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RESEARCH AND THE KNOWLEDGE AGE*

ABSTRACT. The paper examines the pressures on universities to change their priorities and cultures as a result of the recognition by governments that they are at the heart of their efforts to build competitive knowledge economies. Consideration of the implications for universities, and world class research groups within them, of: globalisation and knowledge based competition; devolution of economic development powers from nation states to regions and cities; interactive learning and knowledge transfer clusters; high tech spin-offs and start-ups and commercialisation of intellectual property; leads into a discussion of the changing nature of knowledge transfer and the importance of dynamic collaboration between universities and corporate enterprises.

INTRODUCTION

It is a truism to say that we live in the knowledge age; the generation, communication and transfer of knowledge has always been the core mission of universities. What is new is the accelerating rate of knowledge generation, dissemination and exploitation. Information technology has made scientific research vastly more productive and has revolutionised the speed of communication, dissemination, global access and networking. Furthermore, E science has the potential to have the same revolutionary impact on knowledge generation as the World Wide Web. This paper examines, from both a Scottish and a UK perspective, the implications for the core mission of universities, and their priorities and cultures, of globalisation and knowledge based competition; of devolution of economic development powers from national states to regions and cities; of interactive learning and knowledge transfer clusters; of the growing importance of high tech spin-offs and start-ups and the commercialisation of intellectual property; and the changing nature of knowledge transfer.

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GLOBALISATION AND KNOWLEDGE BASED ECONOMIES

Two of the forces that have transformed and continue to impact upon both the international business environment and upon the economies of countries, regions and cities are: (1) widespread and accelerating technological change and innovation, leading to increased globalisation and the proliferation of knowledge and information; and, as a result (2) a better understanding of, and capacity to respond to, the needs of the customer.

As a consequence of these trends, global economic success is increasingly driven by new knowledge and innovations; by speed of new product or service to market, though improvements in manufacturing processes arising from investments in new technologies and from global network manufacturing have been a major contributor to higher productivity, improved quality and relative cost advantage, particularly in the United States. Today's products and services contain a high proportion of knowledge and intellectual capital. It is estimated, for example, that about 70% of the value of a new car can be attributed to its knowledge inputs, such as design, software and marketing. More liberal trading regions are also leading to more open market places. Consumers with higher disposable incomes taking advantage of the rapid expansion of international electronic communication are becoming more discerning and sophisticated. Dynamic technological advances are increasingly moulding the industrialised world into a single market place, in which information, products, goods, services, people and manufacturing plants are mobile and transient. Intensive global competition is forcing companies, whether manufacturing or service, to locate and relocate operations where they can secure the greatest competitive advantage.

Thus we live in the age of the knowledge economy, and of intensive knowledge based competition, in which the most valuable commodities are no longer materials and physical assets but increasingly information and innovation. Countries, regions and cities are competing to attract and retain successful knowledge based businesses, clusters and industries, because they recognise the dynamic contributions these can make to their economic success and societal development. Whilst higher education institutions have always been in the business of research and innovation, and of knowledge generation and transfer, as well as fulfilling their wider responsibilities to society, today universities are a critical success factor at the heart of successful, competitive knowledge based economies, of learning countries, regions and cities; and of learning and innovative industries, clusters and businesses. Success in exploiting new knowledge to develop innovative products, processes and services is a key not only to creating and sustaining competitive advantage but also to business survival.

Furthermore, burgeoning knowledge means that many businesses can no longer rely on their own resources. They have to collaborate and network, form strategic alliances to develop and exploit new technologies, as well as strengthening their links with the science and engineering base. This is a feature of the aerospace and automotive industries, where collaborative knowledge networks and joint ventures are now, arguably, the basic units for innovation and production.

For Scotland, a small country on the fringe of Europe which forms part of the United Kingdom – but which is benefiting from e-commerce breaking down geographical boundaries and distances – the exploitation of its science and technology base is not an optional extra; it is a necessity. Scotland needs both to continue to develop and to exploit its own distinctive world class research capabilities in biological sciences, computer sciences, physics and electrical and electronic engineering, oil and petroleum engineering. It also requires to maintain a world class research base as part of the UK science base to collaborate with, and for its scientists and engineers in business to benefit from, global developments in research and technology, such as the human genome project. Why is this?

One of the impacts of globalisation and increased competition between countries has been the growing differentiation between economies in the three stages of economic development:

- labour intensive industry economies based on low skill, low labour cost industries, such as agricultural products, footwear and textiles;
- capital and technology intensive economies, based on comparatively low labour cost, technically skilled manufacturing, assembly and service industries, such as automobiles, electronic assembly, steel and financial services call centres (the global company manufacturing plants and services centres in these economies may well be mobile and transient); and
- high added value research and innovation led, knowledge-based economies with highly skilled, educated and paid labour, focusing on new advanced technology industries, such as biotechnology, advanced materials, new energy and conservation, and information technology and communications.

Multi-skilling, continuous upgrading of skills and competences, and re-skilling through lifelong learning are at the core of the second and third stage economies, and higher education institutions have a central role to play in their delivery. They were at the core of the transformation of Ireland from a first stage to a successful second stage economy. However, higher

education institutions in themselves are not sufficient to create and sustain a research and innovation led economy.

Scotland wishes to move from the second to the third stage. In its *Framework for Economic Development in Scotland* (2000), improving productivity is identified by the Scottish Executive, the devolved government in Scotland, as the key source of international competitive advantage, and that sustained increases in the rate of growth of productivity necessitates:

- greater *entrepreneurial dynamism*;
- increasing *basic research and creativity in product development*;
- more *innovation* and *embedding technical advances* in production processes;
- a *skilled and knowledgeable workforce;*
- increasing the quantity – and especially the quality – of *capital investment*; and
- securing the *physical, educational and electronic infrastructures that underpin enterprises'* productivity.

Innovation, the process which turns ideas and knowledge into products and services which consumers are willing to purchase, is at the core of entrepreneurial dynamism and an important driver of increased productivity. Commercialisation of intellectual property out of the science, technology and engineering research base, and the transfer of new knowledge into marketable products, services and industrial processes are key determinants of successful innovation. Whilst the existence of a substantial, high quality research base working at the forefront of leading edge research in new technologies is a prerequisite for successful commercialisation, there also has to be industry 'pull' to match academic 'push'.

One of the weaknesses of the Scottish economy is the low level of corporate research and development and innovation, which is a major constraint on industry 'pull'. As a consequence the best of Scottish research has tended to be exploited outwith Scotland, which increases the importance of another key aspect of commercialisation of intellectual property, new business start-ups, particularly of high technology businesses spun out of a country's science base. Scotland also needs to attract more high added value, R&D and innovation intensive inward investments. A high quality higher education system and science base is a key prerequisite to attracting and retaining such investments.

Many other industrialised countries are pursuing strategies to attract high added value inward investments, to increase the level of corporate research and development, and to become competitive knowledge driven

economies. For example, the Irish government is making significant investments in research, technological development and innovation to:

- develop intellectual infrastructure to 'root' overseas companies in Ireland through more extensive use of research based in Ireland;
- persuade and encourage companies to develop their own research activities;
- develop a world class research environment in Ireland's higher education and research institutes; and
- ensure a vibrant and dynamic pool of high quality, technically literate graduates from the graduate to postdoctoral levels to secure the needs of these companies and start their own companies.

It is already paying dividends. Ireland was selected earlier last year by MIT as the European location for its Media Lab research centre. It accounts for one third of all US electronics investment in Europe, is producing almost as many software graduates as Germany, has overtaken the US as the world's largest exporter of software with the key players in the sector Microsoft, Oracle and Lotus all with a presence in Ireland, and a generation of Irish-owned technology companies is emerging.

Thus higher education institutions are now at the heart of many countries' economic strategies. In its recently published document *Excellence and Opportunity: a science and innovation policy for the 21st century* (DTI 2000), the United Kingdom government states:

> The universities will be at the heart of this effort to build a knowledge economy. Universities can play a central role as dynamos of growth. But they will only fulfil that mission if they match excellence in research and training with innovation and imagination in commercialising research. (p. 27)

This central role will inevitably impact upon the policies and funding decisions of governments and funding bodies, and upon the roles, missions and priorities of institutions, including the relative importance of basic, strategic and applied research, knowledge transfer and exploitation and commercialisation of intellectual property. Furthermore, global collaboration is the driving force of scientific advance. A country's universities and research institutes have to undertake world class research if they are to be partners in global strategic alliances and collaborative ventures with other world class universities and businesses.

GLOBALISATION, DEVOLUTION, CITIES AND REGIONS

It is interesting to observe that at the same time as national governments are developing policies in response to globalisation of research,

new knowledge transfer, markets and competition, the United Kingdom is one of many OECD countries involved in a process of transferring economic development powers from the nation-state to regions and cities. Other European countries actively involved in devolution include Belgium, Denmark, Finland, France, Italy and Spain, whilst federal structures have been established for some time in Austria and Germany.

One consequence of devolution is growing awareness that national economic performance now depends not only on how governments manage the macro-economy or employ national sector policies, but also on how successfully learning and innovative regions and cities can create competitive advantage within the global economy. Globalisation and advances in communications technology have not only created the potential for regions and cities to exploit larger markets and access external sources of research, technology and finance to drive innovation, it has also exposed them to global competition. Thus regions and cities compete. Edinburgh is one of, if not the best, performing city in the UK. Edinburgh successfully competes in financial services with London, Frankfurt, Amsterdam, Zurich ... not with England, Germany, Holland and Switzerland.

Regions and cities recognise that they have to develop policies to improve their innovative and entrepreneurial capacity in the same way as national governments. Naturally they will wish their higher education institutions to play a central role in this process, particularly if these institutions are undertaking leading edge research which supports advanced technology industrial clusters and attracts R&D intensive inward investments. For example, in Finland, Tampere University of Technology's digital media institute and semi-conductor laboratory are at the centre of a cooperative technology cluster of over 120 companies including Nokia. This cluster has driven the Tampere region as well as much of Finland's economic growth and success. Regions and cities will also wish to see universities and research institutes collaborating to support high added value, research and innovation led clusters. They look to high growth areas, such as Silicon Valley, Austin Texas and the Highway 128 area around Boston, where collaboration between universities and with business is an essential characteristic of life.

The study *Building a Cross-Border Region* (Maskell & Tornqvist 1999) highlighted the potential economic and social benefits in the Øresund region of Scandinavia from the development of new models of collaboration between higher education and research institutions and businesses. The new metropolitan area of Øresund, resulting from the building of the bridge over the Øresund, linking the Copenhagen region of Denmark and

the Skane region of Southern Sweden centred on Malmo, is the twelfth largest metropolitan area in Europe. The Øresund University, inaugurated in October 1997, is a strategic alliance between 11 universities on both sides of Øresund. It embraces 120,000 students and approximately 10,000 researchers to form one of Europe's most extensive academic and scientific networks; the fourth highest regional concentration of research in Europe. Its research objectives include strengthening cooperation within research, thus enabling joint research groups and professorships, to cooperate with trade and industry in the region thus establishing common fora within strategic areas. Øresund University is at the heart of a regional strategy for climbing up the ladder of knowledge intensive industries.

Learning and Knowledge Transfer Clusters

Rapid economic growth has been achieved by some regions and cities that host collaborative, learning and knowledge transfer clusters of linked enterprises and institutions, including universities, that are able to benefit from synergies to compete effectively in global markets. Clusters are attractive but it is important they are viewed in the context of globalisation. They are not a panacea. Historically many regions and cities have seen their competitiveness decline as an industrial cluster has failed to adjust to a changing global environment. Whilst increased access to global markets allows greater concentration in clusters, it also increases the chances that established clusters might collapse and emerging clusters may fail, particularly if emerging national and regional clusters are all concentrated on the same areas of high technology as existing clusters in large advanced knowledge economy countries and regions.

For example, Munich (Kluge et al. 2000, p. 105) has become the fourth largest information technology centre in the world, after Silicon Valley, Boston and London. It is also the hub of the German aerospace industry which creates a vast demand for know how from the neighbouring fields of technology, such as energy, environmental technology, laser advanced materials, robotics, sensors and space technologies. Munich also has one of Germany's largest concentrations of biotechnology institutions: the Gene Centre at Ludwig-Maximilians University, the Max Planck Institute of Biotechnology, and the Martinsried/Grosshadern Clinic cluster on the edge of the city. There are plans for this cluster to expand into a research campus with more than 4000 scientists. Many other countries, regions and cities are striving to establish and support globally competitive clusters in these same fields of information technology, biotechnology, and advanced materials

and manufacturing processes, in competition with regions such as Munich. They cannot all succeed as drivers of economic growth.

The flow of knowledge within and into clusters will be one of the factors critical to supporting innovation, adaptation and shift to higher added value products and services. Active participation within clusters of world class research groups in a region's universities and research institutes may be a major determinant of their competitiveness in global markets and possibly their success or failure. In Scotland, the economic development agency, Scottish Enterprise, has established action plans for clusters in semiconductors and biotechnology; both areas in which Scottish universities have world class research groups which collaborate globally. However, most world class research groups have to recognise that most world class, leading edge basic research is increasingly concentrated in a relatively few world class universities. It is both capital intensive and expensive and only a few universities, either alone or in combination are able to engage in it. Furthermore, this is mirrored by the concentration of industrial basic research and development in major global corporations, which also collaborate amongst themselves as well as with an elite group of world class universities.

Small countries, and regions and cities within them, have to recognise that creating and maintaining competitive advantage in research and development intensive, knowledge based industries in competition with large countries, and regions and cities within them, is difficult. Over the period 1981 to 1998 seven countries produced 70.6% of the world's scientific papers (see Table I). The United States spending on science is set to rise by 15% over the next three years, Germany has committed itself to a 6.7% annual increase in R&D and a 50% increase in post genome research, and Japan has a target of doubling its R&D budget.

The United Kingdom government has announced a £1 billion two year programme of additional investment in the research infrastructure, in partnership with the Wellcome Trust; in key new areas of science: genomes, e-science and basic technologies such as nanotechnology, quantum computing and bioengineering an additional £250 million. It has also introduced a raft of other measures to support knowledge transfer and innovation. The French and German governments are also putting much greater emphasis on the commercialisation of publicly funded research.

Maskell and Tornqvist (pp. 53–57) have suggested six reasons why small countries remain low tech. They are challenging issues for small countries.

– activities in R&D intensive industries are closely associated with high risk and countries with a limited portfolio of entrepreneurial activities

TABLE I

World scientific papers – 1989-1998

Country	Share of world scientific papers (%)
United States	34.2
United Kingdom	8.2
Japan	7.8
Germany	7.4
France	5.5
Canada	4.5
Italy	3.0
	70.6

Source: DTI 2000.

run substantially higher risks than countries with a full portfolio of entrepreneurs covering all major areas of promising innovation;

- sustaining competitiveness in R&D intensive industries is also linked to high cost;
- the limited size of the relevant labour market will influence the range of industries in which small countries might successfully specialise;
- for smaller countries to invest substantial resources in R&D, they argue, may be like trying to fertilise a small field when the wind is blowing: the neighbours benefit more from the efforts;
- the domestic market for R&D intensive products is inevitably limited in small countries; and
- at least in some leading edge R&D intensive industries, there seems to be a dependence upon a disproportionately strong and continuous flow of science based output, creating solid ties between science, producers and advanced users in these industries. This necessitates not only a high quality research base but effective knowledge transfer and innovation.

Maskell and Tornqvist conclude that these constraints can, individually or jointly, prevent or restrain small industrial countries, and regions within them, from rapidly restructuring towards R&D intensive industries. “Only within fields where a region possesses a strong and distinct scientific base do R&D intensive firms stand a chance of sustained growth and competitiveness” (p. 56). In Scotland, optoelectronics is such a field. A recent study, for example, suggested that Scotland ranks third out of 46 countries surveyed for the academic impact of its research in optoelectronics.

Scotland is the sole European country in the Four Nation Optoelectronics Association, with the US, Japan and Taiwan.

The United Kingdom has an exceptionally strong science base. The UK Council for Science and Technology (2000) has recently concluded that the UK starts the 21st Century with some very good strengths and advantages including a substantial presence in the UK of the world's best companies; strong companies in such sectors as oil and gas, biotechnology, pharmaceuticals, aerospace and defence, media and communications, finance and business services and the creative industries; a broad balance between manufacturing and service sectors; and an excellent science base. However, it also concludes that the UK will need to increase significantly its capacity to compete through technology based innovation. This is the challenge that is addressed in the Government's *Excellence and Opportunity: a science and innovation policy* (DTI 2000).

Maskell and Tornqvist's analysis, and the Council for Science and Technology's analysis of weaknesses that the UK government is addressing, do give rise to questions concerning Scotland, that might equally apply to other devolved regions with their own parliament.

- Should the Scottish economy be viewed as part of a substantially larger UK economy, and be an integral part of a UK strategy?
- Should the Scottish Executive and Parliament develop its own distinctive strategy?
- Should cluster strategies be developed and supported by regional economic development agencies, which might compete and behave sub-optimally or should they be co-ordinated nationally?

Indeed, given the decision by the European Council to establish a European area of research and innovation and a strategic goal for the European Union to become the most competitive and dynamic knowledge-based economy in the world.

- Should cluster strategies be co-ordinated transnationally?

Thus the European Commission (2000) discussion paper containing broad proposals for the 2002-06 Framework 6 programme suggests framework funds should be diverted into 'large targeted research programmes conducted by consortiums of companies, universities and research centres'.

- Should and can Scottish universities, and their world class research groups, simultaneously be at the heart of Scottish clusters, UK clusters, European and global clusters and strategic alliances?

These are fundamental questions for policy makers, funding bodies, institutions and research groups.

Without a realistic understanding of the key variables and success factors for establishing a competitive high tech cluster there is a significant danger that many clusters will fail as drivers of economic growth. The most successful clusters may not be national or regional, but European or global. Global strategic alliances in industries – such as biotechnology, media and communications, defence and aerospace – exist and continue to be formed by world class corporations supported by alliances of world class research groups. Only by maintaining a world class research base can countries and regions benefit from participating in these alliances. This may involve very hard choices for governments and research funding bodies as to which areas of research should be given priority within the Science Budget; the smaller the country the harder the choices! Cluster strategies also raise questions about the trade-offs between supporting excellent research in non-priority areas *versus* building research excellence and capacity in priority areas; and whether universities should be funded selectively for distinctive research roles and missions.

High Tech Spin-Offs and Start-Ups and Commercialisation of Intellectual Property

One key aspect of the commercialisation of the outputs of the science, technology and engineering research base is the number of successful, new high-tech businesses generated by universities and research institutes; both 'spin-offs' created by universities to exploit intellectual property arising from academic research and 'start-ups' created by current or former students and members of staff. Close collaboration between universities and businesses is not the only characteristic of Silicon Valley, Austin Texas and the Highway 128 area, the high level of new high-tech business start-ups in contrast with European countries is another distinguishing feature; Finland possibly being the exception with its high level of spin-offs arising from the 'Nokiaisation of Finland'. A low business birth rate and low rate of high-tech start-ups is a weakness of both the UK and the Scottish economy.

The commercialisation of the intellectual property generated by Scotland's universities and research institutes is at the core of the Scottish Executive's strategy to create a knowledge driven economy. The Scottish higher education sector is committed to exploiting and commercialising the research base. Indeed, by some measures of commercial exploitation, some Scottish universities appear to compare favourably with the best in

the United States and the rest of the UK. Nevertheless, as the recently published report '*Spin-offs and start-ups in UK universities*' (Hague & Oakley 2000) illustrates, much has been achieved but much remains to be done in Scotland and the rest of the United Kingdom. For example, in Biotechnology, although the UK appears to be a close second to the USA in the citation of research papers, it is some way behind the USA and Japan in the ownership of patents. Furthermore UK industry expenditure on R&D has declined relative to that of our major competitors. For example, industry financed 61.1% of Research and Development Expenditure in Germany in 1995 compared with 48% in the UK. Corporate R&D and innovation is also a weakness of the Scottish economy. R&D, as a percentage of value-added in manufacturing, is estimated to be less than half that in the UK.

Whilst the Scottish Higher Education Funding Council (SHEFC) is not an economic development agency, it has worked closely with Scottish Enterprise to promote commercialisation of research and help universities and colleges build links with business, industry and other users of research. The Council's strategy to achieve these objectives includes:

- helping improve the management and support for the commercialisation of research;
- being a founding sponsor of CONNECT – an organisation which aims to nurture the creation, development and growth of technology enterprises throughout Scotland;
- supporting the development of the web-based Scottish Research Information System (SRIS);
- providing for Technology Ventures Scotland, an organisation which aims to increase deal-flow from the Scottish research base; and
- promotion of a 'mixed economy' of research funding through the incentives offered in the Council's research funding formula and through its Research Development Grant scheme, which helps institutions to develop and realign their research infrastructure to meet future societal needs and areas of importance to Scotland.

The Council is undertaking a fundamental review of its policies and methods for the funding and support of research, including whether the Council's mainstream method of funding is creating the right incentives to encourage greater interaction between the research base and industry and business. In a recent consultation document, *Research and the Knowledge Age* (1999), the Council asked:

> In what ways could the Council's mainstream method of funding research be developed to stimulate, promote and create appropriate conditions for increased knowledge transfer and the application and commercialisation of high quality research? (p. 38)

A strong view expressed from business representatives was that more needed to be done to enhance the reward mechanisms within the main method of funding to encourage knowledge transfer and enhance links between businesses and the research base. Subsequent to the consultation, the UK Government has announced in *Excellence and Opportunity* it will establish a new Higher Education Innovation Fund to build on universities' potential as drivers of growth in the knowledge economy. This will be a permanent third stream of funding. The government recognises that many universities need help now to build their capacity to engage in knowledge transfer, and need continuing help in their efforts to improve the productivity and competitiveness of small firms.

THE NATURE OF KNOWLEDGE TRANSFER

It has long been argued that the most important output of research for society is people with awareness and understanding, who act as the drivers of innovation in all aspects of society; which in turn drives developments in the future economy and public services. Furthermore, the transfer of knowledge and people has a greater longer term impact in optimising the value of the research base than the commercialisation of intellectual property. These arguments are consistent with the view of Donald Kennedy (1997, p. 241), the former President of Stanford University, that technology transfer is accomplished most effectively by the movement of people. This may be the case in the United States with its huge science base, large, sophisticated market, advanced knowledge economy, enterprise culture and an apparently limitless sources of venture capital, and consequent high level of new high tech start-ups and spin-offs.

It will be recalled that the United States generated 34.2% of the world's scientific papers. It may be sufficient to rely on the transfer of knowledge through movement of people in Silicon Valley, Austin Texas and also along Highway 128, but is it sufficient for Scotland and similar countries and regions? Given the rapidity at which new knowledge inputs are being incorporated into processes, products and services, and the critical importance of speed of new products and services to markets, can governments and businesses in countries and regions thriving to develop competitive knowledge based economies rely solely on people with awareness and understanding to act as the drivers? There is a significant difference between sustaining transitional changes in a large, advanced knowledge based economy and driving transformational change to achieve a modern knowledge based economy. The Finnish and Irish governments drove the successful transformational change of their economies.

Companies have found that entrenched faith in the strengths of their core business is not sufficient to remain competitive in fast moving, innovative industries and market places. Unless they can inject the mechanisms of the high tech start-up into their culture to rapidly transform ideas and opportunities into attractive products and services, and innovate to meet sophisticated customer requirements, they are finding 'fleet of foot' entrepreneurs building new businesses based on superior technologies leap frog them in the market place. Countries and regions striving to achieve transformational change may have to be equally 'fleet of foot' if they are to capitalise on the output of intellectual capital from their science bases. If they are to optimise the benefits of commercialising their intellectual capital and play their part in the transformational change of the economy of their country or region, some universities may need to transform their attitudes and culture, embrace the characteristics of Burton Clark's entrepreneurial and innovation universities (1998). The UK government has recognised that much needs to be done to create a climate of change in all universities, the reward and incentive structures have to change to encourage researchers to exploit the results of their work, and substantial incentives are needed for world class knowledge transfer.

Furthermore, is the knowledge transfer process in Silicon Valley, Austin Texas and along Highway 128 linear or interactive? Frans van Vught (2000) has argued that universities need to look for strategic partnerships; research is increasingly a matter of sharing intellectual, financial and physical resources, that universities need to change their view of intellectual capital; and learn to constantly configure and reconfigure their resources, especially their intellectual capital, around different, constantly changing problem contexts. In other words, they will increasingly focus on what Michael Gibbons (1994) and others have described as Mode 2 knowledge production. Van Vught notes that Clark observes that innovative universities have been specifically successful in knowledge transfer, with instruments and mechanisms like science parks, technology centres, incubator programmes and venture capital funds. Interestingly, Van Vught considers that inter active collaborative knowledge transfer appears to work best when it is seen as a team sport. "Knowledge transfer is, rather, a game during which the ball moves continually between the players, and during which all players have to collaborate to be able to win" (p. 18). It is more than the transfer of knowledge and people from universities that is driving developments and innovations.

SHEFC concurs with van Vught's view that changes in the focus of research, particularly towards problem orientated research, have increased the need for greater collaboration between universities, research institutes

and industrial research organisations. A key question for the Council is what role should it play, if any, through its funding policies and mechanisms to facilitate collaboration and make it work effectively. Is it best left to the markets and leaders of innovative universities? Should it intervene strategically when the market has failed to operate effectively and efficiently to respond to national needs and priorities? In response to its recent consultation, *Research and the Knowledge Age*, many considered that the Council's Research Development Grant had been used effectively to help connect the market by stimulating research in emerging policy and priority areas and by supporting collaborative and interdisciplinary approaches to problem orientated research. Nevertheless, should the Funding Council only intervene strategically when it can demonstrate that it can add value and is meeting ministerial guidance and priorities?

These are questions that are no doubt facing governments and funding bodies of all countries and regions that are striving to become competitive, knowledge based economies. Can it be concluded that the more effectively the leaders of innovative, entrepreneurial universities are able to develop adaptive inter-active strategic partnerships and collaborations the less the need for governments and funding bodies to make strategic interventions, or is it inevitable that governments will conclude they have to take a more proactive strategic role because higher education institutions are a critical success factor at the heart of successful knowledge based economies?

The UK Government has concluded that it

> needs to be an effective investor, facilitator and regulator, and that the market alone will not generate the basic investment in research, the networks and the public confidence needed for innovation to prosper. Standing to one side and doing nothing will not deliver in the knowledge-driven economy. (DTI, p. 10)

Governments and funding bodies in small countries striving to become knowledge-based economies inevitably will have to make strategic interventions, as well as hard choices on the allocation of resources to priority areas, and will not have the luxury of relying on the market.

CONCLUSION

This paper has attempted to address the challenges facing universities as a result of governments recognising they are not only at the heart of their efforts to build knowledge economies but are also dynamos of economic growth. The pressures on universities to change both their priorities and cultures to give equal priority to knowledge transfer and commercialising research as they do excellence on research and teaching have been

highlighted. The potential conflicts for world class researchers in being expected to support regional and national strategies and clusters, whilst at the same being active participants in global collaborations, strategic alliances and clusters has also been raised. Throughout the need for small countries wishing to transform into competitive knowledge based economies for realism, and for hard choices concerning priorities and allocation of resources, has been emphasised. Finally, it has been suggested that many more universities will have to adopt the characteristics of Burton Clark's entrepreneurial and innovative universities in response to government pressures to change their cultures and priorities.

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