the Cardinal's description of 15th century strategies for Roman Catholic Corporation and reproduced in the current conventional wisdom.

The first is the belief that, in order to enjoy competitive advantage and gain control over the structure of the industry, firms in these markets will need to be either horizontally diversified or vertically integrated. We see businesses trying to find some particular point in the value chain which will give them the monopoly of these

processes. But the expansion of the knowledge driven economy today, as with the expansion of the knowledge driven economy in the 15th and 16th centuries, will create a proliferation of material, firms and activities at all points and at all levels. No-one can expect to enjoy continued control of these markets. So the search by structural change in the industry for future dominance of the evolution of these markets is simply misconceived.

The second misconception is that the key to competitive advantage lies in being at the point of product delivery. This is as mistaken as the belief that being at the point of delivery of the printed medium would give control of all the processes that went into it. The sheer cheapness and ease of access to that delivery mechanism means that rents will be driven down at the delivery level, and rents will migrate back up the value chain to be enjoyed by those who have genuinely scarce factors and genuinely scarce competitive advantages.

People are making the same two errors today: that by gaining control of other elements of the value chain they can achieve dominance; and the belief that real value lies in the delivery process itself. That is why you can buy Internet companies today on extraordinary multiples of their prospective profits. Both are misapprehensions about the way in which these markets will evolve.

Tables 1 and 2 compare the leading companies in 1912 and 1999. Table 1 shows that US Steel was the world's leading industrial company in 1912. It was formed by arguments which are extraordinarily redolent and resonant today. It was said that this was an industry approaching maturity, that there was need for concentration and rationalisation, that the future lay with economies of scale and with taking cost out of the business. There would be only a small number of global players in the market in future and US Steel intended to be one of them.

Table 1: Top 12 Global Industrials by Market Captialisation 1912

Rank	Company	Industry	HQ	Capitalisation (US$ million)
1	US Steel	steel	US	741
2	Exxon	oil	US	390
3	J&P Coates	textiles	UK	287
4	Pullman	railcars	US	200
5	Royal Dutch Shell	oil	UK/Neth	187
6	Anaconda	copper	US	178
7	General Electric	electricals	US	174
8	Singer	machinery	US	173
9	American Brands	cigarettes	US	169
10	Navistar	machinery	US	160
11	BAT Industries	cigarettes	UK	159
12	De Beers	diamonds	SA	158

We recognise that US Steel is no longer the world's largest industrial company. Today, despite acquiring an oil company twice its size 20 years ago, its market capitalisation is less than 5 per cent of that of the largest company in the world.

When comparing Table 1 and Table 2, the most interesting point, which is in essence of the knowledge driven economy, is that the products that these companies make have simply got smaller. If you compare the size of what it was that Pullman or US Steel did with the size of what is made by Intel or Merck or Coca Cola, you can see the very specific reality of what Danny Quah describes as the weightless economy. The 1912 companies made things you had to climb into while the 1999 companies make things you can actually put in your pocket.

Table 2: Top 12 Global Industrials by Market Captialisation 1999

Rank	Company	Industry	HQ	Capitalisation (US$ billion)
1	General Electric	electricals	US	223
2	Royal Dutch Shell	oil	UK/Neth	191
3	Exxon	oil	US	158
4	Coca Cola	soft drinks	US	151
5	Intel	chips	US	151
6	Merck	pharmaceuticals	US	121
7	Toyota Motor	cars	Japan	117
8	Novartis	pharmaceuticals	Switz	104
9	IBM	computers	US	104
10	Philip Morris	cigarettes	US	101
11	Procter & Gamble	brands	US	93
12	BP	oil	UK	86

That distinction is the key to understanding the nature of this knowledge based revolution and what Quah calls weightlessness. The raw material content of a product and its physical characteristics have become much less significant in terms of their contribution to overall value. What it is that companies add through one aspect or another of the knowledge economy is crucial. Coca Cola may not strike you as an obvious beneficiary of the knowledge economy but of course it is. The value of Coca Cola lies not in the fizzy sticky water which it produces, it doesn't even lie in the secret formula that is locked up somewhere in the Atlanta safe. The value of Coca Cola and its products rests in the international brand which it has created and all the distribution and attributes that follow.

The value of what Merck produces does not lie in the physical value of the chemical which it manufactures. It lies in knowing the match between the chemical which it has and the therapeutic categories which it is intended to treat. For Intel, the value of the chip doesn't lie in the silicon - which is neither here nor there - it lies in the processes and innovation that go into producing it.

So all of these companies are companies which are products of one aspect or another of the knowledge driven economy. But none of them is involved at the sharp end of the delivery processes of that knowledge driven economy, except to a degree for Intel. These companies' competitive advantages derive from the management of knowledge, and the addition of knowledge to what they produce.

Across the century competitive advantage has migrated from factors that were based on market position, on size and on market power - the kind of competitive advantages that US Steel enjoyed at the beginning of the century - to competitive advantages which are based on the incorporation of knowledge into no longer important raw materials. This generates the range of knowledge based competitive advantages that form the distinct capabilities of firms today.

Many are best summed up by the characteristics of brands. Brands serve knowledge management functions in terms of reputation, signalling and recipes. Equally important as a source of knowledge based competitive advantage is internal architecture - the process of trust and knowledge sharing that is developed within organisations. No less important is external architecture, the kind of knowledge sharing and information processing, that happens between organisations and suppliers in Italian networks or in Japanese *keiretsu*. Knowledge based competitive advantages can also stem from:

- standards, such as those enjoyed by Microsoft's copyrights of Windows, or Britain's proprietorship of the English language;
- protective innovations and patents and copyrights;
- reputations, which make a series of new untried products coming out of that particular company more credible and which help them find acceptance both by retailers and by customers.

Competitive advantages in the knowledge based economy derive from distinctive non-reproducible capabilities of organisations themselves, not from changes in market structure or access to technology by itself. Greater access to technology in the knowledge based economy enables companies like Coca Cola, Merck and Intel to leverage their underlying distinctive capabilities much more powerfully than they were able to do in the past.

Likewise with printing. In that process economic rents accrued to those who had scarce factors which were available to the new delivery process, such as authors and skilled publishers, rather than to people who were engaged in the delivery process itself.

We need to see competitive strategy for the firm as establishing a match between the distinctive irreproducible capabilities of the firm and the competitive environment within which the firm operates. We need to think about industrial policy in the same way. The contribution of government to industrial policy is to recognise, understand and develop the distinctive capabilities of a national economy and to match these to the competitive environment which a country faces.

In the latest Competitiveness White Paper the British Government has picked up and developed these themes and is driving us towards an industrial policy which is based on that approach to industrial strategy.

Knowledge in the Modern Economy

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Introduction

The past several centuries have witnessed several fundamental economic transformations, and each of these economic transformations has had fundamental implications for the nature of society.

The industrial revolution laid the foundation for the transformation of the economy from agriculture to industry; with it, not only did living standards rise, but also the location of life changed, from rural communities to metropolitan megalopolises. The scientific revolution of the past century has resulted in the systematisation of change itself: the very process of producing new innovations has been altered, from isolated and independent inventors like Thomas Edison to huge research laboratories. Knowledge and information is being produced today like cars and steel were produced a hundred years ago. Those, like Bill Gates, who know how to produce knowledge and information better than others reap the rewards, just as those who knew how to produce cars and steel a hundred years ago became the magnates of that era.

In what ways are the laws that govern the new economies different from that of the old? To be sure, we still face the economics of scarcity. But just as the importance of land in production changed dramatically as the economy moved from agriculture to industry, so too does the movement to a knowledge economy necessitate a rethinking of economic fundamentals. Knowledge is different from other goods: it has many of the central properties of a public good, indeed of a global public good.[9] While government has a key role in protecting all property rights, its role in intellectual property rights is far more complicated: the appropriate definition of these rights is not even obvious. And in the knowledge economy, the dangers of monopolisation are perhaps even greater than in industrial economies. These are but three examples of the ways in which the role of government in the knowledge economy may differ markedly from that in the industrial economy with which we have become familiar over the past century.

I want, however, to broaden the discussion beyond these technical economic issues in three directions: to the role of knowledge in development, to the *culture* of the knowledge economy and to some of the implications of the new economy for democratic processes.

I approach the problem of the knowledge economy from three perspectives: from that of a theorist, who has spent almost three decades thinking about the economics of information and knowledge; as Chairman of the Council of Economic Advisers, where we struggled with many of the same questions that are the focus of concern in the

[9] See Stiglitz (1995, 1999a).

recent UK Competitiveness White Paper,[10] and, most recently, as Chief Economist at the World Bank. I hope to weave these three perspectives into my remarks this morning. I shall begin by looking at the problem from my current vantage point.

Knowledge and Development

Development Knowledge and the World Bank

The World Bank is concerned with promoting growth and reducing poverty in the developing world. Our 1998 *World Development Report*[11] was devoted to the theme of Knowledge for Development - and I am of course glad to see it cited in the UK White Paper. For many years the received wisdom in economic development focused on building infrastructure and factories. Government officials could proudly show these constructions to visiting economists as the tangible evidence of development. The focus was on the "weighty economy" - if we use the metaphor of knowledge as the basis for the "weightless economy." We now see this strategy as being seriously incomplete - indeed as only focusing on the "easy part" of development.

Today the World Bank has shifted much of its emphasis to the intangibles of knowledge, institutions and culture in an attempt to forge a more comprehensive New Development Framework for our work.[12] We want, for instance, to be a Knowledge Bank[13], not just a bank for infrastructure finance. We now see economic development as less like the construction business and more like education in the broad and comprehensive sense that covers knowledge, institutions and culture.

The shift in focus was motivated, in part, by the experience of the most successful countries - and the failures of many of our efforts around the world. By most accounts, the accumulation of capital could explain only a fraction of the increases in per capita income in the countries in East Asia. Their miraculous growth is largely attributed to closing the knowledge gap, the gap between the more developed and less developed countries in the knowledge about how to transform inputs into outputs. To be sure, some of this closing of the knowledge gap was itself "purchased," the result of investments in capital which embodied more advanced technologies.

The Knowledge Culture

Changing ways of thinking

But more than just knowledge was acquired: there was a change in ways of thinking. It is hard to define this change: an acceptance of change, a recognition that the poverty in which they had been mired for centuries was neither inevitable nor necessary, and, perhaps most important, the appreciation of the centrality of knowledge and education

[10] Department of Trade and Industry (1998a).
[11] World Bank (1998)
[12] See Stiglitz (1998).
[13] The concept of the Knowledge Bank was introduced in Wolfensohn's address to the Annual meetings in 1996. See Wolfensohn (1996).

in general and science and technology in particular. To be sure, even in the most advanced societies, the scientific approach, as much as it has benefited all of us, remains concentrated within relatively small circles - a fact that those of us who moved from academia to government saw all too clearly. The process of development can be seen as extending the reach of these basic ways of thinking, making them more pervasive in every corner of life.

I have often found that a study of the development process highlights aspects of the more developed industrial countries' societies and economies. So too here, for it brings home forcefully the change in culture that must accompany success in the new knowledge economy. I have seen this vividly, as I have moved from teaching at Princeton, on the outskirts of New York, where the culture of Wall Street cast its long shadow, to teaching at Stanford, and then on to Washington. One really felt the entrepreneurial spirit at Stanford. In the corridors and restaurants, there was constant talk of new enterprises, translating the advances in ideas into new products and new businesses. Venture capital firms sought out these new opportunities, providing not just with capital, but with managerial know-how. The focus was on creativity and wealth creation, not on the rearrangements of the use of already existing assets and corporations, the take-overs and mergers, the corporate restructurings that were so much the centre of attention on Wall Street.

There is no prescription for how a country creates such a culture, just as there is no prescription for how a corporation can create such a culture. But government does have a role - a role in education, in encouraging the kind of creativity and risk taking that the scientific entrepreneurship requires, in creating the institutions that facilitate ideas being brought into fruition, and a regulatory and tax environment that rewards this kind of activity. In the discussion below, I shall focus more narrowly on the technical, economic aspects of government policies, but I cannot emphasise enough my belief that the full benefits of these reforms will only be felt if there is a more fundamental change in culture.

Before moving on to a fuller discussion of these technical issues, let me spend a few more moments dwelling on the central role of institutional and cultural change in the creation of a knowledge economy, focusing on our experiences in transferring knowledge to less developed countries.

Tacit knowledge and local adaptation

The *Analysis and Background* report[14] recognises the importance of non-codified or tacit knowledge and the difficulties in transferring it. Indeed, it is precisely the difficulties in transferring a company's tacit knowledge base embedded in its staff that can be a basis for the company's competitive advantage. But viewed the other way around, this means that transferring tacit knowledge is a substantial obstacle to those of us in the economic development business who view knowledge as Bacon viewed money–as a "muck" to be spread as widely as possible.

[14] Department of Trade and Industry (1998b).

Take technology transfer as an example. The technical manuals, blueprints and instruction books are the codified technical knowledge that could be seen as only the tip of the iceberg. The codified technical information assumes a whole background of contextual knowledge and practices that might be very incomplete in a developing country. Implementing a new technology in a rather different environment is itself a creative act, not just a copied behaviour. Getting a complex technical system to function near its norms and repairing it when it malfunctions both draw upon a slowly accumulated reservoir of tacit knowledge that cannot be easily transferred or "downloaded" to a developing country.

If all this is true for relatively cut-and-dry technical knowledge, one can imagine the problems in "transferring" the economic institutions of a private property market economy to developing countries. The word "transferring" must even be enclosed in raised-eyebrow quotes to signify the problematic nature of this venture. Yet we have come to believe that a proper institutional framework *is* key to development.

What part of an institution is only particular to, say, an Anglo-American environment and what part is more universal? To a boy growing up in the American Midwest with baseball, football and basketball, it is a rude shock to find out that most other countries do not play these ballgames and that most countries even play a game where the ball cannot be touched with the hands! America has clearly not been successful in teaching the world the *proper* way to play "football."

But as economists we try to discern more universal principles amidst the "buzzing and booming confusion" of local economic practices, and we try to apply these principles to reform economic institutions. If this is to be more than a quixotic venture to "teach the world the proper way to play football" then we must consider the subtleties of institutional knowledge transfer. Economic agents act in a whole matrix of economic, political and cultural factors, many of which are tacit factors not apparent to the "visiting economist." A quick transplant of a "textbook model" will very likely not take root in the local soil. Instead a longer process of transplanting or grafting is required. That process cannot be engineered from Washington. The local economic agents and agencies - who have the local tacit knowledge - must take charge of the process of recreating the more universal institutional schema within the local matrix of economic, political and cultural factors. It is this complex interplay of international and local agencies that is key to the Bank's vision of knowledge based development, a vision that moves well beyond the idea of universal recipes developed in Washington about "how to play football."

Active learning and intrinsic motivation

Development is about the transformation of societies which ultimately involves people changing how they think. External agencies cannot force people to change how they think or what they believe.[15] People can be forced to adopt certain behaviours and to

[15] "As little as another can go to hell or heaven for me, so little can he believe or disbelieve for me; and as little as he can open or shut heaven or hell for me, so little can he drive me to faith or unbelief." See Luther 1942 (1523). This insight was basic to the liberty of conscience and the attitudes of religious tolerance fostered in Europe by the Reformation.

utter certain words, but they cannot be forced to change their hearts or minds. That, they can only do themselves.

In industry, the shift towards a knowledge based economy involves a shift in organisation away from top-down hierarchical structures to flatter structures such as networks of semi-autonomous teams. Tayloristic vertical structures were designed to enforce and coordinate certain physical behaviours while knowledge based work organisation involves greater recognition of the autonomy and self-direction of the mind. Knowledge is best acquired not by passive rote memorisation but by the active involvement of the learner. Learning is by doing, not by watching or memorising. These activist principles were embodied, for example, in John Dewey's pragmatic philosophy of education.[16]

To foster the active involvement of the learner, the motivation should at best be intrinsic to the activity, not a super-added carrot or stick. While external incentives can modify short-term behaviour, they usually will only temporarily override rather than change the internal system of motivation. When the extrinsic incentives are removed, behaviour reverts to the previous motives. In the management literature, the importance of intrinsic motivation has been emphasised by W. Edwards Deming.[17] An effective quality system is not based on external monitoring buttressed by quality bonuses, but on the intrinsic ethos of producing quality for its own sake based on the pride and self-esteem of the workers.

All of these principles are equally fundamental for the knowledge based transformation of a developing country as they are for a knowledge based company. "Best practices" that are imposed on a country by conditionalities ("carrots and sticks") will not produce lasting change. It will undermine people's incentives to develop their own capacities and weaken their confidence in using their own intelligence. The external development agency, instead of acting as a catalyst or midwife to empower change, will only short-circuit people's learning activities and reinforce their impotence. The external incentives may temporarily overpower the springs of action that are native to the institutional matrix of the country but that will probably not induce any lasting institutional reforms.

Participation in the vital activities of a developing society, like shop-floor participation in a company, is necessary to foster a lasting transformation. Active involvement brings commitment to the lessons being learned and ownership of the results. Participation and involvement is not just a matter for government officials or managers; it needs to reach deeper to include those who are often excluded and who are key to the strengthening of social and organisational capital.[18] Outside experts can encourage "ownership" of "best policies" through persuasion, but the degree of ownership is likely to be much greater if those who must carry out the policies are actively involved

[16] Perhaps the foremost example of a school system based on Deweyian principles was the system in my hometown of Gary, Indiana established in the early twentieth century see Bourne (1970). The effects of these reforms were still evident when Paul Samuelson went through the system to be followed by myself years later.
[17] See Deming (1982, 1994).
[18] See Wolfensohn (1997) for a discussion of the importance of inclusion in the development process.

in the process of shaping and adapting, if not reinventing, these policies in the country (or company) itself.

Basic Analytics of the Knowledge Economy

It should by now by clear that success in the knowledge economy requires a change in culture. But I want to move away from this broader perspective, viewing the knowledge economy within the framework of the economist's more traditional tool-kit. I want to argue that there are some fundamental ways in which knowledge is different from ordinary commodities, differences which have fundamental implications for the way a knowledge economy must be organised and accordingly, fundamental implications for public policy.

The Scarcity-Defying Characteristics of Ideas

First, and perhaps most fundamentally, is the fact alluded to earlier - knowledge is a public good. Thomas Jefferson described the non-rivalrousness of knowledge and information in the following way: "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me."[19] The properties of dynamic processes driven by knowledge seem to ultimately derive from the scarcity-defying expansiveness or non-rivalrous aspect of knowledge. Once knowledge is discovered and made public, there is essentially zero marginal cost to adding more users.

It is useful to differentiate conceptually the pure non-rivalrousness of knowledge from the low cost of dissemination. The information revolution results, in part, from the great strides made in modern technology, which have reduced the costs of processing and disseminating information. But any material embodiment or encoding of information is still strictly speaking rivalrous. As an overdue notice from a library attests, two people in different places cannot use the same book at the same time. And as the waiting time to download from the Internet attests, electronic packets on telephone networks are still rivalrous and can lead to congestion effects. It is only immaterial ("disembodied") knowledge, information, ideas, concepts, functions and other abstract objects of thought that are purely non-rivalrous. It is the process of embodying knowledge in people (learning) and things (application) that is costly in time and resources.

Intellectual Property Rights

A pure public good is a good that is non-rivalrous and also cannot be excluded from certain users. Knowledge is to some extent excludable so it might be considered an impure public good. But efficiency in use requires that there be no charge; yet with no charge, firms would have no incentive to produce knowledge. For knowledge to be provided privately, there must be some form of "protection" - knowledge cannot

[19] See Jefferson (1984).

simply be made publicly available. In some instances, trade secrets will do. But in other instances, the broader protection of intellectual property rights is required.

Not ordinary property rights

Too often, however, the difference between intellectual property and other forms of property rights are glossed over. Clearly, a system of government which protects my physical property from theft is necessary if I am to have any incentive to acquire such property, and there is almost universal agreement that governments should strive to have the most effective protection of physical property as possible. Reasoning by analogy, some have argued for "strong intellectual property right regimes," failing to note the salient differences.

In particular, all ideas build on the work of others, drawing upon the common pool of ideas. Indeed, the basic ideas, such as mathematical theorems (which provided, for instance, the basis for the modern computer) typically are not patentable. Strengthening intellectual property rights often means raising the price of a key ingredient into research - knowledge - and thus it is possible that an excessively "strong" intellectual property regime may actually inhibit the pace of innovation. Issues of the breadth (scope) of a patent, the standards of novelty, and even the duration pose difficult problems and trade-offs: not only between static and dynamic efficiency (a point long emphasised in the literature) but also between initiating and follow on innovations. As we move into the knowledge economy, more thought to these vital issues must be given.

Externalities

Even if knowledge is not a *pure* public good, there are extensive externalities (spillovers) associated with innovations. The full benefits of the transistor or the laser clearly did not accrue to those who contributed to those innovations.

My predecessor as Chairman of the Council of Economic Advisors, and Stanford colleague, Mike Boskin, was often quoted as saying that he did not care whether an economy produced potato chips or computer chips. This was his quip encapsulating his strong opposition to industrial policy. But he was wrong. There may be a difference between someone who makes a better potato chip and someone who makes a better computer chip: the magnitude of the externalities, the spillovers, may be an order of magnitude greater in the latter case than in the former. I shall return to this theme later in my discussion of industrial policy and picking winners.

Competition

The White Paper rightly emphasises the importance of competition for the success of the knowledge economy. I find it remarkable how some of the debates over capitalism of former days are forgotten as the world confronts new challenges. In the 1930s, there was a great deal of worry about *monopoly capitalism*; the concern was that the new industrial technologies required sufficiently large scales of production for efficiency that there would be relatively few firms in any economy, leading to concentrations in economic (and therefore political) power. Adam Smith's famous

invisible hand theorem was predicated on the existence of competition. But was competition consistent with the newly emerging industrial economies?

Fortunately, it turned out that as the scale of markets expanded and technologies evolved, in most (but not all) industries there were many firms, perhaps not enough that the economy was well approximately by the perfect competition ideal that underlay Smith's theorem, but sufficiently great that the worries about monopoly capitalism seemed ill-founded.

But knowledge, almost by definition, gives rise to a form of increasing returns to scale which may undermine competition. These concerns are reinforced by the large network externalities, such as those associated with the use of computer "languages." These network externalities have further consequences. They give rise to positive feedback and lock-in effects, which have profound consequences for both equilibria and dynamics; there may, for instance, exist multiple equilibria (with one Pareto inferior to the other) and the economy will exhibit hysteresis (history matters).[20]

But my concern at this point is the adverse effects on effective competition. Worries about monopoly capitalism are being played out once again, this time on an international scale, with Microsoft being at the centre of attention. Without prejudging the outcome of the trial underway, it has seemed clear to many independent observers that Microsoft has engaged in practices designed to exploit its position as the almost monopoly in PC operating systems, and has clear intentions of leveraging its position further--a view that Judge Jackson seems to have supported in his findings of fact. When I was in the White House, both the Council of Economic Advisers and the Office of Science and Technology Policy were worried about the potential adverse consequences for the pace of innovation. If the practices that they seem to have been engaged in are not against the law, then the issue is, perhaps the law should be changed.

Several fundamental issues are raised. First, this example illustrates the dangers of excessively strong intellectual property rights. Another example may further illustrate what is at issue. Suppose a computer program which turns out to have a high level of success uses the symbol q for "quitting" the program. Should that "innovation" be protected by intellectual property? Doing so can impede the development of common languages and the pace of innovation more broadly.

Historically, patents have sometimes been used to suppress competition (and even competitive innovation). One of the most famous instances was George Baldwin Selden's attempt to use a patent on a horseless, self-propelled vehicle to establish a cartel in the nascent automobile industry. Another example sometimes cited is Xerox's use of basic patents to deter other entrants into the copying business which changed only with the settlement of the Federal Trade Commission's antitrust action in 1975.[21]

Secondly, in the knowledge economy, competition is better described by Schumpeterian competition than by the price taking behaviour of the Arrow-Debreu

[20] See Shapiro and Varian (1999).
[21] See Kearns and Nadler (1992).

model. In the latter, price is driven down to marginal cost. In the knowledge economy, firms live off of their rents, with price well in excess of marginal costs.

I became concerned about the large differences between the two forms of competition almost twenty years ago. This motivated a research program into the economics of innovation.[22] One of the key insights was not only that the standard welfare theorems (on the efficiency of market economies) did not apply,[23] but that Schumpeter's conjecture, that a succession of entrants would provide competitive discipline, was not in general true. Even small entry costs could result in large monopoly power, with not only prices being maintained high, but with the pace of innovation far slower than under competition.[24]

As we move into the "knowledge economy" just as the new technologies provide greater scope for the suppression of competition, the consequences may be more adverse. I argued earlier that the kind of creativity that is essential for the knowledge economy requires the engagement of the mind. Organisationally, small new enterprises have often provided more fertile ground for this kind of creative engagement than do large established bureaucracies. Many of the most important innovations have originated in these small enterprises. These firms typically begin with a number of disadvantages, such as lack of access to inexpensive capital. If, in addition, there are artificially created market (anti-competitive) barriers then the pace of innovation may well be slowed.

Organisational Dimensions of Knowledge and Information

Knowledge and information differ from other commodities in a number of other ways, which result in markets for information and knowledge differing markedly from markets for other commodities. For instance, by definition, each piece of information is different from every other piece of information: intrinsically, information cannot satisfy the essential property of *homogeneity* that characterises competitive markets. For forms of knowledge (information) that are not protected by patents, there are real problems in market transactions. How can I sell the knowledge? I have to tell you at least something about what I will disclose to you, something that you presumably did not know before; thus, in the process of trying to engage in a market transaction, I lose some of my property. In practice, markets for knowledge and information depend critically on reputation, on repeated interactions and on trust.

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[22] See, for instance, Dasgupta and Stiglitz (1980a, 1980b).

[23] Indeed, the standard theorems on welfare economics, which underlay the presumption of the efficiency of the market economy, *assume* that information and knowledge is unaffected by any action taken by any participant in the economy. Thus standard economy theory has little to say about the efficiency of the knowledge based economy. More generally, Greenwald and Stiglitz (1986) showed that whenever information is imperfect (and can be affected by actions of participants) the economy is not, in general, even constrained Pareto efficient (i.e. even taking into account the limitations imposed by the imperfections of information and the costs of acquiring further information).

[24] See Stiglitz (1988) and Dasgupta and Stiglitz (1980b, 1988). See also Gilbert and Newbery (1982).

Knowledge transactions within firms

This is seen most markedly in the myriad of knowledge transactions which occur within a firm. Within an organisation, the "payment" for knowledge sharing is often recognition and prestige or the possibility of future reciprocity. But if managers or team leaders represent the ideas of the team members as their own or if sharing between certain team members is rather one-sided, then the "supply" of knowledge will be diminished. Workers will not assist in codifying their tacit knowledge about doing their job if they feel it will jeopardise their employment. The knowledge market must be built on trust that there will be reciprocity, some *quid pro quo*, in the transaction.

"Knowledge is power" so, in some cases, knowledge that should be freely available in an organisation might be hoarded to create an artificial scarcity or monopoly. In times of difficulty when knowledge sharing might be most important, the threat of downsizing may lead people to hoard their knowledge to increase their indispensability. If knowledge hoarding is rewarded, then there will be a vicious circle of knowledge restriction instead of the virtuous circle of knowledge sharing.

Elsewhere, I have described how managers may deliberately create asymmetries of information, in order to increase their power vis-à-vis outsiders, reducing the chance of a take-over and increasing rents.[25] While these problems may arise in any firm, they may be particularly acute in knowledge based enterprises.

On the demand side, organisational culture will artificially limit demand for knowledge if it denigrates any requests of knowledge as an admission of ignorance (like, for example, a mail driver asking for directions). But a greater limitation on the demand for knowledge is the "not invented here" syndrome. Each individual or group will tend to diminish the importance of any knowledge they might obtain from elsewhere and to greatly embellish the power of the knowledge they already have. This is captured in the barnyard saying that "every rooster likes to crow on top of his own dunghill."

This problem also arises when knowledge is "branded" by an organisation. The organisation's prestige and image is tied up with that branded knowledge. Any admission that there might be superior knowledge elsewhere from which the organisation could benefit would be seen as "criticising" the organisation, "tarnishing" its brand reputation and "diminishing" its franchise value at the very least, by helping its rivals. If *that* is the corporate culture, then little organisational learning will go on. When Ken Olsen, the founder of Digital Equipment Corporation, forbade any discussion or even mention of "personal computers" within the company that was "identified" with mini-computers, he sentenced the company to its eventual fate of being overtaken by the personal computer market.[26]

Openness and knowledge transfer

These knowledge principles carry over (making the necessary changes) to countries as a whole. If basic intellectual property rights are routinely violated, then the supply of

[25] See Edlin and Stiglitz (1995).
[26] See Davenport and Prusak (1998), p. 44.

knowledge will be diminished. Where trust relationships have been flagrantly violated (as has happened, for example, in some cases to companies bringing both financial and knowledge capital to the former Soviet Union), learning opportunities will vanish. The breach of trust will not soon be repaired.

The openness of a country to foreign trade seems to have a far greater effect on its economic success than would be predicted by the standard trade models of comparative advantage. One explanation is knowledge: trade and foreign direct investment provide important channels for the transmission of knowledge.

Knowledge is also obtained by travel across open borders.[27] Both Slovenia and Albania had borders with west Europe but the borders were not equally open. Slovenia had the most *open* border of the socialist countries and is now also the richest in per capita terms; Albania was the most closed and is now the poorest post-socialist country. (To be sure, there were other differences that accounted for the disparity in per capita GDP, but Albania's insulation certainly contributed.) In East Asia, the key event in Japan's economic development was the dramatic opening to foreign knowledge in the second half of the 19th century that marked the beginning of the Meiji period of Japan's determined modernisation drive.

Knowledge transfer also follows the trail of foreign direct investment. For instance, a major source of learning about lean production methods and their adaptation to American culture was Japanese direct investment in production facilities in the United States (so the knowledge flows across the Pacific have been two-way).

Experimentation

Another type of openness important to knowledge based transformation is the willingness to experiment. Societies that do not experiment can be historical dead ends like the closed and static feudal manors of medieval Europe. Modern Europe evolved from the towns which grew up in the "cracks" of an otherwise closed medieval society and which functioned as "special zones" where new forms of economic and social organisation could be tested. Experimentation requires an openness to new knowledge and to change, and change can always be unwelcome to the powers that be.[28]

[27] "It is hardly possible to overrate the value, in the present low state of human improvement, of placing human beings in contact with persons dissimilar to themselves, and with modes of thought and action unlike those with which they are familiar.... Such communication has always been, and is peculiarly in the present age, one of the primary sources of progress." (J.S. Mill, quoted in Hirschman 1981, p. 17).

[28] "And *successful* change requires a large measure of freedom to experiment. A grant of that kind of freedom costs a society's rulers their feeling of control, as if they were conceding to others the power to determine the society's future. The great majority of societies, past and present, have not allowed it. Nor have they escaped from poverty." See Rosenberg and Birdzell (1986).

The Marketplace of Ideas: Decentralisation, Competition and Experimentation

Pluralism in project selection

Thus, pluralism and competition, often associated with openness, are vital to innovation and the growth of knowledge. The structure of economic and political institutions powerfully affect which ideas, innovations or projects are selected to be financed and implemented. Decentralisation provides the scope for greater experimentation and learning and the competition among decentralised units may provide an essential spur.

Some years ago, I explored one aspect of this, in contrasting two opposing extremes in project selection: a hierarchical system, where a proposal must pass a series of hurdles to be accepted; or a decentralised system of alternative decision centres, where a proposal can be accepted by any one of them (and can get a second chance if turned down). The hierarchical system would tend to err on the side of rejecting many good projects while the decentralised system would err on the side of accepting many bad projects. The advisability of the two systems (and various mixtures) would depend on the relative cost of accepting a project that turns out to be bad versus the opportunity cost of rejecting a project that turned out to be good.[29]

The hierarchical system would be best for a decision where accepting a bad project might be fatal–as in the decision to go to war. But where accepted bad projects are not fatal and only expend resources, the clear verdict of history is in favour of a more decentralised system of pluralistic political or economic units.

In a decentralised system, decision-makers compete against one another to find good projects. With centralised or monopoly project selection, there is no fear that a rejected innovation will be adopted by a competitor and an accepted innovation might have an uncertain effect on the monopoly. Thus hierarchical centralisation has been a recipe for uniform and essentially static societies from ancient Egypt to the Soviet Union. In contrast, Columbus was turned down by the King of Portugal and two Spanish dukes before submitting his proposal to Ferdinand and Isabella. After a four-year wait, he was again turned down, but the decision was reversed two years later in 1492. In this manner, the pluralistic and competing channels of selection foster innovation.

Towards robustness: some implications of imperfect knowledge

We live in an imperfect world–and that imperfection is mirrored in our own fallibility. We can never know all that we might know and we are hard put to sift the relevant knowledge from the "knoise" (noise posing as “knowledge”) that is always pressing upon us. We may make poor decisions on the basis of what we know, we often fail to communicate our knowledge to others and we may misrepresent our knowledge, or lack of it, when dealing with others. All of this affects economic transactions and other social interactions as well as the work of enterprises and other organisations.

[29] See Sah and Stiglitz (1986).

The importance of recognising human fallibilities and imperfections of information

Economists have often assumed away these fallibilities in their models, as physicists might assume away the effects of friction. But we now understand that economics without human fallibility is like the play Othello without Iago. If all the characters in Shakespeare's Othello knew what there was to know and communicated it truthfully to others, it would have been a simple story yielding little insight into the real world–like some economic models. While the consequences of being "all too human" can sometimes be tragic, our goal is not pessimism but realism. Economic policy advice extracted from realistic models is likely to be far more valuable than advice divined from elegant but Panglossian models of perfect information, unbounded rationality and truthful behaviour.

If an institution was structured to operate on the basis of "perfect knowledge," then experimentation or critical thinking would be seen as a waste of time and resources. The "one best way" would be known; there is no room for "continuous improvement." But under the actual conditions of imperfect knowledge, bounded rationality and fallible judgement, institutions need to be structured for robustness in the sense of yielding acceptable outcomes with existing or potentially available knowledge (not requiring perfect information in order to function).

The failure of central planning: an example

A major historical example is the recent restructuring of centrally planned economies towards decentralised market economies. Knowledge about beliefs, preferences, technology and local conditions is dispersed among economic agents. Centralised mechanisms for gathering, processing and transmitting this information deteriorate as the informational messages grow more complex (as is illustrated by the children's game of transmitting a piece of information or a story around a circle). The problems are compounded by the difficulties of eliciting and transmitting knowledge that is tacit or implicit in behaviour (like knowing how to operate a machine skilfully). Centralised attempts to reduce "wasteful" duplication of experimentation ultimately stifle innovation. Centralised structures have worked only for relatively short spans of historical time, for example, during a war effort or in a big technology project. Attempts to "command" decentralised behaviour in a centralised framework face severe motivational and principal-agent problems, and lack the credible commitment that the "decentralised" decisions will be respected and sustained by the central authorities.

The available but dispersed, local and tacit knowledge would presumably be used by the agents if they were acting on their own behalf in a decentralised and competitive market process. Instead of postulating some unrealistically ideal information transfer to and from central planners, as well as some idealised central information processing capacity, the plan-to-market type of restructuring allows the available knowledge to be locally utilised by the decentralised agents. The separate agents would also perform many local experiments (which might "wastefully" duplicate one another) to discover new knowledge. Prices would evolve to reflect the relative scarcity of resources and to align subjective expectations with the factual state of affairs.

In a static environment, in which the central output is steel and similar industrial goods, centralisation has a chance of at least working. But, as the century moved on and knowledge became increasingly important, the limitations of centralisation became increasingly apparent and agency problems became more severe.

Decentralisation and participation within firms

The plan-to-market transformation is but one example of a decentralisation to accommodate greater complexity and imperfection of knowledge and information. In the firm, moving from simple repetitive work under central control (Taylorism) to more complex knowledge based work requires a move towards a more decentralised and participative workplace. Central command structures give way to semi-autonomous teams horizontally coordinating according to centrally given rules. Work organised according to the externally determined "one best way" is replaced by participative experimentation leading to continuous improvement.

Within the firm, the transfer of localised tacit knowledge takes place mainly through horizontal apprentice-like relations, not vertical training from managers to workers. Moreover, the information transmitted upwards in a hierarchy to inform decisions is explicit codified information, so decisions are made in a hierarchical structure without lower level uncodified tacit knowledge. Better decisions might be made lower in the hierarchy closer to the source of the knowledge. Decentralised authority also partly unifies principal and agent to mitigate agency problems. When these local decisions require informational inputs from various different job categories, it is best for the decision-makers to have rotated through those job categories to have acquired their tacit components. These arguments for fuzzy job boundaries and job rotation cut against the traditional arguments for specialisation and division of labour.

Openness in the political process

These changes in economic institutions have counterparts in the political sphere. Here again, the basic theme is restructuring institutions to deal with an imperfect world in contrast with a hypothetical "ideal world" where power is combined with "perfect knowledge" and "perfect virtue." In the actual world, institutions are best structured with openness and competition to be robust under the assumption that knowledge and virtue are rather less than perfect. That robustness strategy applied to social and political institutions leads to the institutions of an open society such as a free press, transparent government, pluralism, checks and balances, toleration, freedom of thought and open public debate. The restructuring moves away from the idea of a closed society that "knows the Truth" towards an open society that "knows it does not know the Truth."

This political openness is essential for the success of the transformation towards a knowledge economy. As the economy has gone through successive transformations, there have always been losers as well as winners. The losers, keenly aware of their losses, have often tried to use the political process to thwart the changes that adversely affect them.

We now know a great deal not only about the incentives of these special interest groups, but how they operate and why they are often successful in spite of the fact that society overall loses in the process. Openness, and competition among different political entities, provides one of the most important checks.[30] But as the pace of change may increase, as we learn how to produce even more efficiently in the knowledge economy, the dangers posed by these special interests may also become all the greater.

Public Policy for a Knowledge Economy

Some Recent US Policies

The White Paper should be commended for its treatment of the many facets of public policy for a knowledge economy. I do not want to repeat here the messages that are brought out so clearly there; but I do want to share some of the perspectives on these public policy issues as we viewed them in the early days of the Clinton Administration, when there was more attention focused on these issues. And I want to relate these perspectives to the analytic framework of the past two sections.

Increasing Capacity

A key to success in the knowledge economy is a trained labour force. It is not surprising that so many countries have focused on improving their educational systems. All of this is commendable. I would like to make three observations:

First, in the long run, success in the knowledge economy requires creativity, higher order cognitive skills *in addition to* basic skills. Those countries that find ways of fostering this kind of creativity will, in the long run, have more success in competition in the knowledge economy.

A second key to success in the knowledge economy is training in science and technology. There are good grounds for government subsidies to science education. Because those engaged in research so seldom capture the full benefits of their work, there are, as noted earlier, real externalities. These externalities may be most marked for graduate education.

Thirdly, one of the reasons that the education sector may not be as strong as we would like is that it is one of the sectors in which competition is most limited. Yet there are good reasons why market mechanisms fail to work well and to serve fully national objectives. While I do not want here to enter into the debate on school vouchers and school decentralisation, I do think that we need to continue to look closely at how we can most effectively increase competition *and* pursue broader public objectives.

[30] The literature on these topics is voluminous. See, for example, Olson (1982) and Dixit (1996). On the role of openness, see Stiglitz (1998, 1999b).

Industrial Policy and the Support of Research

Earlier in this paper, I commended the White Paper for its thoughtful approach to industrial policy and I referred critically to my predecessor's remarks concerning potato chips and computer chips. Industrial policy has often been criticised as "picking winners"; it is argued that the government is particularly ill-suited to that task.

In fact, the government has had a remarkable history of success, from the support of agricultural research (the core industry in the 19th century) which led to huge increases in productivity in that sector, to the first telegraph line (between Baltimore and Washington, in 1842) to the development of the Internet.

But the debate has been framed in the wrong way. The objective of the government is not to pick winners, but to identify externality-generating innovations. While critics of industrial policy recognise the necessity of government support for basic research, they fail to note that there is no bright line between basic and applied research; many applied research projects generate large externalities. The objective of government policy is to identify winning projects with large externalities. In this, they have had a history of notable successes.

In the United States, there have been efforts to improve the selection process, by requiring partnerships between the government and the private sector, i.e. requiring the private sector to risk some of its own equity, and by engaging in competitive selection processes. There is some concern that these reforms have been too successful; as they have eliminated the rents associated with government sponsored research programs, they have also reduced some of the sources of political support.

Before leaving this topic, there are three other important observations. First, much of the innovation which has marked the knowledge economy rests on foundations of basic knowledge, a global public good. There may be a tendency both to under-appreciate the importance of basic research and to attempt to free-ride on the basic research provided by others. The result can be disastrous; at the very least a slowing down of the pace of progress.

For at least half a century, in the United States, much of the support for basic research was provided through defence budgets. With the end of the Cold War, this support has dwindled. While the backlog of basic research will continue to feed advances in applied technology for years to come, eventually the well will begin to dry up. Now is the time to begin more active measures to replenish the pool.

Second, governments have a proclivity for fancy projects, like space stations, that attract popular imagination but are not necessarily the best way of spending scarce research funds.

Thirdly, one has to take a hard look at other programs supporting new technologies, to assess their incremental effect. There is some evidence, for instance, that the program

of research support for small businesses in the US, as well intentioned as it may be, has not had any significant effect in increasing research.[31]

Competition

The White Paper rightly emphasises the importance of competition. Earlier, I stressed the real dangers to effective competition in the knowledge economy. We need to revisit both the appropriate competition laws and intellectual property regimes. Again, let me raise a few observations.

First, as we move into a global economy, the issues of competition become raised on a global level. Greater co-operation among competition authorities might be desirable, especially if this led to more effective enforcement of competition standards and a levelling up of those standards - to the highest rather than the lowest common denominator. The world will benefit from a more competitive marketplace and the countries of the world need to work in concert to achieve that goal.

Second, while there has been much progress in reducing tariffs, non-tariff barriers, including dumping duties and countervailing duties (CVDs) have taken on increasing importance. Both can undermine not only competition, but industrial policies which support the new knowledge economy. Restraints against trade in genetically engineered plants and other Luddite measures can similarly impede scientific progress.

Thirdly, the White Paper seeks to encourage collaboration, but does not sound as strong a warning as I would about collaboration slipping into collusion, or providing the basis for tacit coordinated anti- or at least non-competitive policies.

Financial Markets

I believe that one of the important reasons for success of the US in the arena of the knowledge economy is its vibrant capital markets, and especially its venture capital funds. American capital markets have long been far more competitive than those in many other countries. Anti-trust authorities would have looked askance at the kinds of concentrations in banking that are found in many other countries. While it is not apparent what else one can do to encourage this kind of innovative lending, clearly tax policy may be able to play a role.

Tax Policy

In the US, there are some features of the tax code that have encouraged innovation, some that have discouraged it. The incremental research and experimentation tax credit has long received official blessing, but has only been renewed on a year-to-year basis. Perhaps this is because there is some evidence questioning its efficacy. There is a recently enacted provision to encourage small new enterprises (by exempting capital

[31] See Wallsten (1998).

gains), but it is too soon to tell its effectiveness, including the extent to which it helps create new knowledge based enterprises.

The limitations on loss deductibility, however, serve as a major deterrent to risk taking.[32] Research, by its very nature, is a risky undertaking. It is like drilling for oil. Success is measured by whether one strikes one successful hole in ten. The corporate income tax is often described as leading to the government acting as a silent partner; but while a partner who shares risk can encourage risk taking, a partner that shares in the successes but not in the losses is likely to discourage risk taking.

In the United States, preferential treatment of capital gains has been defended on the grounds that it encourages risk taking and entrepreneurship, of the kind associated with the knowledge economy. But most of the tax preferences go not to this kind of entrepreneurship, but, for instance, to speculative real estate lending. I referred earlier to the importance of a change in culture. A tax system that rewards the returns to speculative real estate in the same way that it rewards real innovation is not supporting the culture of innovation.

Conclusion

These are exciting times for the economics of information and knowledge. Industry in the developed countries is moving from metal-bashing to knowledge generation. The information or ICT revolution is pushing to eliminate the effects of "weight" and distance. In the days of the pony express, it took many horses, men and days to send a message from Kansas City to San Francisco whereas today it is done in the blink of an eye by a little quivering in an electromagnetic field. We are slowly shedding the limitations of Matter to unleash the expansiveness of non-rivalrous Ideas.

Economic models that ignore information imperfections and knowledge creation give us poor guidance since so many institutions can only be understood as adaptive responses to informational problems. Only by seeing the central role of informational imperfections can we hope to design and preserve robust institutions. Similarly, understanding the subtleties of tacit and local knowledge, as well as the dynamics of knowledge sharing or hoarding, will do much to determine the competitiveness of a company or an industry or a country.

It is imperative to understand the ways in which the production and distribution of knowledge and information differs from that of goods like steel and cars. Processes where knowledge plays a driving role will tend to display positive feedback. In social and economic life, we now see the ubiquity of self-reinforcing processes which display multiple equilibria, path dependence (sensitivity to initial conditions) and lock-in effects. While impediments to competition may be more important, the advantages to be gleaned from greater decentralisation may be all the greater.

The fact that knowledge is, in central ways, a public good and that there are important externalities means that exclusive or excessive reliance on the market may not result in

[32] See Stiglitz (1969) and Auerbach (1983).

economic efficiency. For those of us who believe in the power of market forces, the challenge is to find the best "partnership" between the private and public sector - an assignment of roles and responsibilities not dictated by the paradigms of the past that are unsuited to the knowledge economy of the future. Unfortunately, in the search for a framework for this new partnership, simple slogans ("picking winners") will not get us very far. We are all in uncharted territories and we will have much to learn from the experiments of each other.

Throughout the world, this new perspective is having profound effects on public policy. In development work, the focus has shifted to the intangibles of knowledge, institutions and culture. The World Bank is now transforming itself into more of a knowledge bank and is forging a more comprehensive development framework to put the new focus into effect. In more advanced industrial economies, the challenge of creating and nurturing a culture of innovation and change is no less daunting.

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Technological Change and R&D

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In this short paper, I concentrate on the economics of technical change and innovation and related policy issues. It appears to me that other papers largely address the question of the importance of R&D and technical change in growth. I have resisted the temptation to present a series of tables on the UK's productivity and technological performance for the general thrust of the UK's problem is well known and also the data is available in the White Paper and the Analysis and Background report.

In line with the general mode of analysis, the core concept is the knowledge stock. This is not simply defined, but may be considered to be global and to encompass the sum of ideas relating to basic scientific and non scientific understanding and their applications in technological and non technological activities. This global knowledge stock may be expected to increase over time through many ways but most notable will be (i) world scientific activity; (ii) other R&D activity; and (iii) experience and the use of knowledge (thus overcoming any supposition that I am re-introducing the linear model of innovation). It may be worth noting that to some degree the forces that drive certain additions to the knowledge stock (scientific knowledge), essentially peer esteem, may be very different from those that drive the use of that knowledge - expected private financial returns. There is not necessarily therefore a close relation between user needs and supplier provision of knowledge.

Economic actors - be they nations, firms or individuals - draw on the global knowledge stock and as they embody such knowledge into their economic processes so output and productivity increase and growth proceeds. Use of knowledge can come about through taking ideas and then building products and using processes (including new management methods) that embody them or alternatively buying and using products and processes in which knowledge has already been embodied by other economic actors. Accessing and using the knowledge stock is the process of technical change. All the past literature suggests that technical change thus defined is either the or, at least, a major driving force of growth and productivity.

Knowledge is considered to be non-rivalrous in that use of it by one country or individual does not prevent its use by another country or individual (Arrow, 1962). In addition, the use of knowledge is not a zero-sum game: if all used the knowledge all would be better off. However, there are advantages to being ahead, thus having a technological lead, i.e. either using later knowledge or using knowledge more effectively than rivals means extra benefits whatever the level of technology. A leader will always be richer than a follower. If a follower catches up, the follower will become better off but it will be partly at the expense of the leader's prosperity (Krugman, 1995). If a follower falls further behind it will become worse off. For an individual country therefore, growth and productivity benefits arise through technical change, but having a technical lead means even greater levels of output and productivity for the leader than if all countries had the same technological level.

For an individual country technical change may involve either catching up and movements towards the knowledge frontier, or if the country is already on the frontier, maintaining a position on a moving frontier. Clearly backward countries that have the opportunity to move towards the frontier have greater growth opportunities than those already on the frontier. For example until recently Japan was able to grow very fast as it caught up. Its growth has now reduced considerably. However catching up will not enable countries to surpass the levels of those already on the frontier. Such growth will just take them to some equality with the leaders. In fact the catch-up may reduce the output levels of the leaders as their technological lead is reduced.

The key issue is how may countries successfully access and utilise the global knowledge stock or, to put it another way, how might some countries be more technologically progressive than others. Jones (1998) emphasises the importance of infrastructure and incentives (for example, the lack of crime). This would lead one to consider for example that economies where private incentives are strong, where risk capital is available and where education levels are high will have an advantage in assimilating and utilising knowledge.

At a more detailed level:

- If knowledge is tacit then experience matters and success will breed success.
- If complementary inputs are important to knowledge assimilation and use then high skill levels in the work-force and perhaps clusters will be important.
- Own knowledge generation activity (R&D) may be necessary to understand the knowledge available in the global pool.
- An effective IPR policy may be essential to effectively benefit from domestic additions to the global knowledge pool.

If the knowledge pool is global, why should any country bother to spend on R&D? Why not free ride? The reasons for spending on R&D, rather than free riding, are that in addition to adding to the world knowledge stock, for a single country, R&D:

- enables the understanding and assimilation of other knowledge in the world stock;
- creates labour skills that enable effective use of knowledge; and
- enables a country to be first in acquiring and using additions to the world stock of knowledge and thus getting the leader's benefits.

One may particularly note the Cohen and Levinthal (1989) idea that R&D has two faces. It both develops new knowledge and also enables firms to assimilate knowledge originating elsewhere.

Will greater R&D in the UK yield higher output, productivity and growth in the UK? In the literature it is accepted that R&D will yield higher growth and output levels, however there is considerable controversy in the literature as to whether any increase in the growth rate will be permanent or temporary. My view is best stated as that R&D will matter (for some period at least) but not only R&D will matter. In many areas of economic activity the UK may well not be on the knowledge frontier and as

such catch-up is feasible. R&D may contribute to this but other actions relating to catch-up may be as or more important. In other areas of economic activity more R&D may well enable the UK to lead more effectively and so contribute to improved performance. Thus, to the extent that R&D means earlier and more extensive use of technology, the UK will benefit.

If not only R&D matters what else matters? I have long argued that to emphasise R&D places excessive stress upon the generation of technology rather than the use of technology. The use or diffusion of technology may be affected by R&D but a number of other factors matter including:

- the availability of long-term finance for technological investments;
- the availability of start-up capital for new firms;
- the availability of skilled labour;
- attitudes to risk;
- macroeconomic conditions;
- information spreading mechanisms; and
- the tax and policy environment.

One must note however that greater R&D or faster catch-up will not necessarily yield a measured increasing growth rate. To some degree at least it is performance relative to competitors that matters and if they also speed up then the UK may only be running faster to stand still. It is noteworthy that the Analysis and Background paper shows how world R&D has been increasing. A country that wishes to keep a technological lead may therefore have to increase its R&D in order just to stand still. Jones (1998) notes that in the US between 1950 and the mid 1990s the fraction of the labour force engaged in R&D increased by a factor of almost three. However average growth rates of output and productivity in the US are no higher today than they were from 1870-1929 (one should note that Jones does not attribute this to the cause stated here).

One might also note that as R&D and related activities are investment activities, such increased investment although possibly generating higher output may not necessarily generate increased consumption and welfare.

The DTI *Analysis and* Background report shows that the UK sits some way down the international league tables in terms of productivity growth, and in terms of R&D/GDP has probably been falling further behind. There may thus be a significant opportunity for the UK to do better both in terms of R&D and in terms of technology diffusion. It is however a matter of dispute as to what is actually required. For example, as regards R&D, it is not clear whether the UK requires more R&D; more R&D relative to GDP; more R&D relative to competitors; or a growing ratio of R&D to GDP relative to competitors.

Finally, to seek more R&D or faster diffusion is fine. To find a mechanism to generate the same is another matter. Much of the academic literature on technology policy is microeconomic in its orientation and is primarily concerned with market failure. The driving force of such literature is thus to ask: can government intervention reduce market failure and increase welfare? The approach here is somewhat different. It is

macro orientated and driven by international comparisons. It is not necessarily the case that poor comparative international R&D performance, for example, is necessarily the result of market failure.

The list of policy instruments is well known to all:

- Tax incentives to R&D (perhaps the alternative of a levy grant scheme is less well known) There is however considerable dispute as to whether such schemes are cost effective.
- Policies to make capital markets more long termist (eg modifications to anti-trust legislation) or turnover taxes and extensions of venture capital.
- Improved skills on the labour market and further investments in trained and scientific personnel.
- The encouragement of inward investment to transmit best practice.
- Risk-shifting launch aid schemes
- Macroeconomic stability (although I have my doubts)
- Effective IPR policies to enable domestic early exploitation
- A reconsideration of the defence and high-tech emphasis of UK government R&D spending.
- Improved access to scientific expertise for potential users of knowledge.

I must admit, however, that in no case am I convinced that there is an easy fix. None of the literature appears to suggest that raising the rate of technical change in an economy, especially a mature economy such as the UK or the US, can be achieved quickly or easily.

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Education and Training for the Knowledge Economy

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Introduction

This short paper examines the reasons for the UK's poor productivity performance. It argues that the UK could make major improvements in productivity by adopting best practice. However, there are a number of barriers to the effective adoption of the best techniques, with skills being the most important.

UK Productivity Performance

In the market sector. output per hour in Britain is about 25 per cent lower than it is in West Germany and about 35 per cent lower than in the United States. The difference between Britain and West Germany is explained by higher levels of both physical and human capital; in fact West Germany has more capital and more skills than the United States. The difference between the United Kingdom and the United States is more interesting. A third of the US lead can be explained by capital, while it is not clear that skill levels in the UK are significantly worse than skill levels in the US.

The fundamental difference between the UK and US is that a far higher percentage of business units in the United States operate at what one might call "best practice". Much of this is quite simple, such as the best way to clean a hotel room or operate a retail banking outlet. GDP is mostly comprised of these processes, many of which will use technology, but are not typically high-tech of themselves. Moreover, tacit knowledge is of fundamental importance here because it is at the heart of best practice.

Barriers to the Spread of Best Practice

To operate at best practice requires a strong incentive to implement it. There are a series of barriers to the effective uptake of best practice:

Competitive intensity. Inadequate competition provides no incentive to adopt best practice.

Market for corporate control. The threat of take-over and large active external share-holders pressure managers to adopt best practice. However, mergers can often lead to large productivity losses and may also lead to losses in competitive intensity.

Information barriers. Information barriers can be overcome by active encouragement. Benchmarking and trade associations can credibly disseminate best practice.

Regulatory barriers. Regulation can encourage best practice. However if regulation serves to reduce competitive intensity, it will have a negative effect.

Human resource management. In general, the UK has weak human resource management practices. Firms which operate good systems of selection, induction and training, followed by systems of job design which involve skill flexibility, team work and job responsibility within appropriate incentive pay systems, find it far easier continuously to improve productivity and far easier to absorb best practice. There is little point in the Government upgrading the education and skills of the work force if those skills are not going to be properly utilised.

Skills. If good human resource practices are in place, then adequate skill levels are essential. The working population can be divided into three levels by education and skills: the top third, middle and bottom thirds. Adequate in this context means that there should be:

- a good layer of top level skilled people who are able to recognise and understand what is best practice;
- a good layer of individuals in the middle who are going to supervise and operate best practice; and
- a good basic education for those in the bottom third, which will give the middle layer an easier supervisory task.

However, the example of the US seems to indicate that, if the middle layer is adequate, best practice can still be achieved even if the bottom group is poorly educated.

UK Skills

In terms of the US/UK/West German comparison, the evidence suggests that the top third are reasonably similar. In the middle third the UK is slightly behind the US which is, in turn, behind West Germany. In the bottom third, the UK and the US are behind West Germany. In fact, it is in the bottom third that the differences with West Germany seem to be very stark. The internationally comparable OECD literacy survey shows that, for the United Kingdom and the US, the number of people who are close to illiterate is over 21 per cent of the work force, while in West Germany it is only 7 per cent.

The UK's main skills gap is in the middle grouping. This gap is important vis-à-vis both the United States with its tradition of 2-year college degrees and Germany with its tradition of high level apprenticeships. A strong middle layer is vital in the US because the bottom third have a rather low level of educational attainment. The UK has a similarly lowly skilled bottom third, so it follows that improving the middle layer is also vital for the UK.

Finally, it is worth recalling that the demand for skills is not static. For at least a century, the combination of technology and competitive forces has increased the demand for skills in all sectors of the economy. This increase in demand not only

involves technical and cognitive skills, but also increasingly applies to social and interpersonal skills. This shift in demand for skills is particularly noticeable in the US and the UK because, over the last 20 years, the increase in demand seems to have outpaced the increase in supply, leading to a significant rise in the relative pay of the skilled. This does not seem to have happened to the same extent elsewhere.

Enterprise, Innovation and High-Tech SMEs

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Introduction

This paper considers enterprise and high-tech small and medium-sized enterprises (SMEs). It is based on surveys that have been conducted by the Centre for Business Research (CBR) which help shed some light on the enterprise sector in the UK and in particular the relative characteristics of high-tech and conventional firms.

The paper is in four parts:

- an overview of the main trends in the enterprise population in the UK in the last 15 years, contrasting the last five with the previous 10;
- an assessment of the performance of the very smallest enterprises in the enterprise population over the last five years;
- a comparison of high-tech firms with conventional firms; and
- a consideration of the broad framework of policy suggested by this analysis.

The paper draws on work carried out with my colleagues in the CBR, Andy Cosh and Barry Moore, reported more fully in Cosh and Hughes (1998). I am grateful to the ESRC for funding the research on which this paper is based.

The Main Trends in the Enterprise Population

During the 1980s, the share of the smallest firms in the economy, whether defined as those employing less than 10 people, or those employing less than 50, rose substantially. Their increased share of employment accounted for nearly all the increase in the employment share of firms employing less than 200. The employment share of those employing less than 200 rose from around 50 per cent to around 58 per cent over the decade. A shift at the very bottom end of the distribution accounted for nearly all of this increase.

Since 1991, there have been some important changes. First, the business stock has more or less stabilised; it dipped in the early 1990s and then partially recovered but it has been reasonably stable for the last three or four years at around the 1991 level. Secondly, the upward shift in the share of activity accounted for by these very small firms has stabilised. The broad shift in activity in the enterprise population that occurred in the 1980s has not been reversed. But the trends of the 1980s have not continued unabated.

Given this context, there are some questions about the main features of the changing performance and other characteristics of the small business enterprise population in the UK in the 1990s. The CBR has been conducting a biennial survey since 1991 which

has generated a panel of over 2000 firms on which we have information from 1987 onwards, owing to a retrospective element in the 1991 survey. That 2000-panel sample runs from 1987 to 1997. Additionally this year we have completed a survey of a new cross-section of 2500 firms.

The firms are all independent, employ less than 500 people and are located in two broad sectors of the economy, manufacturing and business services.

The analysis of innovation and the technological characteristics of these firms is based on a standardised approach which has been developed in partnership with the Office of National Statistics and Eurostat. It attempts to match the CBR survey with the Community Innovation Survey in order to ensure international comparability of results.

The Performance of the Very Smallest Enterprises

A number of findings about the behaviour of the small business population emerge from an analysis of trends in the sector in the last seven years. The first is that there has been a substantial decline during the 1990s in the share of new business start-ups but an increase in the share of spin-offs and buy-outs. This is an interesting development because it suggests that the newer cohorts of smaller firms have higher levels of management experience than those firms that emerged during the brand new start-up phenomenon of the 1980s.

But of more concern is the fact that the portion of the enterprise population that was most dynamic in terms of increases in share in the 1980s declined in performance in the 1991-97 period. Comparing the performance of micro firms (those employing less than 10) between 1991 and 1997, the proportion seeing themselves as innovators fell. Moreover, micro firms grew less fast in terms of employment or sales than larger firms in the enterprise population.

The survey provides information about the perceived constraints facing the smallest firms. Most importantly, there appears to be a decline in the reported extent to which these firms experience financial constraints on their growth. This is not only true for micro firms employing less than 10, but also for the medium-sized firms employing between 10 and 100, and for the larger ones employing between 100 and 500.

This is an interesting result because it suggests that this constraint has previously been over-emphasised. For instance, in 1991 and 1993, when firms were asked whether they perceived a financial constraint, they scored it very highly, as nearly always happens in surveys of this kind. However, in the second part of the survey, they were specifically asked whether they had sought finance and what proportion of the finance requested they had actually received. The surprising result was that firms in each of the size classes achieved 80-90 per cent of the finance that they sought: this success rate increased further over the course of the 1990s.

Market demand constraints were also perceived as being lower in 1997 than they were earlier but that is partly due to changed macroeconomic circumstances.

However, firms regard management and skills as greater constraints. This supports the work on productivity which has shown that the UK's performance gap can partially be explained by a lack of management and middle level skills.

High-Tech Firms

The Importance of High-Tech Firms

There are two broad approaches to assessing the significance and analysis of high-tech firms. The first emphasises what may be called the "atomistic" or "heroic individual" perspective. The notion is that entrepreneurially driven high-tech firms are created, they experience various barriers to their growth which have to be overcome, and then they make a transition from the garage start-up to international world class leadership. The focus is on analysing how to improve that type of transition path.

An alternative approach is to analyse high-tech firms in terms of a "systems" or "systemic networking" or "diffusion" perspective. Here the emphasis is not on the individual firm alone as a growth vehicle carrying a new technology or a new product into wider markets. The emphasis is on the firm as a component of a system through which knowledge and best practice is diffused. This leads to a number of systems such as supply chains, inter-industry networks and clusters.

In practice, very many of the studies which analyse high-tech firms define them as those firms that are located in high-tech industries. The conventional approach is to rank industries according to the degree of their reliance on R&D, expressed for instance in the R&D to sales ratio, or in terms of the extent to which they are dependent on highly qualified labour in their labour force. The essential characteristic of a high-tech firm is that there is a dependence on the application of scientific or technological skills or knowledge in the production of new goods and services. A small high-tech firm is one that is perceived as being independent and which falls below some chosen size cut-off point.

It must be emphasised that the analysis of high-tech sectors shows that high-tech industries are dominated by large firms, not small firms. The top six firms' share of sales or value-added in those sectors averages between 33 per cent and 88 per cent, and firms with more than 99 employees account for over 90 per cent of the business R&D spend in those sectors. There is nevertheless considerable interest in the characteristics of smaller firms in these sectors as a potential source of future giants and as a seedbed for new ideas.

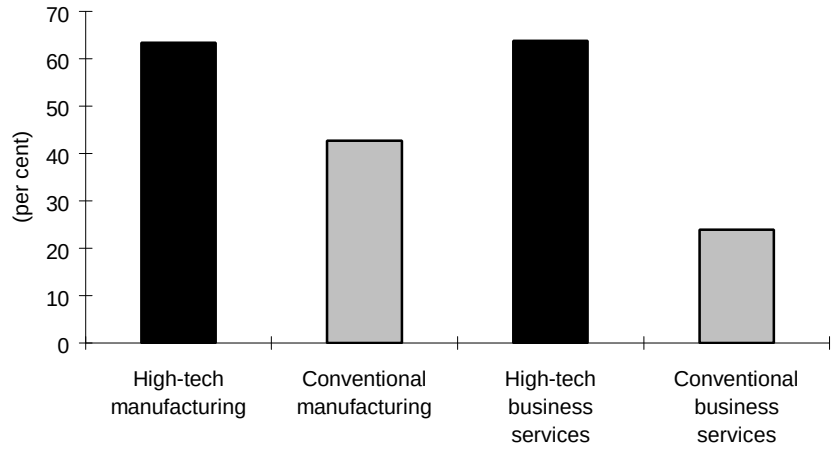
The CBR data-set is well suited to an analysis of such small high-tech firms. Moreover it allows them to be identified in all sectors, rather than the high-tech sector alone. The data-set includes a whole range of ratios that can be used to classify the firms - R&D to sales ratio, proportion of technologists in the labour force, and self-perception of sources of competitive advantage.

This analysis uses the OECD high-tech definition in which a high-tech sector is one which reports an R&D to sales ratio of over 4 per cent. By using that definition it is

possible to work out what proportion of a high-tech industry is composed of high-tech firms, similarly defined. This also applies to conventional industries. In order to aid classification, manufacturing and business services can be separately decomposed into high-tech and conventional manufacturing, and high-tech and conventional business services.

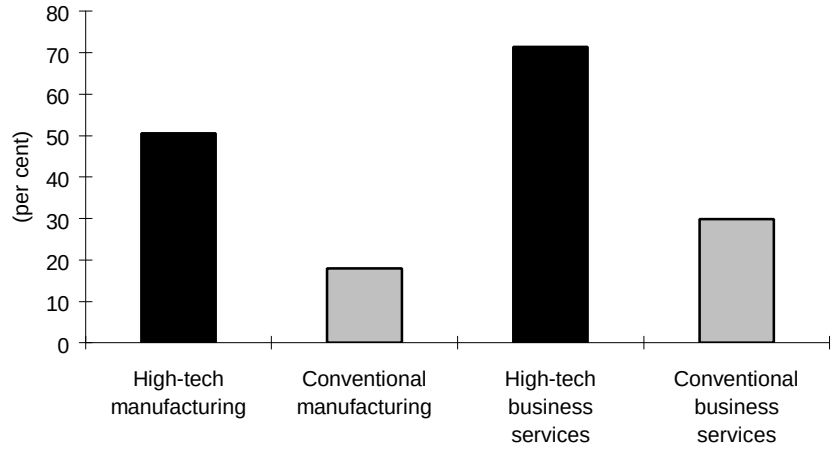
This produces some interesting findings (Chart 12). The initial, unsurprising, finding is that a much higher proportion of firms in the high-tech sectors report R&D than do firms in the conventional sectors. However, the White Paper's *Analysis and Background* document showed that high-tech sectors on these usual definitions account for between 20 and 25 per cent of all activity in the UK. So the fact that 42 per cent of conventional manufacturing firms, and a quarter of conventional business services, carry out R&D means that the number of high-tech firms is greater outside the high-tech industries than inside.

Chart 12: Proportion of SMEs carrying out R&D in 1997



This emphasises the importance of thinking about the firm as the appropriate level of analysis for high-tech activity rather than the industry. This is reinforced by Chart 13, which takes the firms that carry out R&D and shows the proportion where the R&D to sales ratio was 5 per cent or more. Again there is a significant proportion of the firms in conventional industries with substantial R&D to sales ratios. As a result of the relative weight of conventional and high-tech sectors in the economy, this means very large proportions of R&D intensive firms are found outside the high-tech industries. Alternative classification schemes produce similar results.

Chart 13: Proportion of R&D SMEs with R&D/sales ratios of 5 per cent or more in 1997

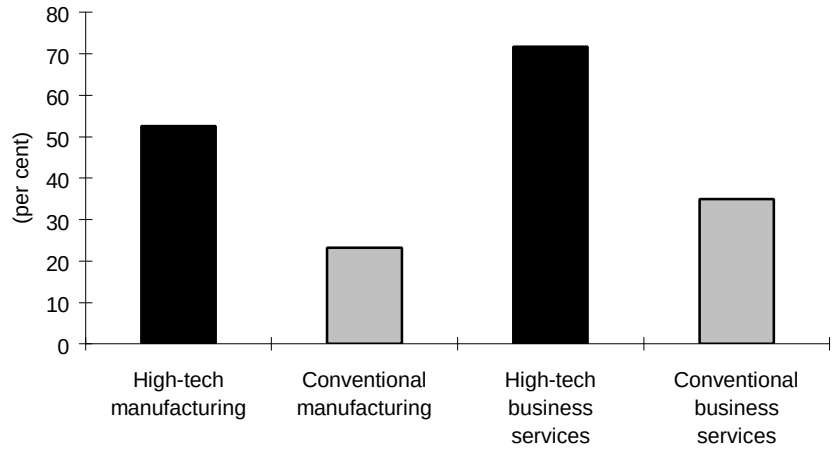


Collaboration

The discussion of knowledge and the knowledge based economy emphasised the importance of the way in which information flows take place. So it is important when analysing high-tech firms to look at this systemic perspective and see to what extent these firms are more heavily reliant on networked information flows or various kinds of collaborative activity.

The CBR survey addresses this issue. Firms were asked whether they have entered into formal or informal collaborative arrangements or partnership arrangements with other firms in the last three years. Chart 14 makes it quite clear that high-tech firms do rely much more heavily on networking and collaborative arrangements than conventional firms.

Chart 14: Proportion of SMEs with collaborative or partnership arrangements, 1995-97



Further analysis of the CBR data shows that the most common forms of collaboration are sharing R&D, sharing knowledge and information systems. Firms are much less likely to be using these collaborative arrangements to keep current customers, which suggests that these forward-looking, technological collaborations may not be worrying from a competition policy perspective.

Concluding Remarks and Policy Implications

The growth of the SME sector in the UK for the past 15 years has been dominated by the very smallest firms. But the upward shift in the share of activity accounted for by these firms stabilised in the 1990s. Moreover, these very small firms provided less training for employees and were less likely to be innovative in 1997 than they were in 1991. This raises a policy challenge which needs to be addressed, especially in view of the finding that labour and management skills are now a more important constraint on growth than finance.

High-tech firms are much more heavily embedded in systems of networking and collaborative arrangements. In terms of the balance of policy between the emphasis on "atomistic" issues and "systemic" issues, it is very important to place a great deal of emphasis on the way in which policy can address systemic issues. This is because these firms are much more involved in collaborative and networking activities.

Moreover, there is an iron law of business growth which is that if there is reliance on the growth of individual firms, then only very few firms will reach very large size. Few small firms grow systematically in a sustained way over a long period to reach the status of giant firms. There is a very important question about the balance of policy initiatives between those designed to overcome barriers to growth in individual firms and those which are designed to influence the network and collaborative infrastructure in which small high-tech firms work.

The *White Paper* goes some way to addressing these issues by emphasising competition and collaboration. The major policy issue is the development of a decentralised institutional framework which is pragmatic in the way in which it emphasises an industry, sector, cluster or region as the object of policy.

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Clusters and Networks

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Introduction

This paper will address the following four topics:

- Why do geographical clusters and networks of firms arise and what are the benefits of collaboration and co-location?
- Are these benefits greater within the knowledge driven economy, that is to say, why do we find there an increasing number of technology or knowledge based alliances?
- What are the conditions for clusters or inter-company networks to succeed over time?
- And, finally, what is the role of foreign direct investment?

Why do Clusters and Networks of Firms Arise?

Research undertaken with my colleagues at Reading University and by David Mowery and others at Berkeley suggests that it may be useful to distinguish between alliances which essentially involve a simple exchange of knowledge and those which involve active co-operation in learning (Cantwell and Barrera, 1998; Mowery, Oxley and Silverman, 1996, 1998). Those which involve active co-operation in learning, such as collaborative R&D tend to bring partners close together in broad terms. They are predicated on some initial degree of technological complementarity between the partners as a basis for collaboration but this then encourages spillovers. In other words, as Cohen and Levinthal (1989) suggested, spillovers are not costless, since they require some absorptive capacity.

However, partners, although they become more similar in general terms, become more specialised at the detailed level and this allows them to increase their rate of innovation in their respective lines of focus. In other words, while there are an increasing number of overlaps or spillovers between co-operating partners, each of them can still focus on some specific line of activity. Work in the US, by Jaffe and others, suggests that this idea could be extended to industry-university linkages, which also tend to be geographically localised (Jaffe, Trajtenberg and Henderson, 1993, Almeida, 1996). This echoes Paul Stoneman's point that we should not worry about free riders when doing basic R&D because while much knowledge is global, many of these active science and technology linkages require local face-to-face interaction. Doing basic research enables us to tap into knowledge elsewhere in the world.

John Hagedoorn and some of his colleagues at MERIT in Maastricht have shown that the number technology based alliances has been increasing (Hagedoorn and Schakenraad, 1992; Hagedoorn and Narula, 1996). Hagedoorn finds that the number

of alliances between the early 1980s and the mid-1990s more than tripled. Alliances have many justifications, but technology is an increasingly important motive.

Why have Alliances been Increasing?

Keith Pavitt and his colleagues have shown that technologies tend to be increasingly interrelated to one another (Granstrand, Patel and Pavitt, 1997). An increasing number of inter-dependencies and complementarities have arisen between formerly separate branches of innovation, which encourages firms to co-operate across different disciplinary boundaries. Technological systems run across firms so if innovation is systemic, it is not possible for one firm to innovate unilaterally, especially in the case of smaller high-tech firms. Finally, the costs of R&D have been rising sharply which helps to explain the dramatic increase in R&D budgets in recent years.

This leads to various forms of technological diversification, initially, perhaps, within the firm itself (the multi-technology corporation) as an increasing number of products require a diverse range of technologies to produce them. Motor vehicles or telephones may seem to be standardised straightforward products, but the components of the telephone or the motor vehicle today are entirely different from what they were in the past. They depend on a range of new technologies and knowledge inputs. As Brian Loasby (1998) has argued, companies have become increasingly multi-technology in their production processes and rely on a growing range of alliances to provide access to external capabilities.

Moreover, multinational firms can use their geographical spread in order to achieve technological diversification by tapping into alternative localised sources of specialised expertise, as argued by John Dunning, Michael Porter and others (Porter, 1996, 1999; Dunning, 2000). Companies can thereby gain competitive edge through their location strategies.

What are the Conditions for Successful Geographical Clusters?

Geographic clusters rely on sector-specific resources and, as a result, most of these clusters tend to be essentially industry-specific, as shown by Peter Swann's recent work (Baptista and Swann, 1998, 1999). Furthermore, this research finds that locations tend to be specialised and that cluster success depends on the balance of the benefits of spillovers against the possible costs of congestion. These congestion costs may outweigh potential spillover benefits at the level of inter-industry analysis, but within the industry the spillovers predominate as a result of the sector-specific resources and skills. Alan Hughes has shown that firms, large and small, foreign-owned and indigenous, may co-operate and interact successfully in a region or a location that succeeds over time.

These regional specialisations may often have a path-dependent history, as illustrated quite well by Krugman (1991a, 1991b) in his work on some of the historical developments of industries which are geographically localised. In the UK we find pretty striking patterns of regional specialisation (Cantwell and Iammarino, 1999). The

North West is strong in chemicals, the West Midlands in engineering and transport, the South East has a broader range of specialisation, but particular strengths in areas such as pharmaceuticals and radio systems. This should come as no great surprise as much is derived from historical circumstances. For example, in the North West one could perhaps trace the chemical specialisation back to the earliest textile mills and a movement from textiles into synthetic fibres and thus chemicals, and likewise in the other regions.

The Role of Foreign Direct Investment

So what role does foreign direct investment (FDI), and in particular the interaction between foreign-owned and indigenous firms, play within such regions? FDI can be a potential catalyst for local development, where there is an established related regional tradition. Where there are associated firms in the same area of technological development as the foreign-owned company, there is the potential for a positive interaction between the two. My work on US investment in Europe found this result both at region and country level (Cantwell, 1989). Contrary to the arguments of the 1960s, when those such as Servan-Schreiber suggested that the American challenge would drive out technological initiatives in Europe, we found there was a process of European revival. The revival was specific to particular industries in particular locations and was largely a function of the traditions of that particular area. For example, in some of the German regions there was a strong chemical tradition, and in those locations the presence of US-owned firms led to a revival, a positive interaction between the two, and a virtuous cycle of cumulative take-off.

Furthermore, in more recent work the role of direct investment depends on the status of the region in the national system. We can identify *higher order locations* which tend to attract the largest share of both domestic and foreign technology development and have a much broader range of technological specialisation or activity (Cantwell and Iammarino, 1998, 1999).

Table 3 shows the share of large corporate patenting organised by UK region. Most research and development, as measured by patenting that derives from R&D in large firms, is concentrated in the South East even when adjusted for population. In the case of foreign-owned firms the R&D or technological development is even more geographically concentrated.

So, in higher order locations, such as the South East, both outward and inward investment matters because there are knowledge transfers between the major centres of activity. These transfers rely on the activities of UK and foreign multinational firms. This is a point worth making since many policy discussions talk exclusively about inward investment, but outward investment also plays a very similar role in terms of the knowledge relationship between the major centres.

These knowledge flows within multinational firms should be encouraged since the domestic specialisation of technology in specific regions in some sense feeds off complementary specialisations elsewhere in the world. These international knowledge flows, particularly within the firm, will become increasingly important over time. This

Table 3: Share of US patents attributable to research in UK regions
(As per cent of UK total, 1969-95)

REGION	UK firms	Foreign firms	Total
North	4.0	2.3	3.4
Yorks & Humberside	4.4	3.9	4.3
East Midlands	6.3	4.5	5.7
East Anglia	1.5	5.3	2.7
South East	40.2	60.8	47.1
South West	5.7	4.2	5.2
West Midlands	16.4	3.6	12.1
North West	17.0	7.8	13.9
Wales	2.4	3.4	2.7
Scotland	2.0	4.0	2.7
Northern Ireland	0.1	0.3	0.1
Total UK	100	100	100
Total UK (absolute nos.)	23404	11815	35219

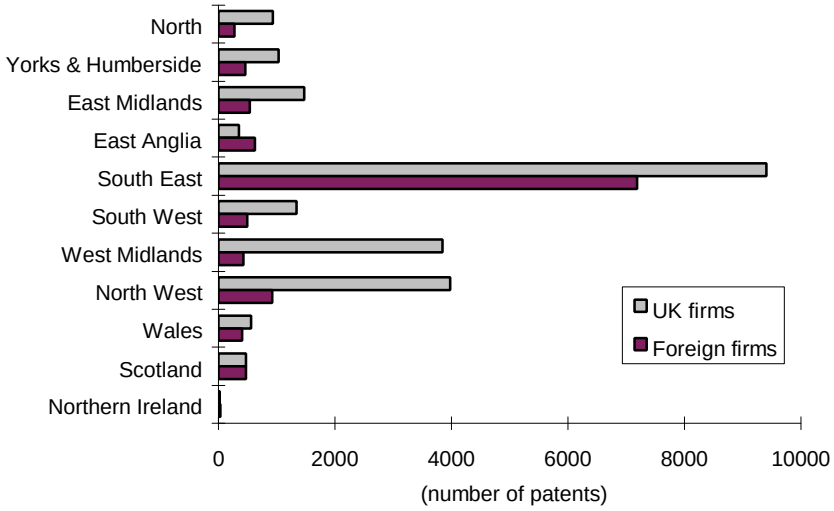
is a characteristic of the knowledge based economy which is worth stressing, and it is a counterpoint to the view that knowledge should be kept local and exclusive.

However, lower order locations, such as the North West and the West Midlands, have a somewhat different pattern. They tend to be more heavily specialised and they tend to have the potential for attracting foreign-owned technology development, but particularly in their areas of strength, that is to say, chemicals in the North West and engineering and motor vehicles in the West Midlands.

Chart 15 shows a contrast between the South East on the one hand, and the North West and West Midlands on the other. In the higher order location - the South East - foreign-owned firms are not necessarily performing the same activities as the locally owned firms. The foreign-owned firms are more internationally inter-connected and there is a greater degree of diversity than in the case of the other regions. There is a statistically insignificant positive correlation between foreign and domestic firms.

In the North West and the West Midlands, there is a clear, positive and significant correlation between the activities of foreign-owned firms and indigenous firms. That is to say, in the North West activity is based around various chemical sectors, whereas in the West Midlands it is centred on engineering and transport.

Chart 15: US patents attributable to research in UK regions, 1969-1995



Geographical hierarchies matter to the composition of activity and to the nature of the relationship within a cluster between indigenous and foreign-owned firms. In other words, the effects of FDI vary between regions. In the higher order centres, the effect is to broaden the technology base, extending the scope of their technology creation. In other locations, technology-based FDI tends to increase the focus of innovation within that region, while raising the intensity of progress in the selected fields in question: in other words, it tends to have the effect of deepening rather than widening technological change.

Summary and conclusions

- Clusters and networks provide the context and the spillovers. Free riders do not exist, nor do free lunches, in the sense of complete knowledge transfers. Certain items of knowledge may flow relatively freely, but other types need to be more localised in their transfer, and these spillovers can raise the innovation of localised partner firms.

- Alliances have grown in the knowledge driven economy, due both to more inter-relatedness between scientific disciplines, between technologies and a greater degree of linkage between science and technology.

- Clusters tend to succeed where they already have sector-specific skills. Development in other words tends to be locally specialised in terms of its composition.

- Research-based foreign direct investment tends to have differing effects between regions. In higher order regions it extends the composition of activity, while deepening it in the lower order locations.

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Competition Policy in the Knowledge Economy

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Introduction

This paper addresses two questions. This first is whether the knowledge economy poses new challenges for regulators and for competition policy enforcers compared with the economy of yesterday. The second question is about the challenges raised by the knowledge driven economy in specifically high-tech industries - and in particular the fascinating discussion contained in the DTI's *Analysis and Background* document about the role of competition policy. In short, are there grounds for a different treatment of cases which involve the production or dissemination of knowledge?

Is there a New Economy?

There are four reasons - two that have to do with the demand side and two that have to do with the supply side - for thinking that the knowledge driven economy has a competitive process that works rather differently from the past.

Demand Side

The ready availability of information makes markets considerably more transparent than they used to be - which implies to a broadly optimistic view about evolving competitive conditions. Internet shopping offered by companies such as Amazon.com is only one, rather strong, illustration of a much more general phenomenon where prices and characteristics of products can be compared much more immediately and much more informatively than they used to be in the past.

However, information-based products have a tendency to create bottleneck rents because their components have high complementarities with each other. The most obvious example of this is when you log on to a computer. The piece of information embodied in the password is complementary to the rest of the information in the network. Without the password, the rest of the computer and the information it holds are valueless. There are other examples of complementary components of the information network, such as Internet browsers and set-top boxes.

These bottleneck components can create very large rents. It is impossible to judge whether, globally speaking, it makes sense to be optimistic or pessimistic about the ability of Schumpeterian competition to bid away those rents. Little can be learned by looking at the experience of the big trusts of the United States in the past and seeing the way in which market shares were eaten into by new competitors. We are in uncharted territory here. There are rents from these complementarities that may create quite significant problems for competition authorities even if there are genuine grounds for being optimistic because of the greater general market transparency.

Supply Side

Information intensity has made physical technologies much more interchangeable than they used to be. For example, a lap-top computer can also be a fax machine. A piece of physical equipment can be re-programmed to do the job that used to be done by two quite different pieces of physical equipment in the past. This means we can be considerably more optimistic about the nature of supply side substitutability to bring about competitive pressures in a market. However, it also creates huge market definition problems. We need to think of new products as having quite different competitive relationships with each other than they used to in the past. The demand curve faced by individual firms may be a lot flatter than it used to be, because of competition from physical products that appear to be classified differently but can do many of the same jobs.

This process also appears to be occurring in the labour market. There is a change in the extent to which people can switch industry as well as switching firm. There are many people working in banking who can move to IT firms and many people working in IT firms who can move to banking. Cross-industry moving appears to be rather easier than it used to be.

On the downside, all of us work surrounded by bigger piles of paper than ever before. This is because the information revolution has made available much more information, and done so in ways in which we have difficulty filtering.

In a sense the ultimate bottleneck technology is the human brain. All of the information we create using information-intensive technologies has at some point to be simplified down and aggregated again so that it appears in forms that are useful for us to absorb. That is to say, in forms that result in better decisions and ways of living.

This has affected competition in two rather different ways. First, many aggregation processes are essentially repeatable. For example, complicated time-consuming techniques such as plotting ordinary least squares regressions are now very easy to do because the technology has been codified and is easily repeated.

However, many kinds of aggregation technology, such as the ability to exercise judgement in filtering this excess information, are based on tacit knowledge. These cannot be simply repeated but have to be learned. The difficulty of transmitting them from one person to another means that those who can exercise them in economically productive ways will enjoy significant rents that competition cannot easily challenge.

An example is the banking industry. The changing nature of competition in banks is something that is starting to become particularly exciting with the advent of monetary union. There is a lot of curiosity as to whether the structure of the European banking industry after EMU is likely to be really different from what it has been before - in particular whether we are going to see very many more cross-border mergers between banks than we have done in the past.

The banking industry makes use of various filtering techniques. Banks collect and use an enormous amount of information about both depositors and borrowers. Quite a lot

of this information is relatively easily codifiable, using technologies that involve repetition and are therefore subject to quite significant economies of scale. However, much of the information used by banks requires the exercise of judgement. At least in the foreseeable future, nobody will be able to use software to go into a start-up company and decide whether it is a good bet. That is going to involve tacit knowledge exercised by local banking officers who acquire the information through interaction with the individuals themselves.

This suggests that the modern bank uses two kinds of information processing activity. There is the kind that is subject to large economies of scale. This can generate rents but they are easily bid down by competitors because the technology can be copied. However, modern banks also use information processing of the tacit kind, which gives them very significant rents due to their access to local knowledge about the circumstances of local borrowers.

Information processing is going to transform the banking industry. Banks are distinguished from other industrial firms on the one hand and securities markets on the other hand, purely by the flow of information within the organisations. The only reason we can explain why banks need to engage in loan contracts with firms rather than engage in other kinds of market-based activity - for example, taking an equity stake - has to do with the incentives this gives them to monitor the activities of those firms. As soon as the information flows between banks and the firms themselves start to change, the comparative advantage of one kind of financial organisation - namely a bank - over other kinds of financial organisation - namely securities markets - changes as well.

Banking is an information processing organisation in just the same way as the IT industries and the telecommunications industries are. Changes will occur wherever this kind of repetitive aggregation takes place. By contrast, there will be comparatively little change to the aspects of banking that require tacit knowledge-based aggregation.

Are there any Issues for Competition Policy?

There are two reasons why there ought to be differential treatment of knowledge-intensive cases. First, the literature from Williamson onwards points to the fact that many types of information-intensive process involve scale economies. This implies a serious trade-off between the dangers of market power and the benefits of efficiency.

Secondly, a more subtle and interesting reason relates to the weak character of many intellectual property rights. This is clearly the driving force behind a lot of information-intensive mergers that are currently taking place. It is often quite useless to rely upon the exercise of patents or of copyrights. As John Kay has shown, often the only way to gain the rents from ownership of ideas is to embody them within an organisation. This provides a rationale for engaging in research joint ventures because this is the only organisational form in which you can realistically hope to capture rents from the intellectual property since formal intellectual property rights will be inadequate.

This analysis suggests that regulators should look more benignly at information-intensive deals. However, there are several reasons why we should be extremely careful before we accept these arguments as the basis for a systematic shift in policy stance.

First, information can be strategically manipulated. Joe Stiglitz has written about the extent to which members of individual organisations use and withhold access to information in order to gain monetary and non monetary rents. Competition policy enforcers are very much aware of and concerned with this, because during negotiations between competition authorities and firms the provision of information becomes an important bargaining variable. If the authorities signal a change of attitude to certain kinds of information, then there will be a change to the type of information revealed by the firm.

For example, it may well be very much in the interests of firms to exaggerate the character of the alliance that they are forming if they believe that the competition authorities will behave more leniently towards knowledge based deals. Structures, as well as information, may be manipulated by employing research scientists in order to convince the authorities that the arrangement is in a more favourable category. Changing the stance of competition policy provides additional incentives for strategic behaviour.

Secondly, the history of economic development is replete with cases of networks, such as cartels and guilds, which internalise some of the positive externalities while leaving those excluded from the network to carry the negative externalities. The competition authorities need to bear in mind that just as high-tech industries allow for the possibility of internalising significant externalities within a network, they also allow for the exercise of certain kinds of proprietary bottleneck power against the people left out.

This does not mean that in the current status quo we have an optimal solution. As Alan Hughes has pointed out, there is a need to take a more systemic approach. In particular we need to re-assess the generally negative view of arrangements between firms in similar industries. This needs to be modified when we take into account the fact that various kinds of networks are often the only way to exploit information technologies. It seems inconsistent that many firms can clear regulatory hurdles perfectly easily if they wish to merge while they have terrible legal difficulties if they merely wish to exchange information.

Finally, we should bear in mind that the joint venture form as opposed to the merger form is becoming more predominant among even very many large firms. Indeed the merger task force in DGIV in Brussels will soon need to rename itself the joint venture task force, because the proportion of mergers as opposed to joint ventures has been falling significantly and is now below 50 per cent. Most large deals in the future in Europe will actually be joint ventures. They take that form because joint ventures allow for certain kinds of organisational architecture that are not possible in mergers where the whole of the assets of a company are transferred. It is clear that the thinking of competition authorities needs to evolve towards understanding the kinds of benefits that can come from the joint venture format.

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