A Study of How a Region Can Lever Participation in a Global Network to Accelerate the Development of a Sustainable Technology Cluster

By:

James Abbey

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C O N N E X I O N S

Rice University, Houston, Texas

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Chapter 1

Introduction[1]

1.1 Economic Development in Wales

The region of focus in this study is Southwest Wales and in particular, the City of Swansea hinterland. The development of this region has a turbulent history stretching over the past two centuries and now faces many new challenges which are similar to those faced by regions throughout the world.

Many new initiatives have been introduced with the aim of addressing the economic challenges in Wales. Such initiatives include the Welsh Assembly Government (WAG) and Welsh European Funding Organization (WEFO) investment at Swansea University in the area of Life Science and NanoHealth. Inclusive to this is the involvement of Swansea University in the Texas/United Kingdom Collaborative, a research network focused on the emerging nano technologies in Texas and the United Kingdom particularly in the emerging Bio/Nano Health cluster in the Southwest region of Wales. This thesis will focus on the challenges related the knowledge economy and in particular the creation of sustainable clusters. These challenges include not only worldwide phenomena such as globalisation and the emergence of the Knowledge Economy, but also an industrial and social legacy that leaves Wales with a relatively weak economic base. Due to this, Wales has many sectors in decline or facing intense pressure from overseas competitors, where low wages make activities such as manufacturing cheaper.

The following sections chart the economic history of Wales, tying it in with the various instruments applied by European, UK and Welsh governmental layers to support economic development. This brief history is discussed in the context of the accompanying political changes.

1.1.1 The Industrial Revolution

While the industrial revolution is often associated with certain technological advances the concept stems not from adoption of a particular invention, but rather from the start of a massive economic restructuring that saw the United Kingdom established as the world's first industrial nation (Mathias 1983). This restructuring saw the migration of economic activity from agriculture to industry and the migration of the workforce from the countryside to towns and cities (Stiglitz 1999). While agriculture started to become mechanised production industries such as textiles, iron and steel became drivers of economic growth. These industries, however, were not the preserve of manual unskilled labour. 'Skilled' workers were required to sign legally enforceable contracts that would prevent them taking their knowledge elsewhere if they received a better offer (Ross 2005). Though this would not relate to circuit layouts in microelectronics or recombinant DNA, it was an early example of practice we now see as common in our modern 'Knowledge-Based' economy.

The growth of the Welsh economy was however to be boosted by the great innovation of the industrial revolution; the steam engine (Ross 2005). The great impact of this was not in making the process of mining

[1] This content is available online at <http://cnx.org/content/m43443/1.1/>.

more efficient but in providing a global market for Welsh coal to power the steamships and locomotives of the British Empire.

As the term revolution implies, this massive industrial growth was not sustained and this led to massive economic and political upheaval in Wales. Despite industrialisation around the world, various factors combined to reduce the scale of the Welsh coal industry long before its eventual collapse in the 1980s. This came about due to a variety of factors including modernisation of industries in competing nations such as Poland, service of overseas markets by closer competitors (such as Canada importing coal from the United States), and even the war reparations enforced on Germany, which lacking cash were settled in coal (Morgan 1981).

1.1.2 Industrial Decline and the 'FDI' Era

The massive contraction of the steel industry and the almost complete disappearance of the coal industry during the 1970s and 1980s punctuated a trend of economic decline that had set in during the post-war period (Morgan 2001). To stem this decline, major efforts were made to develop other sectors, including attracting Foreign Direct Investment (FDI). Since the 1970s this restructuring has absorbed 200,000 jobs from these declining industries into a more modern base of services and manufacturing (WAG 2001). This was also accompanied by a gender restructuring of the workforce that included the proportion of women rising from 38% in 1975 to 50% in 1994 (Cameron et al. 2002).

The GDP of Wales has broadly tracked that of the UK as a whole, though trailing somewhat behind, since records began at the beginning of 1970. This lagging performance, is an effect of the structure of the Welsh economy relying heavily on low value-add employment, compounded by higher rates of economic inactivity in Wales (and particularly the West Wales and Valleys region), along with lower productivity per employee as shown in Table 1.1 (WEFO 2004).

Industrial Sector	**Wales**	**UK**
Agriculture, hunting, forestry and fishing	12.8	22.6
Mining, quarrying, including oil and gas Extraction	55.1	60.0
Manufacturing	33.9	32.8
Electricity, gas and water supply	98.2	105.7
Construction	18.9	20.9
Wholesale and Retail Trade	22.4	25.0
Transport and communication	30.6	35.1
Public administration and defence	20.4	26.1
Education, health and social work	17.6	18.2
Other services	5.3	4.7
Total	**22.8**	**25.1**

Table 1.1: GDP per employee ('000s) by sector, Wales and UK, 1996 (WEFO 2004)

1.1.3 The Regional Development Agency Approach

This massive economic pressure and the rise of nationalism led to the UK government establishing development agencies in Wales and Scotland in 1976 (Cooke and Clifton 2005). In Wales this took the form of the Welsh Development Agency (WDA). Its core strategy to provide job creation was to pursue Foreign Direct Investment (FDI) from around the globe. Though much of the literature mentioned in the following section focuses upon FDI in the UK and Wales, it should be noted that this phenomenon of economic development through FDI occurred throughout the European Union (EU) and Organisation for Economic Cooperation and Development (OECD) (Barrell and Pain 1997), including the United States (Friedman et al. 1992). However, FDI interventions occurred at (proportionally) higher rates in the EU than the OECD, which were higher in the UK than the EU, and higher in Wales than the UK as a whole.

The prime hunting ground for such opportunities was the 'Tiger economies' of South-east Asia and the following decades would see names such as Panasonic, Sony and LG all establish operations in the region, mainly of an assembly nature. The attraction for these investors included access to markets, low wages and other financial incentives. Access to markets is seen as a key factor in the location decisions of FDI as discussed by various observers, for example, the increase in FDI in Spain following its joining of the EU (Friedman et al. 1992). This has now become a challenge for older EU regions in competition with the newly joined countries of Eastern Europe. However, the prizes of attracting FDI, which could bring thousands of jobs at a time, were massive. This often led to interregional competition for investments with packages of aid being offered including grant aid, assistance with planning issues etc. (Phelps and Tewdwr-Jones 2001, Cooke and Clifton 2005). Alongside these packages, however, was what often figured as the key determinant in attracting FDI (in both Wales and other regions): a low wage rate (Friedman et al. 1992).

The WDA proved to be most successful at this competition, securing over two thousand projects between 1983 and 2000 (Salvador and Harding 2005), consistently attracting between 15-20% of FDI coming to the UK between 1983 and 1993 (Cooke 1998). One major investment could deliver massive opportunities to the surrounding region and much like the iron works of old, would become the prime employer in a town or region (Mathias 1983). The approach of the WDA in speculatively preparing sites across Wales to attract investors was likened by some commentators to the "*build it and they will come*" concept seen in the American movie 'Field of Dreams' (Cooke 2005).

This successful attraction of FDI into Wales meant that by 1992, 30% of Welsh manufacturing employment, some 68,000 workers, were employed in foreign-owned firms compared to 45,000 just over a decade earlier in 1981; a proportional increase double that of the UK as a whole (Cameron et al., 2002). The increase in FDI during this period led to much research to understand issues such as policies to support its role in regional economies (Gripaios et al. 1997, Young et al. 1994); its 'embeddedness' within the region (Phelps et al. 2003, Phelps et al. 1998); the 'quality' of investments (Gripaios et al. 1997); and their role in technological change and technology transfer (Barrell and Pain 1997).

Observers note in retrospect that this focus on inward investment may have led to the missed opportunity of investing in entrepreneurship and indigenous development that received greater attention in regions such as Scotland and Northern Ireland (Cooke and Clifton 2005).

Other criticisms of FDI include weak linkages with the regional economies within which they reside, such as supply chains (Young et al. 1994) and the 'quality' of the jobs provided, which were primarily assembly functions in branch plant operations. However, where the Multinational enterprise (MNE) is investing far from its home country the linkages it establishes are generally found to be stronger (Rodriguez-Clare, 1996). Young et al. (1994) describe strategies that can be applied to make use of MNE FDI in the development of cluster formation through creation of linkages with local R&D. Such linkages may be with universities and development of supply chain opportunities.

By the end of the century the Steel industry had suffered greatly in the face of global competition and the start of a phase of massive sectoral consolidation was set to continue into the new millennium. Meanwhile the efforts of the Thatcher government meant the coal mining industry had virtually been destroyed, leaving a very different Welsh economy to that which had fuelled the industrial revolution and transformed the entire world.

Wales, however, was to face political upheaval on a scale to match that of the changes in its economy, as the subsequent Labour government promised a referendum for a National Assembly. The proposal was for an Assembly, which would have responsibility for certain limited portfolios (including particularly challenging ones such as Health and Education), something not attempted since a previous referendum (also attempted by a Labour UK Government) was defeated by a margin of 80% in 1979 (Keating 1998).

1.1.4 The National Assembly for Wales

Following successful referenda on the proposals in Scotland and Wales, the National Assembly for Wales and the Welsh Assembly Government (WAG) took over control of affairs including health, education and economic development. Scotland regained its parliament, which it lost in the act of Union in 1707, providing greater control for Scots over their own affairs. This marked a massive political change for the devolved countries and the UK as a whole, marking the greatest constitutional change in what was seen to be an ongoing process of devolution (Keating 1998) since the abolition of the House of Lords veto in 1910 and the establishment of the Irish Free State in 1921 (Morgan 2001).

Since its integration with England in 1536, Wales had long been regarded as being tied more closely with England than its northern Celtic neighbour, despite clear religious and linguistic differences (Keating 1998). This is further reflected by the Welsh Office having only existed since 1965, while Scotland had enjoyed such representation within Westminster since 1885. This is seen, along with a perceived lack of consensus amongst the Welsh people for devolution, as one of the reasons for a lower level of power being devolved to Wales (Salvador and Harding 2005).

The 'Assembly' itself is a body that encompasses the legislative functions (National Assembly for Wales) and the executive functions (WAG). The legislature comprises 60 elected members representing constituencies and regions. Much of the power of the Assembly is held by the First Minister who appoints a cabinet of Ministers to hold portfolios including Education, Health, Culture, Local Government, and Economic Development and Transport. This structure is shown in Figure 1.1, cited from Salvador and Harding (2005). However, the level of devolved power given to the Assembly is far less than that afforded to Scotland and this is cited by some as a debilitating factor in the Assembly's ability to deliver economic revival (Cooke and Clifton 2005).

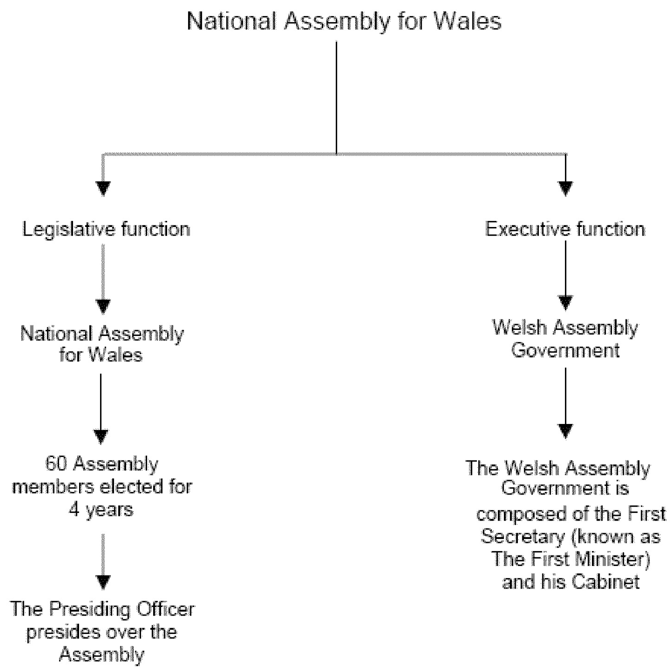


Figure 1.1: Structure of the National Assembly for Wales, from Salvador and Harding (2005).

Funding for the Assembly is provided by the UK Government with adjustments made according to the Barnett formula that effectively sees Wales receive 6% of UK funds, roughly in line with its proportion of population. This mechanism is however seen by many, including its creator, as a badly designed formula in desperate need of replacement that has operated to the detriment of Wales (McLean and McMillan 2003). However, it should be noted that recent years have seen additional funding from the UK Treasury in reflection of support it is receiving from EU Structural Funds (Salvador and Harding 2003), which itself represents an important source of funding. However, this represents only 1% of the annual Assembly budget (Brooksbank et al. 2001).

In terms of economic development the Welsh Development Agency was now accountable to a Cardiff based minister, rather than the Secretary of State for Wales at the Welsh Office in London. The budget for economic development and transport in 2005-06 totalled just under £1.5bn, or 12% of the total Assembly expenditure. It should though be noted that this includes a significant portion for transport. Approximately £120m p.a. has been allocated for 'Innovation and Competitiveness' with a further £80m p.a. for 'Entrepreneurship' (WAG 2005).

Much commentary and study has been of this transition, often in comparison with the 'settlements' in the other devolved regions of the United Kingdom (Morgan 2001, Salvador and Harding 2005, Cooke and Clifton 2005), as a new level of politics was introduced to Wales. Some observers argue the asymmetric settlements have led to varying outcomes for individual regions (Cooke and Clifton 2005), while others such as Morgan (2001) describe the risk of highlighting regional inequalities and developing interregional rivalry rather than co-operation. The observations of Cooke and Clifton (2005) are of particular relevance to this study. They argue that a project such as Technium is an 'overambitious' initiative and a return by the Assembly to the 'Field of Dreams' approach as part of a 'precautionary' approach to economic development.

1.2 Knowledge Economy and Innovation

The previous section has outlined the migration of the Southwest Wales region from an industrial base built upon heavy industries to one which is more knowledge driven. This section provides an overview of the Knowledge Economy with global, national and regional perspectives.

Here we introduce the concept of knowledge and its role in the Knowledge Economy, together with a 'three pillar' model of the Knowledge Economy consisting of: Human Capital, Innovation and Infrastructure. This model is then used in subsequent sections to discuss the Knowledge Economy at the Global, European, UK and Regional levels.

1.2.1 Growth of the Global Knowledge Economy

Economies have always been built upon knowledge (EU 1997), though it is only recently that knowledge has become the driving force behind regional, national and global economies. Developed nations such as the UK have seen their economies become increasingly dependent upon knowledge sectors, particularly over recent years.

While much discussion has been made of the rise of the US Knowledge Economy during the 1990s (Porter and Stern 1999), the development of the Knowledge Economy has taken place throughout the world over a more significant timescale. This is shown in Figure 1.2 where the increase in high-technology exports from all OECD nations has taken place since the end of the 1970s (OECD 1996).

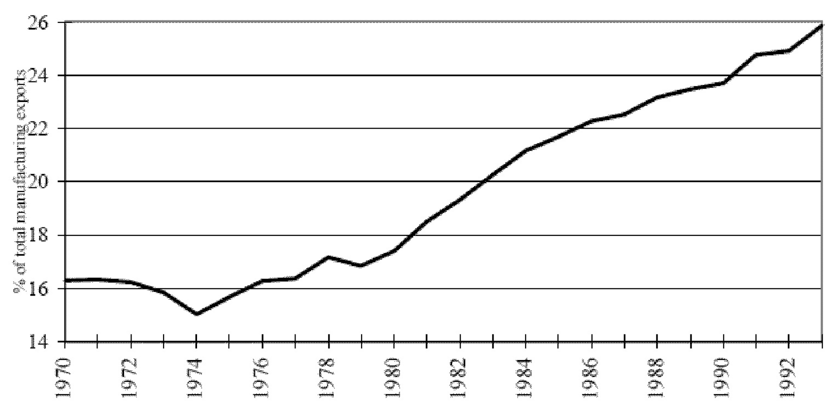


Figure 1.2: Total OECD high-technology exports as a percentage of total manufacturing exports (OECD 1996).

The behaviour of economies has traditionally been studied in relation to the availability and application of production factors of labour, land, capital and natural resources. Economic growth has come from improvements in productivity of these factors, improved labour productivity (e.g., improved skills or longer hours), better use of land (e.g., larger farms), restructuring of industries (e.g., vertical integration) and technological change (e.g., the steam engine) or a combination thereof (Samuelson 1964). However, recent years have seen the emerging dominance of another production factor – knowledge. This also changes the way in which resources are considered for the most important ones are now *created*, rather than *inherited* (Porter 1990) This relates to creating competitive advantage at both the individual firm (Porter 1985) and national levels (Porter 1990). This is captured in the following observation by the World Bank (World Bank 1998):

"*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*"

Herein we examine the concept of the knowledge economy at the global, European, national and regional (Wales and South West Wales) levels.

1.2.2 Knowledge

In consideration of the Knowledge Economy it is useful to consider the core concept: knowledge itself. Traditional economic factors can be (relatively) easily defined and quantified. For example capital can be counted in pounds or dollars, land - in acres or hectares, labour (considered as a physical resource) – number of men (and women) and natural resources in volumes of reserves. There are of course other issues to consider regarding factors, such as quality (e.g., whether land is fertile or located in a useful position such as on a major river or coast, and purity of mineral resources).

However, each of the traditional resources is finite and subject to '*scarcity*' whereby choices have to be made as to how they are to be applied (Samuelson 1964). Knowledge on the other hand is different in that it can be duplicated and disseminated. This means that value can often be exploited from the same instance of the resource several times. Doring and Shnellenbach (2006) provide a interesting study that investigates how this occurs, allowing growth that runs contrary to the traditional neoclassical economics suggestion that growth would only occur in step with the 'stock' of new knowledge. Furthermore, when knowledge is mixed with other knowledge further opportunities can be realised. This phenomenon is discussed in the context of '*Knowledge Spillovers*' later in this section. Knowledge is also regarded as a public good and therefore monopolisation of its use is both difficult in terms of practicality and acceptability (World Bank 1999)

1.2.2.1 Knowledge Types

Knowledge exists in various forms which make it complex and therefore difficult to use in economic analysis. The OECD report '*The Knowledge-Based Economy*' (OECD 1996) describes types as including '*Know-what*', referring to facts, '*Know-why*', relating to knowledge such as scientific principles and laws, '*Know-how*' for knowledge such as skill in using a machine or judging a market and '*Know-who*', in recognition of relationships and access to further knowledge (OECD 1996).

A useful common dichotomy for knowledge types is into '*codified*' and '*tacit*' types. (Lundvall and Johnson 1994). Codified knowledge is that which is recorded onto some form of media and which can be transferred to others for their use. Tacit knowledge exists within people and is regarded as requiring 'face to face' interaction between supplier and recipient for its transferral (Boddy 2005). A useful illustration of these knowledge types is provided by the World Bank (World Bank 1999); blueprints of a system are an example of codified knowledge, while the experience of an engineer to find the route of a malfunction demonstrates the importance of tacit knowledge. Information, knowledge and its typologies are studied in detail in the work of Lundvall (Lundvall 1998) who provides a useful explanation of how tacit knowledge arises through;

"*. . . learning gives rise to know-how, skills and competencies which are often tacit rather than explicit and which cannot easily be transmitted through telecommunications networks.*"

Tacit knowledge itself comprises various elements – namely information, skills, judgement and wisdom (Gorman 2002). These elements can be developed in an individual over decades from unique experiences, including from previous employment (Lawson and Lorenz 1999). Lawson and Lorenz also describe a form of tacit knowledge arising from 'shared learning' within an organisation.

By its very nature, tacit knowledge is more difficult to duplicate and is therefore central in holding competitive advantage (Coates and Warwick 1999). Its importance has increased significantly with the advent of ICT. As codified knowledge can be disseminated at ever-increasing speeds its exclusivity is easily lost beyond a region. Meanwhile the tacit knowledge, which does not so easily diffuse, can provide competitive advantage to those who have access to it; i.e., those nearby. The idea is captured by Asheim and Isaken (2002) in terms of '*Local 'Sticky'* and *'Global Ubiquitous'*. This is an underlying principle that supports *knowledge spillovers* and the development of *clusters*.

1.2.3 The Knowledge Economy / Knowledge-based economy

The term knowledge-based economy stems from '*the fuller recognition of the role of knowledge and technology in economic growth*' (OECD 1996). The role of knowledge in the economy is embraced in a wide set of concepts including the '*knowledge-driven economy*', '*knowledge-based society*', '*the new economy*', the '*weightless economy*' and the '*learning economy*' (Boddy 2005). Although each of these concepts has been developed by authors examining different perspectives of economics they may be treated as synonymous.

Recent years have seen the greater recognition and discussion of the importance of knowledge due to reasons including disruptive technological advance and globalisation. The drivers of this new 'knowledge economy' have been summarised as (DTI 1999):

- Revolutionary changes in information and communications technology (ICT).
- More rapid scientific and technological advance.
- Competition becoming more global.
- Changes in income, tastes and lifestyle.

These drivers have combined to make the Knowledge the main factors in economic growth. Expansion in knowledge sectors is outpacing others to such an extent that more than 50% of the GDP of OECD countries are now knowledge-based (OECD 1996). This is highlighted by the United States, where even in the early part of the 20^{th} century, 85% economic growth was driven by technological advance (Quah 1999). Further weight is given to this by the changes in employment seen over recent years. Within the EU for example, employment growth in knowledge-based industries has been far stronger than the rest of the economy. This can be seen in the figures from EUROSTAT cited by the Work Foundation shown in Table 1.2.

Change in Employment	**Knowledge-based industries**	**Other industries**
Spain	+ 74.6%	+ 42.4%
Ireland	+ 70.7%	+ 42.9%
Netherlands	+ 29.9%	+ 12.3%
Finland	+ 29.6%	+ 13.5%
Germany	+17.1%	- 8.6%
UK	+ 16.7%	+ 1.0%
France	+ 16.3%	+ 7.3%
Denmark	+ 11.6%	- 0.2%
Sweden	+ 12.8%	+ 2.0%
EU-15	+ 23.9%	+ 5.7%

Table 1.2: Change in employment in knowledge-based industries in selected EU member states 1995-2005, Work Foundation (2006).

In Table 1.2 it can be clearly seen that many of the countries experiencing the greatest growth in knowledge-based industries are those developing from the weakest bases. These figures are projected against a period of economic change that saw recession in much of the Euro-zone during the early years of the 21^{st} century. This is apparent in the 'other industries' statistic in figure for Germany, which was particularly hard hit during this period.

1.2.3.1 Defining a Knowledge Economy

The role of knowledge in the Knowledge Economy is described in the definitions of the Knowledge Economy provided by the OECD (OECD 1996) and the UK DTI (DTI 2004):

"...*economies which are directly based on the production, distribution and use of knowledge and information*"

"...*one in which the generation and exploitation of knowledge has come to play the predominant part in the creation of wealth*"

While the above is useful in defining and understanding the origins of the Knowledge Economy, how can it be determined whether an economy is knowledge-based?

Methods such as the World Bank Knowledge Assessment Methodology (KAM) exist for benchmarking performance of countries in the transition to a knowledge-based economy. This builds upon the World Bank 'Pillar Model' of the Knowledge Economy, which describes the key supports of such an economy as being (World Bank 1998):

1.2.3.2 Human Capital: Educated and skilled workers

People; their knowledge, talents, ideas and graft form the fundamental pillar of the Knowledge Economy. Developing a successful regional Knowledge Economy depends upon creating and nurturing the skills, aspirations and motivations of the people therein and attracting talent from outside.

1.2.3.3 Innovation: An effective innovation system

Regional innovation systems have been shown to be the motors of the Knowledge Economy (UNIEDO 2003). A region's ability to develop new products and services and improve upon the manner it produces existing ones is key in determining its economic fortune. Along with companies these systems include interrelated actors including universities, research centres, knowledge services etc.

1.2.3.4 Infrastructure: A modern and adequate information infrastructure

To facilitate innovation and create clusters of growing knowledge-based businesses an infrastructure is required for its support. Infrastructure not only encompasses physical entities such as development facilities, offices and ICT systems. 'Soft' infrastructure is equally critical. Important examples include not only enterprise and specialist support such as legal services but also knowledge networks of individuals and organisations that disseminate and exploit knowledge and opportunities.

1.2.3.5 Economic and Institutional Regime

The economic environment of a nation or region plays an important part in the growth of the Knowledge Economy. Factors such as taxation, strength of Intellectual Property Rights, export controls/tariffs etc. are examples of this economic and institutional regime. Many of these aspects of the Knowledge Economy are managed at the UK or EU level. They therefore fall outside the devolved powers of the National Assembly for Wales and regional actors. It is however, important to understand how they affect the regional Knowledge Economy in order to maximise potential growth and opportunities.

Using these pillars the KAM system tracks variety of including: literacy of population; availability of ICT; levels of entrepreneurship and innovation; proportion of population with higher-level skills etc. As these indices are easily collated and comparable between nations it makes benchmarking straightforward. However, as the methodology was developed to assist developing countries, many of the indices used are less relevant to developed nations.

1.2.3.6 Threshold of a Knowledge Economy

While the concept of the Knowledge Economy is clear, the challenge remains in determining the extent to which an economy is knowledge intensive (Shapira et al., 2005). A practical approach toward defining whether an economy is 'knowledge-based' is to determine whether it exceeds a threshold of knowledge intensiveness. Using their sectoral definition of the Knowledge Economy the OECD (OECD 1996) provides such an approach, defining a knowledge-based economy as being:

"*..an economy in which more than 40% of employees are employed in high technology manufacturing and knowledge-intensive industries*"

Cooke and De Laurentis (2003) have used this approach to study the role of the Knowledge Economy in various European regions demonstrating significantly varying knowledge intensiveness across the EU.

This approach of tracking knowledge intensive sectors provides a useful metric in that it makes use of official statistics that are consistent across national and regional boundaries. However, a sectoral approach is limiting in that the Knowledge Economy is relevant to all industries, not only those included in the definitions provided by EUROSTAT and the OECD (1996). This applies in particular to those sectors not related to science, engineering and technology (SET).

1.2.4 Context of Global R&D

Innovation, the exploitation of new ideas, is absolutely essential to safeguard and deliver high-quality jobs, successful businesses, and better products and services for our consumers, and new, more environmentally friendly processes.

The importance of innovation is highlighted in the UK Department of Trade and Industry (DTI) economics paper; *Competing in the Global Economy: The Innovation Challenge*. Despite there being no single indicator of national innovation performance it was found through a range of measures that the UK is lagging behind other advanced economies. The measures used examined patenting, business expenditure on R&D and other related indicators.

The difference in our innovation intensity is highlighted by Figure 1.3, showing a far higher number of employees working in R&D in the US and leading competitor countries. This combined with an ever-declining number engineering and science graduates has created a less innovative culture. However, compared to European competitors the Community and Innovation Study (CIS) statistics show a relatively large proportion of UK companies bringing new products or services to market or developing new process technologies (EU 2003).

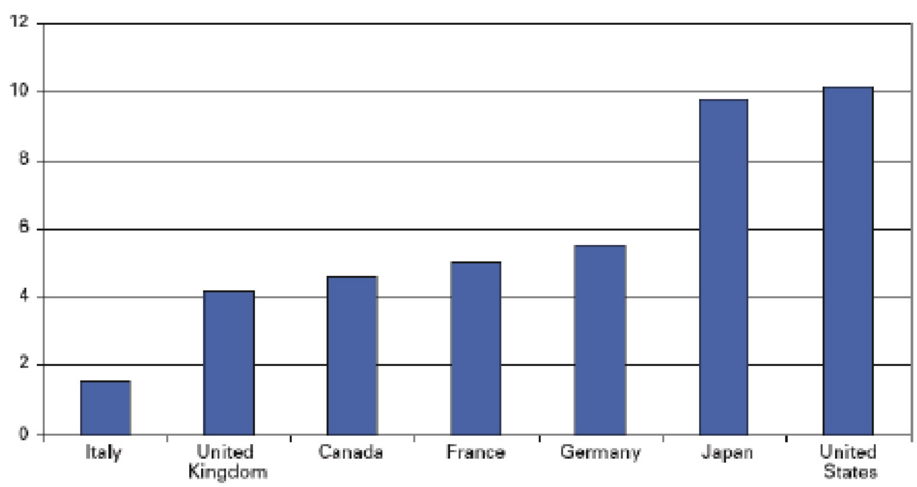


Figure 1.3: Business enterprise researchers per thousand employments in industry, 2000 Source: OECD, 2000.

Figure 1.4 shows the level of expenditure in R&D of regions that are member of Organisation for Economic Co-operation and Development. Demonstrating the level at which the US spends in relation to R&D exceeds that of the EU with the UK included. Innovation is created through innovation systems, which are inherently linked to research and development. Understandably a key factor in measure of innovation is patents. Looking at patents is a good measure, however there are inherent and significant differences between the patenting systems of the US and UK which must be considered and addressed in order to understand how the systems are used.

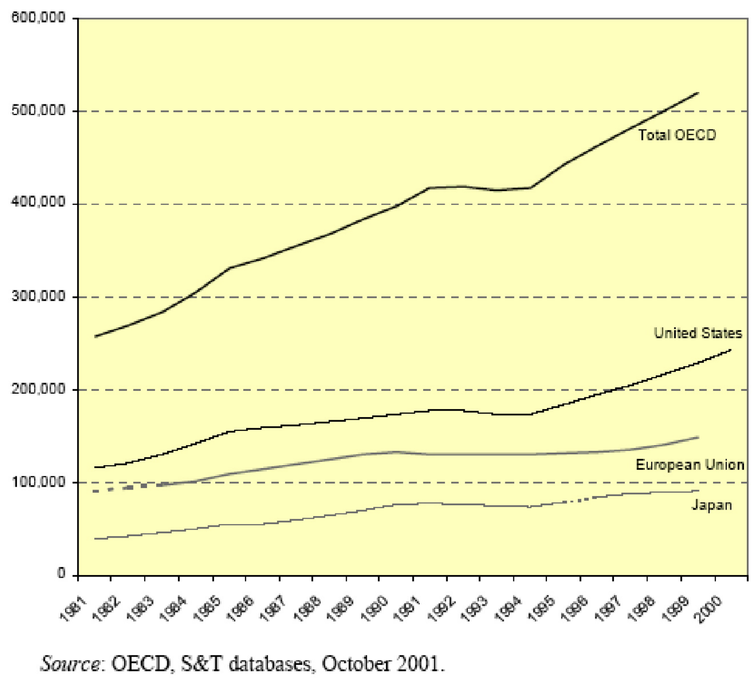


Figure 1.4: Global R&D expenditures in the OECD area 1981-2000.

1.2.5 Patenting in the US and UK

Intellectual property (IP) is a highly valuable asset. The accounting firm Duffs & Phelps estimates that on average 87 percent of company value in 2002 was in intangibles including IP. (Jarboe 2008)

Patents are the codification of research and development into a property right. They are a key step in protecting and subsequently realising the value of the company's R&D investment. Not all patents are equal, as can be clearly seen in blockbuster patents on drugs or fundamental electronics or computer inventions. Therefore, the number of patents alone is not a measure of value. There are several factors that determine value, including whether a company uses its patent portfolio to protect its business by litigation or generate income from licensing.

Furthermore it must be considered whether competitors respect a company's patents and avoiding them or designing around them, thereby allowing the patent holder to price its products without infringement of their rights. As a general rule a robust patent portfolio indicates a successful R & D program available for management to use to create value. Patents are being treated more like other types of property. They are licensed, sold and used as equity in joint ventures. Licensing is a substantial business with annual royalty revenue estimated at over $125 billion a year and growing. Most of this activity comes from licenses between corporations in the pharmaceutical/biotech, chemical and manufacturing industries (Cohen 2008).

“Patents are a recently rediscovered corporate weapon.” For most of this century," says Rivette and Kline, "intellectual property played only a minimal role in shaping the commercial and strategic fortunes of American business. Patents were for the most part used defensively, if at all and few companies outside the pharmaceutical, biotechnology, or certain other sectors ever thought of them as strategic assets" (Rivette 2000).

The knowledge economy is all about the commercial exploitation of new ideas. It is essential that in any organisation or company have a carefully planned strategy for the management of it intellectual property. Indeed copyright is now one of the biggest US exports (International Intellectual Property Alliance 2002).

During the research it was found that there exists an uneven playing field regarding intellectual property management and protection that lends itself to the US patent system giving its citizens, universities and companies a significant advantage over its UK counterparts.

- The first being the first to invent. The US system is firstto invent and the EU and UK systems are firstto file. This is particularly useful to academics that can seek protection from the priority date on which the concept is invented. The second advantage is that a US inventor can make a public disclosure though still be protected in the US market. However the US inventor has sacrificed any Patent Cooperation Treaty (PCT) application.
- The US patent system also has a Provisional Patent System. This Provisional Patent filing requires a superficial document containing claims only, not the specific details as required by UK patents. This allows greater flexibility in developing the technology and drafting the application.
- The patenting process itself is a cheaper process. US universities and companies enjoy a cost advantage when it comes to obtaining IP protection, along with the economies of a large domestic market and other beneficial idiosyncrasies of the US patent system. For example first 2 year protection of IP costs in the US can be $500, to the UK $5000, offering the same level of IP protection.
- Another key advantage is efficiency of the patent process and its time to grant. US patents can be granted in 18 months to 2 years, whereas the European system can take significantly longer. This is borne out by the work under progress at the University of Wales Swansea, investigating the patenting in universities.

Figure 1.5 shows national output of granted patents over a period of 11 years, clearly showing the US far ahead of the UK in the race for granted patents. Overall, the UK has a strong science base, but lags in patenting and commercialisation. Also, the UK’s strength in the life sciences masks lower performance in other areas of science and technology. Current levels of UK innovation are insufficient to drive UK productivity growth and close the UK productivity gap versus key competitors (DTI 2003).

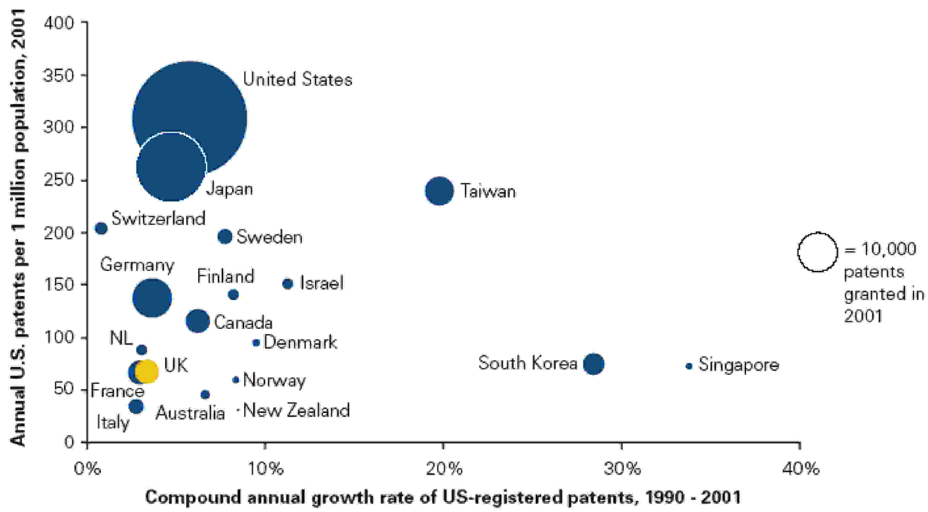


Figure 1.5: International Patenting Output *Source*: US Patent and Trademark Office (2002), author's analysis.

The experience curve that a university holds also plays a factor in the efficiency of the IP management process. Many US universities have extensive experience of IP management, which is not replicated in the UK. The US government has used the Patent and Trademark Law Amendments Act 1980 (Bayh-Dole Act) to facilitate and remove barriers for the management and utilisation of IP by and for universities and small businesses. This Act obliged US universities to commercialise its IP, the US universities have had 25 years to streamline the process and create an efficient system of IP commercialisation potential and evaluation.

US universities have also been able to utilise professional groups such as the Association of University Technology Management (AUTM), who have assisted in setting up framework for best practice in the management of IP in US universities. The UK though have acted back by creating *Knowledge Transfer Networks (KTN)*, to draw together sector focused communities and *Knowledge Transfer Partnerships(KTPs)* to support discreet projects involving academic-industrial collaboration have been set up to drive the flow of knowledge within and in and out of specific communities.

1.2.5.1 Knowledge Transfer Networks

Knowledge Transfer Networks provide both a vehicle for the community to develop its ideas and interactions and a communications route between that community and the Government. Their activities are increasingly playing an important role in the development of the Government's Technology Strategy and as focal points for the Technology Programme. They are an evolving part of the overall Government Technology Strategy and the Technology Strategy Board has put in place a review of their goals and activities which reflect their growing importance and to ensure that we move towards a coherent and integrated use of KTNs to feed and drive the Collaborative Research & Development programme and other innovation interventions (www.ktnetworks.co.uk, 2007).

1.2.5.2 Knowledge Transfer Partnerships

Knowledge Transfer Partnerships (KTP) is a UK based program to support business in improving their competiveness and productivity through the better use of knowledge, technology and skills that reside within the UK knowledge base. KTP is funded by the Technology Strategy Board with 17 other funding organisations. Each partnership employs one or more high calibre Associates (recently qualified people) to work on a project, which is core to the strategic development of the business. Both of these, Technology Strategy Board, (formerly known as the DTI) initiatives aim to address some of these disparities (www.ktponline.org.uk, 2007).

1.2.5.3 KESS

In November of 2009 the Welsh Assembly Government unveiled a £33 million programme that is focused in the Convergence region of Wales, aimed at providing hundreds of scholarship opportunities to develop the skills needed to drive Wales' Knowledge Economy forward. Each scholarship aims to provide an annual bursary of up to £13,300 as well as research and business training tailored to each individual. The program focuses on sectors that the Welsh Assembly Government has identified as key sector low carbon economy, health and bioscience as well as advanced engineering and manufacturing. The scholarships goal is to deliver the high level skills needed by businesses in Wales, building knowledge and boosting the R&D capability in the strategically important sectors of the Welsh economy.

1.2.5.4 POWIS

The Prince of Wales Innovation Scholarships (POWIS) program is aimed at providing 100 world-class graduates to welsh SME's between 2009 and 2014. Each of the scholars is partly funded by the European Union and places scholar within a company for a period of three years, during which the scholars undertake research and development on any aspect of the company's work; whether being to improve the company's products and services, internal processes or the way that they interact with other companies. Each of the scholars is supported by a project manager, a local academic supervisor and a local or international academic supervisor with expertise in the chosen field of research. The scholar is expected to be based with their host company in Wales on a full time basis and use the outcomes of that time to complete a PhD (www.wales.ac.uk, 2010).

1.2.6 Non-SET and Service sectors

Knowledge-economy activities are often noticeable in the domains of Science, Engineering and Technology, particularly those that manufacture some patented product, though it is important to give consideration to the wider economy, in particular the service sector. Many of these, such as finance and telecommunications are captured in the OECD '*knowledge-intensive industries*' definition (Coates and Warwick 1999). Growth in services led to almost all of the new jobs created in the EU in the period 1997-2002 and account for 70% of EU added value (EU 2005).

The importance of all sectors to the Knowledge Economy is emphasised by Michael Porter in '*The New Challenge to America's Prosperity: Findings from the Innovation Index*', (Porter and Stern 1999) where he outlines that there are no 'low tech' industries, only companies that fail to embrace new ideas and methods into their products. Porter and Stern also emphasise innovation in the context of '*discerning and meeting the needs of customers*', rather than being a domain restricted to science and engineering, arguing that improvements in marketing, distribution and service can be as important as those generated in laboratories relating to new products and processes.

The role of the service sector in the Knowledge Economy and its economic impact is emphasised by the growth in knowledge services over the past decade. This is shown below in Table 1.3, cited from the Work Foundation report for the 2007 EU Spring Council (Work Foundation 2006).

Knowledge services	Change (jobs)	Change %
Business and Communications	+ 5,090,000	+ 54.5%
High tech services	+ 1,581,000	+ 37.1%
Health and Education	+ 6,838,000	+ 26.7%
Financial Services	+ 129,000	+ 2.5%
Total Knowledge Services	+ 13,637,000	+ 30.7%

Table 1.3: Growth in knowledge services in EU15 1995-2005 Source: EUROSTAT, cited from Work Foundation 2006.

The importance of non-SET sectors is supported by historical observations. Peter Drucker in his book '*Innovation and Entrepreneurship*' (Drucker 1985) describes how the economic growth of the US in the second half of the 20th Century saw only one eighth of new jobs created in high technology. In fact technological effects such as automation often had negative effects on job creation. However, while robots appearing in factories may be an obvious example of how technology has affected manufacturing industries it should be remembered that something similar has also happened in the service sector. Telephone and on-line banking, e-commerce etc., are all examples of how growth in services has been accompanied by rationalisation and labour saving innovation (Hauknes 1999).

1.2.7 Knowledge Spillovers

Knowledge Spillovers allow knowledge to be reused providing increased productivity through greater leverage of the investment made into its creation or acquisition (OECD 1996). Whereas other resources such as capital or fuel can only be exploited once, knowledge can be used to provide many and separate returns. For example, research for materials to make stronger car components may also allow improvements in aerospace components.

Spillovers can occur between organisations of any type and can be either intra- or inter-industry (Cantwell and Piscitello 2005). They can occur between organisations of any nature, and also through intermediaries (Lawson and Lorenz 1999). Another interesting factor in knowledge spillovers is that they can be voluntary or involuntary (EU 2003). The spill-over of knowledge within regions is an important driver of cluster theory, which is described later in this section, though the spatial spilling of knowledge is not restricted to regions, particularly thanks to modern communications systems and the increasing mobility of workers. Research by Luintel and Khan (2004) for example demonstrates this cluster development role, together with the potential negative effects of spillovers. Their work describes how research and development spillovers from the US provide greater assistance to competitors than that which they receive in return.

Both public and private investments in basic research can have significant spill-over effects beyond their initial objectives (Porter and Stern 1999). Public sources of knowledge are of particular importance as they are more likely to spill-over, as the dissemination of knowledge is typically part of the mission of the public research institution (Doring and Shnellenbach 2006).

The knowledge involved can be technical or non-technical in nature and spill from one industry to another. Tacit knowledge spillovers tend to be localised in nature (Boddy 2005). As ICT makes dissemination of codified information fast and inexpensive, face-to-face interactions and interpersonal relationships have come to have a comparative advantage in facilitating tacit knowledge flows (Porter 1990). The effects of these spillovers have been shown to be important drivers of cluster development.

As described by Doring and Shnellenbach (2006), however, knowledge spillovers do not only give access to 'exclusive' knowledge available from a specific source, but also provide easier or cheaper access to other, often widely available knowledge.

The effect of knowledge spillovers not only figures as a benefit to existing businesses within a locality, but also as a factor influencing the decisions of multinational firms as to where they locate R&D operations (Cantwell and Piscitello 2005).

1.2.8 Competitive Advantage

When a firm sustains profits that exceed the average for its industry, the firm is said to possess a competitive advantage over its rivals. The goal of much of business strategy is to achieve a sustainable competitive advantage. Michael Porter identified two basic types of competitive advantage:

- Cost advantage.
- Differentiation advantage.

A competitive advantage exists when the firm is able to deliver the same benefits as competitors but at a lower cost (cost advantage), or deliver benefits that exceed those of competing products (differentiation advantage). Thus, a competitive advantage enables the firm to create superior value for its customers and superior profits for itself.

Cost and differentiation advantages are known as positional advantages since they describe the firm's position in the industry as a leader in either cost or differentiation. A resource-based view emphasizes that a firm utilizes its resources and capabilities to create a competitive advantage that ultimately results in superior value creation (Hughes 2007). Figure 1.6 combines the resource-based and positioning views to illustrate the concept of competitive advantage.

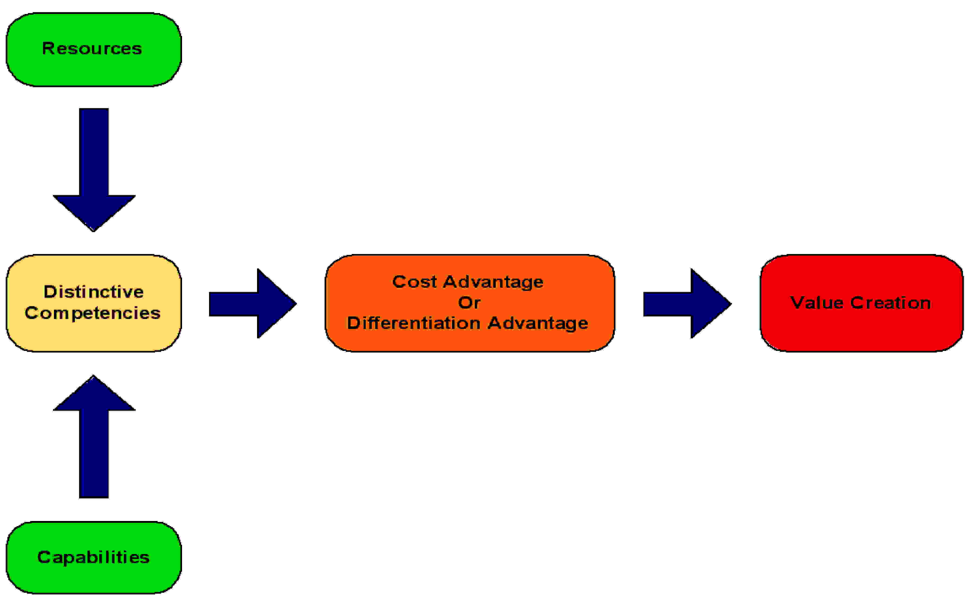


Figure 1.6: A model of competitive advantage.

1.2.8.1 Resources and Capabilities

According to the resource-based view, in order to develop a competitive advantage the firm must have resources and capabilities that are superior to those of its competitors. Without this superiority, the competitors simply could replicate what the firm was doing and any advantage quickly would disappear.

Resources are the firm-specific assets useful for creating a cost or differentiation advantage and that few competitors can acquire easily. The following are some examples of such resources:

- Patents.
- Know-how.
- Facilities.
- Installed customer base.
- Reputation of the firm.

Capabilities refer to the firm's ability to utilize its resources effectively. An example of a capability is the ability to bring a product to market faster than competitors. Such capabilities are embedded in the routines of the organization and are not easily documented as procedures and thus making it difficult for competitors to duplicate.

The firm's resources and capabilities together form its distinctive competencies. These competencies enable innovation, efficiency, quality, and customer responsiveness, all of which can be leveraged to create a cost advantage or a differentiation advantage.

1.3 The Texas/United Kingdom Collaborative

1.3.1 Overview of the "Collaborative" and Phase I

The Texas - UK Collaborative was established in the fall of 2002 to foster collaborations among researchers in the nanosciences, information sciences and the biosciences located in top institutions in Texas and the UK thereby building new areas of research and capacity generating new ideas, techniques, products and opportunities.

The top institutions in Texas became partners in Phase I of the Collaborative including Baylor College of Medicine, Rice University, Texas A&M University, University of Houston, University of Texas at Austin, University of Texas Health Science Center at Houston, University of Texas M.D. Anderson Cancer Center and University of Texas Medical Branch (UTMB).

In Phase I thirty thematic events, were organized involving more than 400 researchers from Texas and the UK and 60 collaborations, involving more than 180 researchers, were established. Outputs include fifty manuscripts reporting the results of collaborative research have been prepared and four patents have been filed.

As scientific advances increasingly emerge from collaborative efforts, the resolution of the world's greatest challenges will depend upon, and result from, the internationalization of research. Initiated in January 2003 by the DTI through Lord Sainsbury in the UK, Malcolm Gillis at Rice University and Iain Murray the then Consul General in Houston, The Texas-United Kingdom Collaborative harnesses the collective experience and ambitions of nine universities and medical colleges in Texas and nine universities in the UK including the UK's top universities. The Collaborative was created to stimulate the exchange of ideas and research in the fields of biomedicine, nanotechnology and information and communications technology (ICT). Since its inception in 2003, the Collaborative has brought together some of the world's leading scientists, engineers, and medical experts to foster collaborative research projects in areas such as biomedicine, biotechnology, and nanotechnology. Texas is a leading centre of bioscience research and is home to the world's largest medical centre, situated in Houston, with more than 35 million square feet of space housing more than 70,000 personnel. In 2008, Texas has been named as one of the top five regions in the world for biotechnology development.Texas also ranks as the fourth largest recipient of US Federal Research Dollars, amounting to almost US$1.5 billion per annum. Most recently the State of Texas has committed US$3 billion over 10 years to cancer research and is looking for international partnerships to make the best use of this money. The UK has complementary strengths in the biosciences and rapidly growing expertise in nanotechnology.

1.3.2 The Texas/UK Collaborative Phase I Translational Outcomes

The importance of translational outcomes of Phase I of the "Collaborative" was enhanced by the standing of both Texas and Houston in the medical, bioscience and nanotechnology fields. The UT MD Anderson Cancer Center located in the TMC is ranked the number one Cancer Research Center in the US. Rice University, located in Houston, opened the Smalley Center for Nanoscale Science and Technology in 1993, the first such center in the world, Rice leads in the development and commercialization of nanotechnology in several sectors including medical and bio sciences.

The Alliance for NanoHealth, an alliance of all academic institutions in the region and internationally, has more than 170 researchers researching applications of nanotechnology in medicine and health. The University of Texas Medical Branch in Galveston with international recognition in emerging infectious diseases is home to a National Laboratory providing Bio-safety Level 4 (BSL-4) facilities. All of these attributes compound the expertise in translating basic and applied research.

> NOTE: Bio-safety level 4 is the highest level of bio-safety. This level is used for the diagnosis of exotic agents such as the Ebola virus that pose a high risk of life-threatening disease, which may be transmitted by the aerosol route and for which there is no vaccine or therapy (www.medterms.com, 2008).

Phase I demonstrated that collaboration between member institutions could lead to significant benefits to academic partners and impact upon the regional knowledge economy. Examples of such outcomes include:

1.3.2.1 Texas Proteomic Collaborative

Building on an agreement, signed on December 15, 2004, between M. D. Anderson Cancer Research Center and Imperial College London, for the establishment of a research program focused on identifying new molecular targets for cancer diagnosis and treatments. Both MD Anderson and Imperial are internationally renowned for their commitment to and excellence in translational medicine, driving pioneering cancer research from the laboratory to patient therapies at the bedside. Both institutions invested in technology transfer and collaborative applied research initiatives in order to bring research discoveries to the market for the benefit of cancer patients. The strategy of the collaboration is to maximize their strengths in basic science research and clinical programs, accelerating the speed of scientific discoveries. Creating advantage for both MD Anderson and Imperial, were as M. D. Anderson could look for additional opportunities to identify promising new anticancer agents for clinical development and investigate new methods for diagnosing and treating cancer, and Imperial could expand its range of research programs and further contribute to the improvement of healthcare globally.

The Rector of Imperial at the time, Sir Richard Sykes, said, "Cancer research has long been a major focus at Imperial, and collaborations with such prestigious international partners as M. D. Anderson will help to further strengthen exploration of cancer treatments as a key part of Imperials research strategy."

The Proteomics Collaborative between the two institutions received $1M for its development and was significantly supported by the Texas/ UK Collaborative.

1.3.2.2 Endomagnetics Ltd.

At the close of Phase I of the “Collaborative” there were research collaborations that lead to translational outcomes, two of which have significant results. Endomagnetics Ltd, a spin out company from the University of Houston and University College London, supported by the Collaborative, have completed a clinical trial detecting Sentinel Lymph nodes in 12 breast cancer patients (Figure 1.7). This technology allows for enhanced Sentinel node biopsy results in shorter breast cancer operations and better patient recovery, which saves money and frees up resources for healthcare providers like the NHS in the UK. There is also the opportunity to move the operations away from the largest cancer centres – the ones with access to radioactive tracers – to short-stay clinics and regional hospitals, which help to spread the load and to provide the services that patients need, locally.

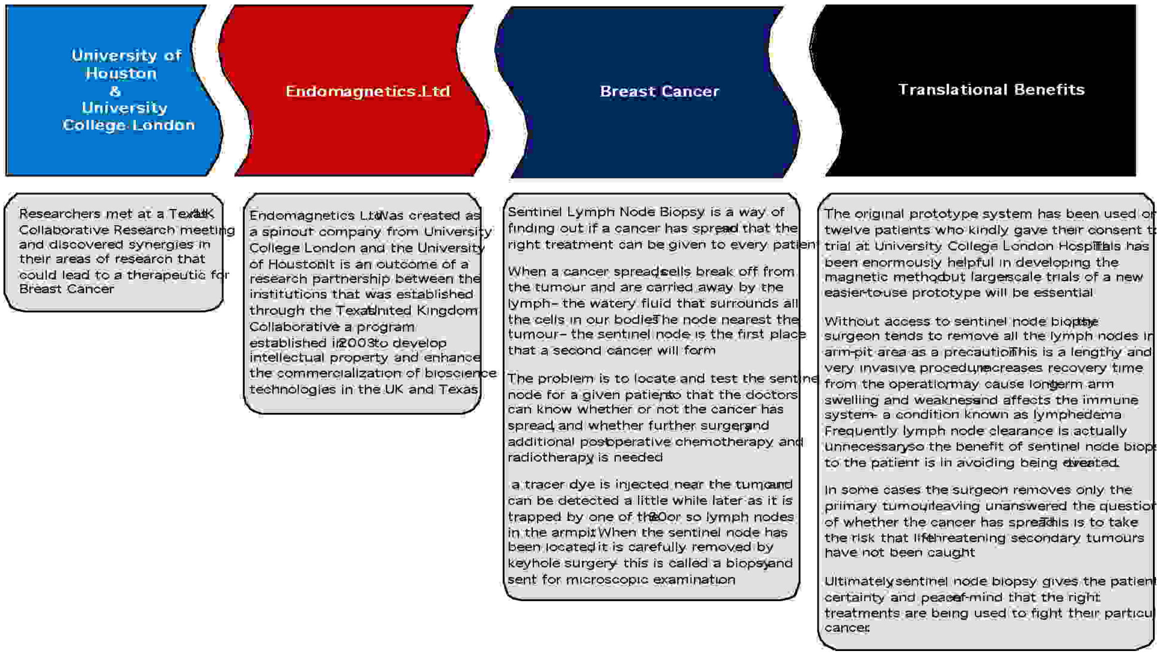


Figure 1.7: University of Houston and University College London spin-out: Endomagnetics Ltd.

1.3.2.3 National Institute of Health Quantum Grant Award

Inclusive to this outcome there was the National Institute of Biomedical Imaging and Bioengineering (NIBIB) of the National Institutes of Health (NIH) established the Quantum Grants Program to make a profound (quantum) improvement in health care. This program challenged the research community to propose projects that have a highly focused, collaborative, and interdisciplinary approach targeted to solve a major medical problem or to resolve a highly prevalent technology-based medical challenge. The program consists of a 3-year exploratory phase to assess feasibility and identify best approaches, followed by a second phase of 5 to 7 years. To date, the NIBIB has awarded Quantum Grants to five interdisciplinary teams. The research collaboration between Baylor College of Medicine, Rice University, the National Institute of Medical Research in London, King's College of London, and Edinburgh UniversityreceivedNIBIB Awards First Quantum Grant of $2.9 Million over three-yearon for Engineering Brain Microenvironments to Promote Stroke Recovery. A stroke occurs when compromised blood flow to the brain results in the death of neurons. Individuals who have had a stroke may experience partial paralysis or problems with awareness, attention, learning, judgment, memory or speech. Post-stroke rehabilitation can help stroke victims overcome some of these disabilities, but does not promote regeneration of the underlying damaged brain tissue. Injection of naked neural stem cells can stimulate some repair, but is generally inefficient.

With support from multiple corporate partners, an international team of researchers is integrating cutting-edge imaging and engineering techniques to map and regenerate the stem cell niche of the brain regions that promote generation of new neurons. The team has already discovered that the niche contains neural precursors in intimate association with capillaries that provide (at a minimum) critical nutrition and communication. The ultimate goal is to bioengineer an *ex vivo* system mimicking these niches. It is hoped that these neurovascular units can eventually be used to replace and/or drive repair of stroke-damaged tissue.

1.3.3 Phase II and Swansea "Joins the Club"

With the successes in Phase I and with the increasing emphasis on and funding opportunities for international research collaborations in Texas funding of US$1.0MM over 4 years was secured from the Farish Fund Foundation of Houston to support Phase II of the Collaborative. The President of the Farish Foundation, Ambassador Farish, was the US Ambassador to the United Kingdom from 2001 to 2005. This funding together with contributions from the participating institutions in Texas and in the UK and additional sources provides the resources for the Collaborative. The projected budget over four years is approximately US$5 million.

The Collaborative supports thematic workshops, bringing researchers from diverse backgrounds to focus on specific problems; research planning meetings for the preparation of research proposals; faculty/student visits/exchanges, including student internships; and provide resources to seed fund research.

Phase II of the Collaborative consists of the institutions in Texas previously mentioned in Phase I, together with the Methodist Hospital Research Institute, and the institutions in the UK most engaged in Phase I, which include Imperial College London, University of Cambridge and University College London. The Welsh Partner is Swansea University.

Dr. Malcolm Gillis, former president of Rice University who played the leading role in the establishment of the Collaborative in 2002, serves as the Executive Director. The Collaborative is led by the founding Director, Denis Headon, working with an advisory group composed of one representative from each of the participating institutions. The UK institution representatives include Professor Mary Ritter, Pro Rector for Postgraduate and International Affairs, Imperial College London; Professor Mike Spyer, Vice-Provost (Enterprise), University College London; Professor Ian Leslie, Pro-Vice-Chancellor (Research), University of Cambridge; and Professor Richard Oreffo, Professor in Musculoskeletal Science, University of Southampton.

The Collaborative requires total funding of approximately US$1.5MM per year supporting thematic workshops, research planning meetings, personnel exchanges (including student training through internships) and visits by individual researchers to Texas and to the UK. The budget for the UK shows a £600K over four years, in addition to the contributions of £20K by each of the UK institutions.

The additional funds will support the sustainability of a network of leading research and entrepreneurial universities in the UK and the USA. Additional funds on both sides of the Atlantic, over and above the basic budget, will provide for seed funding of collaborative projects generating a history of collaboration and preliminary data thereby enhancing the potential for successful outcomes from future research proposals and, also, fund 'proof of concept studies'. Calls for proposals and funding opportunities for international collaborations are increasing - there are very significant opportunities ahead, buildings achievements of Phase I.

A recent indicator of the commitment in Texas to interdisciplinary collaborations is that Rice University has commenced construction of a Collaborative Research Center, of more the 500,000 sq. feet, strategically located between the Rice campus and the Texas Medical Center, the world's largest medical center. In addition the State of Texas has committed to the provision of US$3 billion for cancer research over the coming decade.

In 2007 Swansea University became a member of the Texas/UK Collaborative, an elite network of world leading research organisations. This partnership has been developed, and is managed by the author, with the member shown in Table 1.4.

UK	**Texas**
	continued on next page

Imperial College London, Kings College London, Oxford University, Cambridge University, University College London, Strathclyde University, Southampton University, Swansea University, and Queens University	Rice University, Texas A&M University, University of Houston, University of Texas Health Science Center, University of Texas Medical Branch, Baylor College of Medicine, MD Anderson Cancer Research Center, and Methodist Hospital Research Institute

Table 1.4: Members of the Texas United Kingdom Collaborative Phase II.

1.3.3.1 The Swansea Approach

The strategy undertaken by Swansea Universities was to have strategic key researchers of decision-making level from Swansea's Medical School to accompany the director of the Collaborative in Swansea to Houston to engage in a pre-Collaborative Scoping and Mapping Exercise to lay firm ground work for future collaboration. A network of researchers was established within Swansea University drawing in expertise from across the Schools of Medicine and Engineering. Wherever possible, members of this network participated in visit, workshops and other joint activities to develop awareness of their respective research interests and strengths, and to identify/scope potential collaborations.

1.4 The Research Question

The previous section has described how the Texas/United Kingdom Collaborative combines the strategic expansion of academic research with the involvement of the private sector, bringing economic development through enterprise and job creation.

The aspiration of participation of Swansea in the Texas/UK Collaborative is not solely to support growth of its research agenda but also to assist in creating a sustainable innovation system. Earlier sections have outlined the economic development challenges faced by Southwest Wales and the global context of innovation and knowledge economies. Phase I of the Texas/United Kingdom Collaborative demonstrated the potential for academic industrial collaboration across global networks to support economic development. Therefore it can be suggested that Swansea, as a new member of the initiative, has an opportunity to derive benefit in a similar manner leading to the question:

Can a region lever participation in a Global Network to accelerate the development of a sustainable Technology Cluster?

1.5 Bibliography

- Asheim B.T. and Isaken A., 2002, "Regional Innovation Systems: The Integration of Local 'Sticky' and Global 'Ubiquitous' Knowledge", The Journal of Technology Transfer, Vol. 27, No. 1.
- Barrell R. and Pain N., 1997, "Foreign Direct Investment, Technological Change, and Economic Growth Within Europe", The Economic Journal, Vol. 107, No. 445, pp. 1770-1786. Friedman J., Gerlowski D .A. and Silberman J., 1992,"What attracts Foreign Multinational Corporations? Evidence from Branch Plant Location in the United States", Journal of Regional Science, Vol. 32, No. 4 pp. 403-418.
- Boddy M., 2005, "The Knowledge-Driven Economy, Regional Economic Strategy and the Regional Spatial Strategy in the South West of England", South West Regional Development Agency.
- Brooksbank D.J., Clifton N.C., Jones-Evans D. and Pickernell D.G., 2001, "The End of the Beginning?: Welsh Regional Policy and Objective One", European Planning Studies, Vol. 9, No. 2.
- Cameron G., Muellbauer J. and Snicker J., 2002, "A Study in Structural Change: Relative Earnings in Wales Since the 1970's", G Cameron, J Muellbauer and J Snicker, Regional Studies, Vol. 36, Iss. 1, pp. 1-11.

- Cantwell J. and Piscitello L., 2005, “Recent Location of Foreign-owned Research and Development Activities by Large Multinational Corporations in the European Regions: The Role of the Spillovers and Externalities”, Regional Studies, Vol. 39, Iss.1, pp. 1-16.
- Coates D. and Warwick K., 1999, “The Knowledge Driven Economy: Analysis and Background”, Conference Paper, The Economics of the Knowledge Driven Economy, UK DTI, 1999.
- Cohen J., Gangi W., Lineen J. and Manard A, 2008, “Strategic Alternatives in the Pharmaceutical Industry”, Kellogg School of Management, www.kellogg.northwestern.edu, Accessed May 2008.
- Cooke P., 1998, “Innovation Systems”, P Cooke, ISBN 1-85728-690-1, UCL Press.
- Cooke P. and Clifton N., 2005, “Visionary, Precautionary and Constrained ‘Varieties of Devolution‘ in the Economic Governance of the Devolved UK Territories”, Regional Studies, Vol. 39, Iss. 4, pp. 437-451.
- De Laurentis C., Cooke P. and Williams, G., 2003, “Barriers to the Knowledge Economy- New Media Cluster in the Periphery”, Paper presented at the Regional Studies Association International Conference, Scuola Superiore Sant’ Anna Pisa 12th -15th April 2003.
- Doring T. and Shnellenbach J., 2006, “What Do We Know about Geographical Knowledge Spillovers and Regional Growth?: A Survey of the Literature”, Regional Studies, Vol. 40, Iss. 3, pp. 375-395.
- Drucker P.F, 1985, “Innovation Entrepreneurship”, Elsevier, ISBN 0-7506-4388-9.
- DTI, 2004, “Our Competitive Future: Building the Knowledge-Driven Economy”, Department of Trade and Industry, UK Government.
- EU, 1997, “First Action Plan for Innovation in Europe”, Cordis, European Commission.
- DTI, 1999, “The Economics of the Knowledge Driven Economy”, Department of Trade and Industry, UK Government.
- DTI, 2003, “Competing in the Global Economy – The Innovation Challenge”, DTI Economics Paper, No. 7, Department of Trade and Industry, UK Government.
- EU, 2003, “Final Report of the Expert Group on Enterprise Clusters and Networks”, Enterprise Directorate General, European Commission.
- Europa (2003), Community Innovation Survey, 1994-1996, Brussels, Belgium: European Union.
- Gripaios P., Gripaios R., and Munday M., 1997, “The role of Inward Investment in Urban Economic Development: The Cases of Bristol, Cardiff and Plymouth”, Urban Studies, Vol. 34, No. 4, pp. 597-603.
- Hauknes J., 1999, “Services in Innovation – Innovation Services, Realising the Potential of the Service Economy: Facilitating Growth, Innovation and Competition”, OECD Business and Industry Policy Forum.
- Hughes P. and Morgan R.E, 2007, “A resource-advantage perspective of product–market strategy performance & strategic capital in high technology firms”, Industrial Marketing Management, Vol. 36, Iss. 4, pp. 503-517.
- International Intellectual Property Alliance (2002) U.S. Copyright Industries Continue to Lead the Economy in Job Growth, Contribution to the GDP and Foreign Sales/Exports, US Patent and Trademark Office: US Government.
- Jarboe K. P. and Furrow R., 2008, “Intangible Asset Monetization: The Promise and the Reality”, Working Paper, No. 3, Athena Alliance, Accessed May 2008.
- Keating M., 1998, “Reforging the Union: Devolution and Constitutional Change in the United Kingdom”, Publius, The Journal of Federalism, Vol. 28, No. 1, pp.217-234.
- Lawson C. and Lorenz E., 1999, “Collective Learning, Tacit Knowledge and Regional Innovation Capacity”, Regional Studies, Vol. 33, pp. 379-389.
- Luintel K.B. and Khan M., 2004, “Are International R&D Spillovers Costly for the United States?”, The Review of Economics and Statistics, Vol. 86, No.4, pp. 896-910.
- Lundval B. and Johnson B., 1994, “The Learning Economy”, Journal of Industrial Studies, Vol. 1, Iss. 2, pp. 23-42.
- Mathias P., 1983, “The First Industrial Nation: An Economic History of Britain: 1700-1914”, 2nd Ed., P Mathias, Routledge.

- McLean I. and McMilan A., 2003, “The Distribution of Public Expenditure across the UK Regions”, Fiscal Studies, Vol.25, pp. 325-335.
- Morgan K., 1981, “Wales: Rebirth of a Nation 1880-1980”, K Morgan, Oxford University Press, ISBN 0-19-821-760-9.
- Morgan K., 2001, “The New Territorial Politics: Rivalry and Justice in Post-devolution”, Vol. 35, Iss. 4, pp. 343-348.
- Phelps N., Mackinnon D., Stone I. and Braidford P., 2003, “Embedding the Multinationals? Institutions and the Development of Overseas Manufacturing Affiliates in Wales and North East England”, Regional Studies, Vol. 37, Iss. 1, pp. 27-40.
- OECD, 1996, “The Knowledge-based Economy”, Organisation for Economic Co-operation and Development.
- Phelps N. and Tewdwr-JonesM., 2001, “Globalisation, Regions and the State: Exploring the Limitations of Economic Modernisation through Inward Investment” Urban Studies, Vol. 38, No. 8, pp. 1253-1272.
- Phelps N.A., Lovering J., and Morgan K., 1998, “Tying the Firm to the Region or Tying the Region to the Firm?: Early Observations on the Case of LG in South Wales”, European Urban and Regional Studies, Vol. 5, No. 2, pp. 119-137.
- Porter M.E., 1985, “Competitive Advantage: Creating and Sustaining Superior Performance”, Free Press, ISBN 0-7432-6087-2.
- Porter M. and Stern S., 1999, “The New Challenge to Americas Prosperity: Findings from the Innovation Index”, Council of Competitiveness.
- Porter M.E., 1990, “Competitive Advantage of Nations”, Free Press, ISBN 0-684-84147-9.
- Quah D., 1999, “Growth and Increasingly Weightless Economies, The Economics of the Knowledge Driven Economy” Conference Paper, Department for Trade and Industry, UK Government.
- Rivette G. and Kline D., 2000, “Rembrandts in the attic: unlocking the hidden value of patents”, Harvard, USA: Harvard Business School Press.
- Rodriguez-Clare A., 1996, “Multinationals, Linkages and Economic Development”, The American Economic Review, Vol. 86, No. 4, pp. 852-872.
- Ross D., 2005, “Wales: History of a Nation”, Geddes & Grosset, ISBN 1-84205-018-4.
- Samuelson, 1964, “Econimics”, P.A. Samuelson, 6^{th} Ed., McGraw-Hill.
- Salvador E. and Harding R., 2005,“Innovation Policy at the Regional Level: the Case of Wales”, 5^{th} Triple Helix Conference, Turin, E Salvador and R Harding, Paper ID: W385.
- Shapira P., Youtie J., Yogeesvaran K. and Jaafar Z., 2005, “A125: Knowledge Economy Measurements: Methods, Results and Insights from the Malaysian Knowledge Content Study”, Conference Paper, Triple Helix 5 Conference, Turin.
- Stiglitz J., 1999, “Knowledge in the Modern Economy”, Senior Vice President and Chief Economist, World Bank, Conference Paper, The Economics of the Knowledge Driven Economy. Department of Trade and Industry, UK Government.
- UNIEDO, 2003, “Strategies for Regional Innovation Systems: Learning Transfer and Applications” United Nations Industrial Development Organisation.
- WAG, 2001, “A Winning Wales: The National Economic Development Strategy of the Welsh Assembly Government”, Welsh Assembly Government.
- WAG, 2005, “A Budget for the Future of Wales, The Assembly Government’s Spending Plans 2005-2006 and 2007-2008”, National Assembly for Wales.
- WEFO, 2004, “Single Programming Document including Mid-term Review Changes”, West Wales and Valleys, Objective 1, Welsh European Funding Office, Welsh Assembly Government.
- Work Foundation, 2006, “The Knowledge Economy in Europe: A Report prepared for the 2007 EU Spring Council, The Work Foundation.
- World Bank, 1998, “Knowledge for Development”, World Bank Report, New York, Oxford University Press.
- World Bank, 1999, “Public Policy for Knowledge Economy”, World Bank, 1999.
- www.ktnetworks.co.uk, Accessed 2007.

- www.ktponline.org.uk, Accessed 2007.
- Young S., Hood N. and Peters E., 1994, "Multinational Enterprises and Regional Economic Development", Regional Studies, Vol. 28, No. 7, pp. 657–677.

Chapter 2

Regions and Clusters[1]

2.1 Regions

This thesis sets out to explore the potential impact of harnessing "international collaboration" to the benefit of the participant regions. The emergence of the role of regions within national and international economies has become a field of increasing interest and importance (Karlsson 2007 and Ketels et al. 2008). This chapter explores the concepts of regions and clusters in the context of the facilitating the development of sustainable knowledge driven local economy and in particular the role of government policy in its facilitation.

2.1.1 Knowledge Economy - Global, European and UK Global

As described earlier, the emergence of the knowledge-based economy around the world has been widely acknowledged at an international level, (OECD 1996 and Work Foundation 2006), and also increasingly so at national (DTI 2003 and Shapira et al. 2005) and regional levels. This has led to many countries large and small developing strategies to harness the opportunities of the Knowledge Economy, including nations as diverse as the US, UK (DTI 2004), New Zealand, Malaysia and Scotland (Scot Exec 2001).

Knowledge creation is a key driver of the Knowledge Economy and the United States is the world leader in this regard investing the most into the creation of knowledge; some $285bn annually. This compares with other leading nations as shown in Table 2.1 (OECD 2005).

Country	**R&D Investment**	**% of OECD expenditure**	**% of National GDP**
United States	$285bn	42	2.6
EU	$211bn	31	2.0
Japan	$114bn	17	3.2

Table 2.1: R&D Expenditure by leading nations (OECD 2005).

2.1.1.1 EU and UK

Developing the world's strongest Knowledge-based economy has become a key goal for the European Union as launched at the Lisbon 2000 Council (Lisbon 2000 EU Council Strategy).

"*...to become the most dynamic and competitive knowledge based economy in the world*"

At a European level the disparities in economic performance between regions, even within countries, are highlighted by Figures compiled by the European Commission (EUROSTAT 2004) and shown in Figure 2.1.

[1] This content is available online at <http://cnx.org/content/m43448/1.1/>.

The United Kingdom provides the most striking example of this with Inner London generating GDP per capita at 288% of the EU average while at the other end of UK performance are the Isles of Scilly registering 65% (Wales Objective One region – 73%).

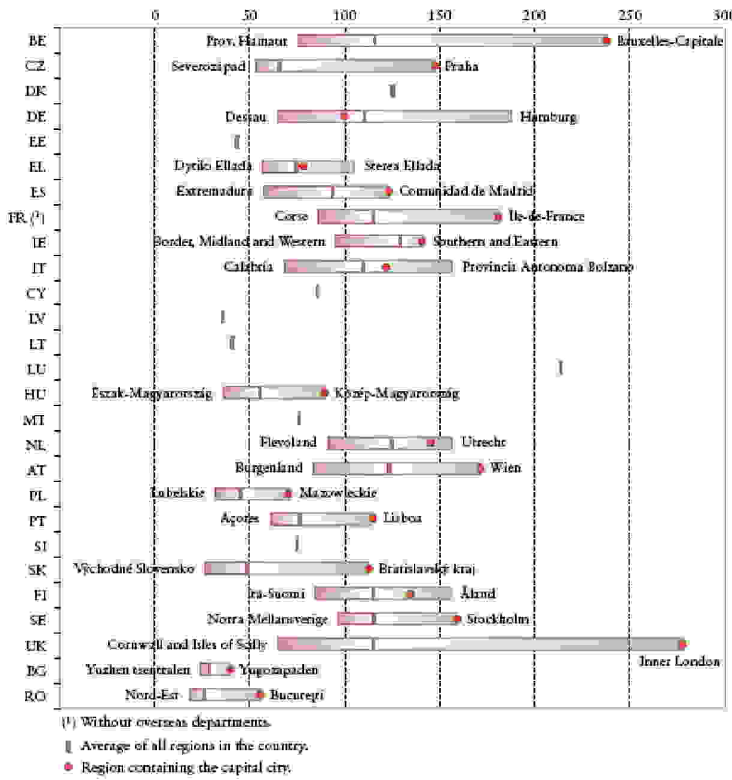


Figure 2.1: GDP per capita 2001, NUTS 2 level in % of EU-25 average (EU-25 = 100).

The leading regions are typically those including the capital city and this performance aligns with the intensity of knowledge-based activity as has been shown in Cooke and Clifton (2005). However, this measure serves to highlight one of the limitations of simple GDP measures. As 'output' location is recorded rather than 'income' region the apparent prosperity of regions can be misleading. For example, relatively few people live in Central London, though a huge amount of GDP is generated. Much of the wealth created in the capital flows out in pay packets to be spent in the commuter-belt. Wales experiences the same phenomenon, with workers flowing into the capital, many from the relatively poor Valleys, to create GDP that registers as an output of Cardiff.

Much of the Community level action focuses on issues such as reform of state aid, removal of obstacles to physical, labour and academic mobility and completion of an agreement in the ongoing World Trade Organisation negotiations. However, as described in Chapter 2, this follows through down to the national and regional levels, including strategy for Structural Funds interventions.

Considering the intentions of the European Union, how does it currently perform in terms of the knowledge-based economy? Statistics compiled by EUROSTAT show that over 40% of EU employment is in knowledge-based industries with about half of this in manufacturing and market services (i.e., not

Health or Education), as shown in Table 2.2.

Sector	**% of total employment**
Tech based manufacturing	**6.9%**
- High-tech manufacturing	1.1%
- Medium tech manufacturing	5.8%
Market Services	**15.3%**
- High tech services	3.5%
- Financial services	3.2%
- Business / Communications	8.6%
Health, Education, Cultural	**19.4%**
Total	**41.5%**

Table 2.2: EU Knowledge Based Employment – 2005, Work Foundation (2006).

The importance of the Knowledge Economy is continually growing in the UK. Current trends would see manufacturing and agriculture account for only 15% of UK output by the end of the decade as the service sector continues to grow (Leadbeater 1999). These trends are reflected in the growth of employment in knowledge-based industries since the mid-80s shown in Figure 2.2.

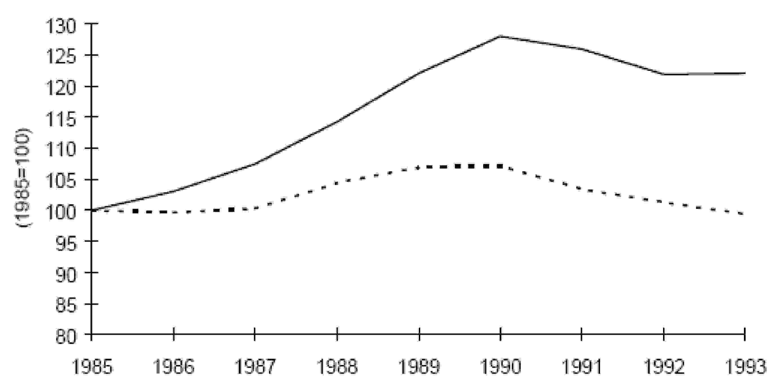


Figure 2.2: UK Employment in knowledge based (solid line) and other (dashed line) industries, from Coates and Warwick (1999).

However, this overall growth of the Knowledge Economy sits above a wide variance in performance amongst UK regions that is acknowledged by both Government (Edmonds 2000 and DTI 2001) and academic observers (Hughes 1999, Cooke 2002, Clement 2004 and K Group 2006).

2.1.2 Knowledge Economy - Welsh and Regional Context

Over recent years there has been a restructuring of the Welsh economy in the face of global challenges that have squeezed traditional sectors, in particular manufacturing. In this regard, the Welsh Assembly

Government is trying to support the development of the knowledge-based economy. This ambition, reflecting the pillars of the knowledge economy is captured in the Wales Spatial Plan (WAG 2004c):

"*We need an innovative, high value economy for Wales which utilises and develops the skills and knowledge of our people: an economy which both creates wealth and allows that prosperity to be spread throughout Wales: an economy which adds to the quality of people's lives as well as their living and working environments.*"

Great differences in prosperity can be noted within the regions of Wales (Morgan 2001). This is demonstrated by Figure 2.3 presenting the disparity between East Wales, and West Wales and the Valleys (K GROUP 2006).

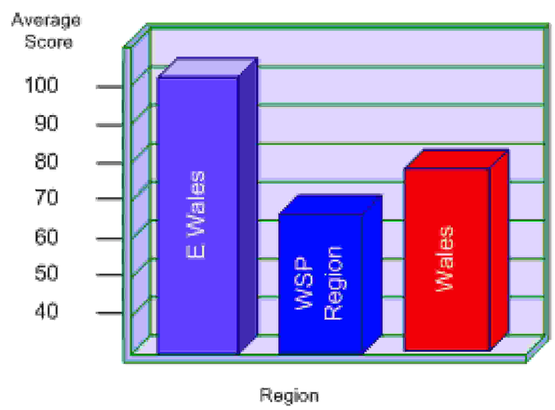


Figure 2.3: GVA by South Wales region compared to UK average – 2003 from Knowledge Economy Theme: Interim Report (Stats Wales Welsh Assembly Government 2006).

Wales Spatial Plan, Swansea Bay, Waterfront and Western Valleys Using a definition developed from the OECD sectoral description of the knowledge economy (OECD 1996), De Laurentis and Cooke (2003) present the regions of West Wales and the Valleys against other key European regions (in Table 2.3).

Region	% knowledge economy	Ranking
Stockholm, Sweden	58.65	1
London, UK	57.73	2
Helsinki, Finland	51.50	11
Paris, France	50.17	16
South West Scotland, UK	47.59	24
East Scotland, UK	47.05	30
East Wales, UK	43.91	53
West Wales and Valleys, UK	42.87	60
Rhone-Alpes, France	42.22	67
South and East Ireland	40.18	86
Gelderland, the Netherlands	39.99	87
North East Scotland, UK	38.09	101
Northern Ireland, UK	37.31	107
Sachsen, Germany	35.97	119
Highlands and Islands, UK	34.45	132
Upper Austria	34.28	133
Athens, Greece	33.79	135
Calabria, Italy	31.29	151
Navarre, Spain	32.06	145
Aegean Islands, Greece	12.70	188

Table 2.3: Selected regions from the Knowledge Economy Index (1998) (De Laurentis and Cooke 2003).

This suggests that both 'East Wales' and the 'West Wales and Valleys' regions 'qualify' as regions with a knowledge-based economy, meaning that there is an existing knowledge-economy to be supported and developed.

'West Wales and Valleys' includes the Wales Spatial Plan region of Swansea Bay, Waterfront and Western Valleys, which is developing its own Knowledge Economy strategy as part of the Spatial Planning process. The neighbouring region of 'East Wales' is also developing a strategy for development of the Knowledge Economy using the services of an external commercial consultancy (Local Futures 2006).

The research and strategy development of the South West Wales effort is being driven by the Knowledge Economy Research Group at Swansea University. This work has focused on identifying regional challenges, relating to human capital, innovation and infrastructure, and developing recommendations and actions through use of regional and international experts (K-Group 2006 and Davies et al. 2007).

NOTE: The identification of regional challenges in this process forms part of this study of Technium.

This approach to developing 'regional' knowledge economy strategies has been adopted in the United States, Europe and the UK (Boddy 2005).

2.2 Clusters

Economic development based on sole, albeit sometimes large, investments are not a recipe for sustainable knowledge based economic development. To ensure enterprise becomes embedded and sustained within the region it must form links and dependencies upon and amongst neighbouring firms.

All firms in a region have a certain level of interdependence, in what are ultimately aggregated to represent regional, national and international economies. However, where geographically concentrated groups of interrelated businesses and other organisations participating in a certain field exist, they are regarded as a cluster (EU 2003).

2.2.1 Knowledge-Based Clusters

While the term 'cluster' has been increasingly used over recent years, the concept has been apparent for centuries and acknowledged for some time, though perhaps subject to different terminology. Rocha (2004) for example charts how academics have studied the phenomenon since the 'Industrial Districts' described by Marshall in the 1890s, all the way through to Porter (1990) at the end of the last millennium. Rocha's work cites early examples of silk traders in China, along with the coming together of suppliers and manufacturers during the industrial revolution, together with their contemporary equivalents, such as the software companies of India or the call centres of Sydney.

These groupings of companies suggest that much of the competitive advantage enjoyed by their members lies outside the firm (Porter 2000), such that the '*the whole is greater than the sum of the parts*'. Porter describes how 'clustering' can help the productivity of both firms and regions in a number of ways:

- Increasing the productivity of constituent firms or industries.
- Increasing the capacity of cluster participants for innovation and productivity growth.
- Stimulating new business formation that supports innovation and expands the cluster.

Elsewhere Porter and Stern (1999) provide a formal definition of the concept (which is also used by the DTI (2001);

'*Clusters are geographically proximate groups of interconnected companies, industries, and associated institutions in a particular field, linked by commonalities and complementarities.*

As the definition suggests a cluster does not include solely competing firms, but is a much broader phenomenon, which "*extend(s)downstream to channels or customers and laterally to manufacturers of complementary product* (and services) *or companies related by skills, technologies or common inputs*" (Porter 2000). This encompasses the roles of other stakeholders within clusters including universities, trade associations and government.

Porter and Stern (1998) also point out that not all actors within a cluster are necessarily aligned with a particular industry, though rather they come together to support each other's innovative activity. However, when considering a cluster it should be done with regard to the sector under investigation as aggregation to the level of industry or broad groupings such as 'manufacturing' or 'high-technology' lose the meaning of the connections and interrelationships.

Clusters exist in all manner of industries, though are of particular interest in knowledge-driven sectors because of the importance of localised skills and tacit knowledge spillovers. Clusters differ from networks in that they do not rely on any formal or informal organisation of actors such as chambers of commerce, industrial fora etc. (EU 2003).Furthermore, clusters are not necessarily dominated by large companies: an EC study (EU 2003) shows that they typically involve a mix of small and large firms, as shown in Figure 2.4.

NOTE: The role of these different sized actors is specifically addressed as part of this study.

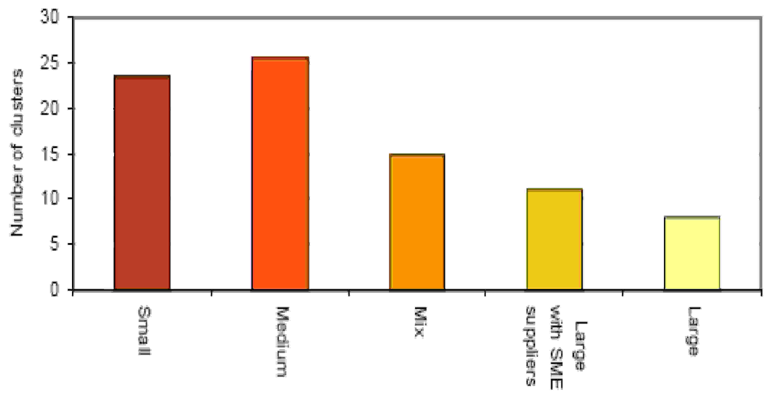


Figure 2.4: Dominating firm size of clusters included in European Commission study (EU 2003).

Clusters historically often developed around a natural resource, such as mineral deposits or a natural harbour, or a large market, such as towns or cities (Figure 2.5). This last influence is still reflected in the European Commission study of European clusters, which shows most exist in urban settings (EU 2003);

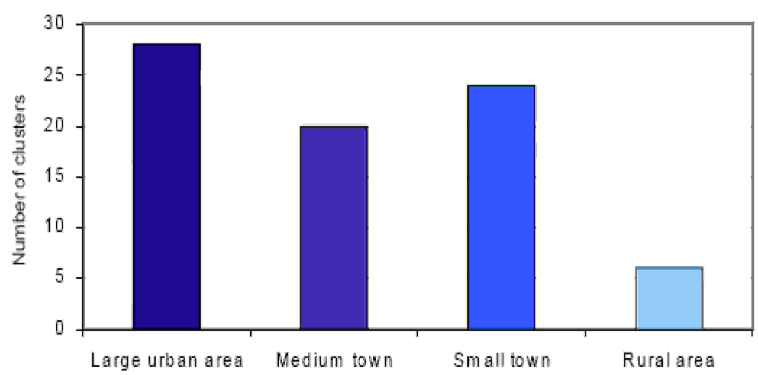


Figure 2.5: Geographic location of clusters included in European Commission study (EU 2003).

Many clusters have developed around the availability of knowledge in the region and this is evermore important in the modern Knowledge Economy sectors. This leads to co-location of firms, the spin-off and start-up of new related firms and the development of other businesses to support their activities, and the growth of a cluster. The nature of such firms is not just competitive and often occurs with overlap between sectors (e.g., venture capitalists, patent attorneys, recruitment agencies, accountancy firms etc.). The interrelationships that give rise to this are presented in Porter's 'Diamond' Model shown in Figure 2.6.

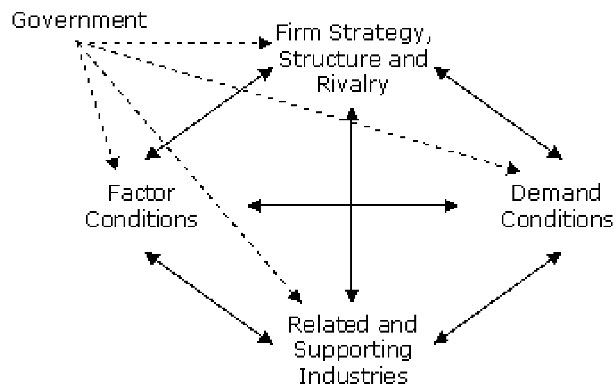


Figure 2.6: Porter's 'Diamond' Model for Competitive Advantage of Nations (Porter 1990).

Clusters of businesses related to a specific sector not only draw upon the common innovation infrastructure (or *innovation system* as discussed later), but also add to it, creating a self-reinforcing virtuous circle (Porter and Stern 1999). This effect is also demonstrated by the work of Varga (2000), who notes, however, that a critical mass of agglomeration within the region is needed for this to occur.

The study conducted by the European Commission also investigated the interaction and types of networking between businesses in the clusters examined. As shown in Figure 2.7 most of the clusters investigated had extensive informal networking and collaborative R&D activity;

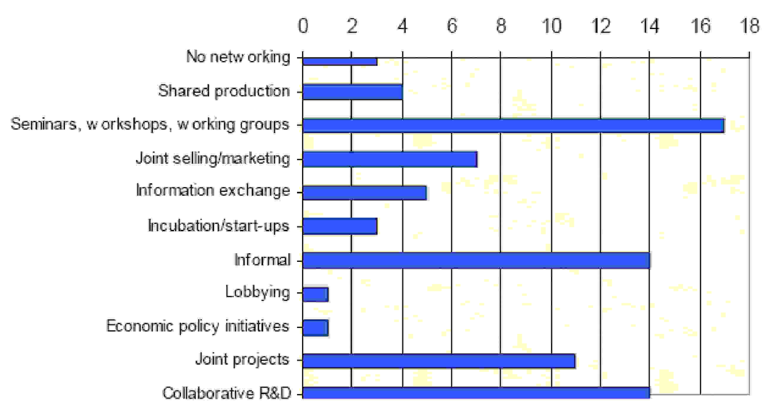


Figure 2.7: Networking between firms in clusters: European Commission study (EU 2003).

The virtuous circle can lead to growth that is then compounded by the establishment of reputation, further attracting skills, investment and opportunities to the region. Examples of this include 'Silicon Valley' (Bresnehan et al. 2001, 2007) and 'Route 128' (Dorfman 1983), along with Silicon Glen (Turok 1993) and Cambridge Biotechnology clusters in the UK (Keeble and Tomlinson 1999 and Todtling and Trippl 2005).

As described earlier the effects of clusters do not solely relate to existing firms therein, but also to the formation of new enterprise. The availability of new opportunities within a cluster helps promote entrepreneurship and the presence of support organisations, potential customers and suppliers' acts to facilitate innovation and entrepreneurship (Rocha 2004). The presence of local networks can also help decrease cost and uncertainty in the development of start-ups, aided by flow of knowledge (Almeida and Kogut 1997).

2.2.2 Knowledge and Innovation

Clusters also represent a foundation for the formation of formal and informal knowledge distribution networks that support innovation (OECD 1996), which ties in with the concept of knowledge spillovers discussed earlier. The information and knowledge exchange within clusters is the key driver in their development in what Keeble and Wilkinson term an '*innovative milieu*' (Keeble and Tomlinson 1999) as part of '*regional collective learning*'. This concept describes the development of a collective regional knowledge base caused through interactions such as networking, research collaborations and the movement of personnel between companies and other organisations.

2.2.3 Proximity

Proximity is a key component in successful clusters (OECD 1996 and Porter 2000), particularly in regard to facilitating knowledge-spillovers (EU 2003), described as:

"*The proximity of customers, competitors, suppliers, universities and research institutions provided impetus (for) the creation and exchange of information and increases opportunities for innovation.*"

Maskell and Malmberg (1999) outline how the competitiveness of a firm, particularly in the long-term, depends upon its ability to continuously upgrade its knowledge base. To achieve this it must find knowledge sources that provide competitive advantage. As tacit knowledge is the least transferable it requires that businesses place themselves close to its source. Additionally, cost is a factor in developing and maintaining a company's knowledge base, making proximity to knowledge sources a cost-effective way of closer and more frequent personal contacts.

While proximity to sources of knowledge and other linkages are important elements of clusters, it must not be forgotten that high-technology companies generally exist in national and international networks, serving global markets (Keeble and Tomlinson 1999; Muller, 2007).

2.2.4 UK and Wales

On a global scale the DTI report 'UK Competitiveness: Moving to the Next Stage', (Porter and Ketels 2003), presents the UK as a whole as figuring in a number of significant clusters including services, defence, telecommunications, health care, entertainment. Further sectors such as biotechnology and motor sport are also noted to be of particular significance.

Wales as recorded in documents such as the Wales Spatial Plan already acknowledge a number of sector clusters including electronics, biotechnology, automotive and aerospace. These have been identified in the DTI study of UK clusters (DTI 2001). Each of these represents a significant employment and numbers of businesses (Table 2.4).

Cluster	**Employment**
Electronics	22,000
Automotive	12,000
Aerospace	5,650
Biotechnology	2,147

Table 2.4: Employment in selected Welsh clusters (DTI 2001).

While not all of the employment may refer to higher skilled employment or 'knowledge workers' the sectors involved fall within sectoral definitions of the knowledge economy (OECD 1996) and present the importance of the knowledge economy employment within the region.

An observation in the DTI assessment of clusters (DTI 2001) in Wales; is that while there exists significant specialisation with a number of clusters, they are generally and often weakly embedded and dependent upon foreign owners and markets or industries across the border in England. This reflects the concerns regarding the 'embeddedness' of businesses in the region and the focus given to developing indigenous enterprise within sectors and clusters (Cooke and Clifton 2005).

2.3 Government Policy

2.3.1 Clusters on Demand?

Clusters are generally built up spontaneously (EU 2003). However, the question remains as to whether it is possible to develop them in cities and regions and how it could be achieved. The conclusion put forward by governmental organisations (EU 2003), academics (Cooke 2002, Porter 2000) and other bodies is that it is possible, subject to the availability of key components including leadership and vision (Porter 1990, Cooke 2002).

This is in keeping with the model proposed by Porter (1990, 2000), where government can affect aspects including factor conditions, firm strategy, and rivalry and demand conditions. Examples of each of these include provision of training or new knowledge (e.g., funding training schemes or funding academic research), competition policy (regulation/deregulation of industries) and changing consumer behaviour (e.g., environmental legislation), as shown in Figure 2.8 (Porter 2000). It is also suggested that because of the importance of proximity regional administrations are best placed to assist cluster development (EU 2003).

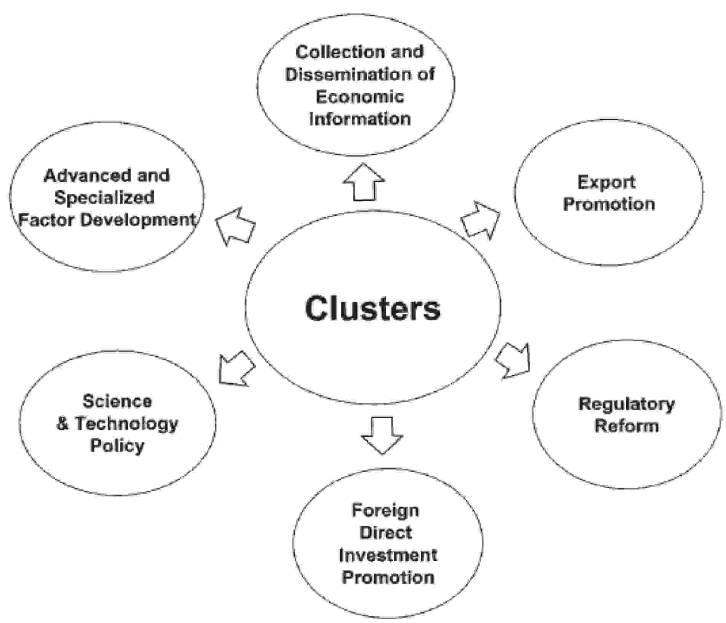


Figure 2.8: Aspects of Economic Policy in Cluster Development (Porter 2000).

2.3.2 European and United Kingdom Policy

2.3.2.1 Europe: the Lisbon Agenda

The need to invest in the Knowledge Economy is at the heart of the European Union's Lisbon Strategy. Investment in human capital and development of innovation is recognised as the key mechanism for realising the strategic objectives. The European Commission's accompanying 'Community Lisbon Programme' proposes development of policy measures under the themes of (EU 2005):

- Knowledge and innovation for growth
- Making Europe a more attractive place to invest and work
- Creating more and better jobs

Recognising R&D as a key driver for innovation, the European Union has set the objective of raising expenditure on R&D to 3% of GDP by 2010. If left to follow current trends by the end of the decade it would remain at 2.2% (EU 2005), just below the OECD average of 2.3% (OECD 1996).

2.3.2.2 United Kingdom: Strengthening Innovation

The UK Government has put much emphasis on the promotion of Innovation to reduce the productivity gap with our major competitors. This was the focus of the Department of Trade and Industry '*Innovation Review*' undertaken in 2003 (DTI 2003).

One of the most pivotal pieces of work on University Collaboration was the Lambert Review of Business – University Collaboration by Richard Lambert the former Editor of the-Financial Times from August 2002 Lambert spent a semester at the Kennedy School of Government at Harvard University. He was subsequently asked to write an independent review of Business-University for the then known Department of Trade and Industry.

It is reported in the Lambert Review of Business University Collaboration, that the exploitation of university IP played a vital role in improving UK's innovation.

The number of patents issued to business and universities has increased rapidly in the US, EU and Japan since the mid 1980s. The highest levels are found in the most innovative countries such as the US, Sweden and Finland. In many industry sectors, businesses will not invest in research and development (R&D) to develop early stage technologies without a patent to guarantee them exclusive rights to commercialise their work. (DTI 2003)

Patent application numbers in the UK are low and have been falling relative to the US, France and Germany, mainly because of its low investment in R&D. The UK's investment in R&D is heavily concentrated in the pharmaceutical industry, which has a high propensity to patent. So its low level of patent output is especially worrying. The UK has a strong science base, which is highly productive in creating "pure" research outputs such as publications and citations. There is significant potential to transfer this knowledge to industry through IP. (DTI 2003)

Universities account for only a small share of the UK's patents each year. The highest proportion is in Scotland where, partly due to low industry investment in R&D, universities file around 10 per cent of patent applications. This is more than double the proportion across the UK. (DTI 2003)

It has been noted in the Lambert review that there is a change in the way that business and universities are interacting and that there is optimism in the prospect of creating innovation from these interactions.

Historically, US universities were Land Grant universities or colleges, which are US institutions, which have been designated by a Congress to receive the benefits of the Morrill Acts of 1862 and 1890. These acts funded educational institutions by granting federally controlled land to the states. The mission of these institutions, as set forth in the 1862 Act, is to teach agriculture, military tactics, and the mechanic arts, not to the exclusion of classical studies, so that members of the working classes might obtain a practical college education (www.wordiq.com 2007).

The US also has *private schools* that are schools not administered by local or national government, and retain their right to select their student body and are funded in whole or in part by charging their students tuition rather than by public funds many of which receive endowments from businesses. Strengthening universities links to business and industry. Also in the US, the universities are governed by boards, several of the people on these boards are also lead business people in the region and in their fields of expertise, which help guide the university into what areas are in demand from the market, so that the universities can better set their curricula to match the market needs. The US Universities also have a very strong alumni base that contributes endowments to the university strengthening its funding resource.

These links have perpetuated a culture that is underlying in the US universities and academics of collaboration between them and business. It should also be stated that US universities allow for their academics during non-contract hours to work with business in their field of expertise. Thus creating a deeper interaction on a personal level, and allowing transfer of knowledge from business back into the university. These links also aid in the interaction of marketing of university IP, a majority of licensing in US universities comes from the network that the academic themselves has created through their interaction with business.

While in the UK the view of business is quite different, the view of business was not held in regard by academics and the contracts that they are employed through do not allow for the interaction as it does for their US counterparts. Yet as Richard Lambert stated in his review," there has been a marked culture change in the UK's universities over the past decade; most universities are actively seeking to play a broader role in the regional and national economy" (HSMO 2003).

"Two thirds of growth comes from innovation" *Chancellor Exchequer, June 2002*

2.3.3 Welsh Assembly Government Policy

2.3.3.1 Economic Development

2.3.3.1.1 A Winning Wales and Wales: A Vibrant Economy

The Welsh Assembly Government outlines its overarching strategic agenda in 'Wales: A Better Country' (WAG 2003b) with policy areas including:

- Helping more people into jobs.
- Improving health.
- Developing strong and safe communities.
- Creating better jobs and skills.

This agenda ties together the policy areas of health, education, transport, local government and economic development.

The economic development agenda is captured in 'A Winning Wales', which was first delivered in 2001 (WAG 2001), updated in 2003 (WAG 2003a). It is supported by a host of interrelated strategies and accompanying action plans for aspects of economic development including innovation (WAG 2003), entrepreneurship, skills, (WAG 2005c), the environment and specific industry sectors (Figure 2.9). The Strategy also aims to outline how Structural Funds, including Objective 1 funding are to be used in economic development for West Wales and the Valleys.

Figure 2.9: A Winning Wales and associated Action Plans, from Wales for Innovation (from WAG 2003).

The strategy is built around a vision that clearly reflects the ambition to develop a strong and vibrant Knowledge-Based economy in Wales (WAG 2001):

"To achieve a prosperous Welsh economy that is dynamic, inclusive and sustainable, based on successful, innovative businesses with highly skilled, well-motivated people"

To realise this vision the strategy (WAG 2001) outlines the key targets, again reflecting the agenda of a knowledge-based economy:

- Raising total employment by 135,000.
- Improving enterprise and innovation.
- Raising not just skill levels but learning performance at every level.
- Ensuring Wales uses world-class electronic communications to their full potential.

In order to achieve these, the Strategy outlines key requirements including:

- Improving rates of new business formation.
- Addressing under representation of rapidly growing sectors such as financial and business services.
- Building upon strengths in key sectors including aerospace, opto-electronics and automotive.

In 2003 WAG published an Annual Report (WAG 2003a) on the progress towards fulfilling the vision of 'A Winning Wales' (WAG 2001), prior to delivering an updated version of the strategy in 2004 (WAG). This reinforced the WAG objective of bringing the prosperity of Wales to 90% of the UK level within a decade and in line with that of the UK within a generation.

'A Winning Wales' has also been recently supplemented by Wales: A Vibrant Economy' (WAG 2005b) which presents WAG's 'Strategic Framework for Economic Development'. This further reinforces the agenda of the Knowledge Economy, with specific regard to the West Wales and the Valleys region, with its focus on:

- Promoting the knowledge economy, by fostering research, technology and innovation, building a stronger entrepreneurial environment, supporting the development of clusters/centres of excellence in key sectors and improving access to business finance.
- Improving skills levels, both as a means of tackling innovation and providing the skills for higher value-added employment. This will include supplying young people and new entrants to the labour market with the skills needed to in turn develop the skills and qualifications needed for more senior jobs in the economy.

2.3.3.1.2 Wales for Innovation - Innovation Action Plan

The Innovation Action Plan aims to set out how innovation can be fostered in Wales to help deliver the Knowledge Economy aspired to in 'A Winning Wales' (WAG 2001). Actions proposed by the plan consist of five groupings namely;

- Communicating what can be achieved through more innovation.
- Developing more high growth potential businesses.
- Better equipping people to innovate.
- Simpler, more accessible, business innovation support.
- Maximising the economic development impact of our universities and colleges.

Core to the Plan is the further development of the 'Technium' initiative where the plans for this pan-Wales network were described with a pledge to invest "*up to £150m...rolling out across Wales* ... (to) *act as innovation focal points within their regions*".

The plan also describes how innovation and skills are to be supported through programmes such as the Technology Exploitation Programme (TEP) and SMARTCymru.

> NOTE: SMARTCymru is a WAG initiative created to support the development of new products and processes.

It also describes how this would be achieved in conjunction with other WAG bodies including the Higher Education Funding Council for Wales (HEFCW) and Education and Learning Wales (ELWa).

2.3.3.1.3 A Science Policy for Wales

The Science Policy for Wales (WAG 2006) underlines the importance given by WAG to the Knowledge Economy in the future of the country, citing the vital role of science, engineering and technology. Three key priority areas were identified for focus of support and resources of:

- Health/life sciences.
- The low carbon economy.
- Sustainable economic and social regeneration.

The policy recognises the potential for enterprise developing from scientific endeavour in Wales, though recognises fundamental challenges including the relatively low intensity of scientific research within the country and the low level of Research Funding Council resources won by Welsh Higher Education Institutes (HEIs). This is reflected in much of the evidence supplied to the review that preceded the policy (NAW 2006). However, the Policy does also acknowledge that Wales is a small nation that could not and should not aspire to the breadth and depth of science activity in which much larger territories have the resources to engage. It is though recognised that despite this, scientists and engineers working in Wales will be working in their specific fields with science of the highest quality on national and international stages.

2.3.3.1.4 A Science Advisor for Wales

In 2008, the First Minister for Wales Rhodri Morgan commissioned a study on the appointment of a Science Advisor for Wales. The First Minister in Wales also has the role of Science Minister.

It was seen that the promotion of science in Wales is fundamental to developing the country as a world-respected knowledge-led economy by building up the science base, and the ability to quickly commercialise on the science base that is in place. Also, the promotion of STEM subjects in the schools and colleges, to ensure that there is a throughput of students that are choosing to study science subjects in schools and universities, and pursuing science careers thereafter.

This appointment was built on the already high standard of science and research in Wales in areas such as medical technology held in high regards in Europe, and a track record of innovations, including automated DNA testing, dispersive X-ray spectrometry and 3D intelligent sensor technology In addition to this is the people that have been conducting pioneering work, such as Professor Sir Martin Evans, who was awarded the Nobel Prize for Medicine for his research into stem cell technology.

This was compounded by the investment in leading-edge research and development centres, including the £16.5 million PETIC in Cardiff, the £22 million NanoHealth Centre and the £50m Institute of Life Sciences that houses the Boots Innovation Centre at Swansea University

In 2009 Professor John Harries was appointed to the post of Chief Scientific Advisor for Wales.

2.3.3.1.5 The Wales Spatial Plan

Spatial Planning refers to the methods used by the public sector to plan activities within a space and has been used extensively in the European Union for planning within regions since 1984 (ESPON 2007). '*People, Places, Futures: The Wales Spatial Plan*' (WAG 2004c) represents WAG's vision of future development across Wales. The vision encompasses all aspects of future development including transport, health, education and economic development. The planning process examines Wales in the context of six distinct regions as shown in Figure 2.10.

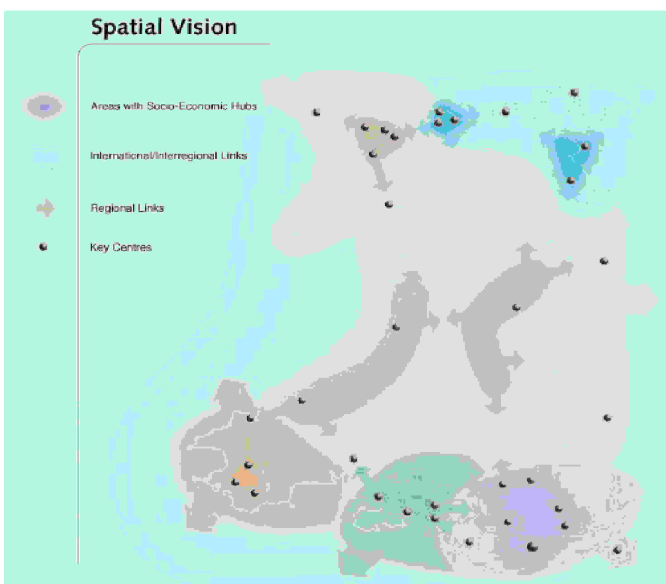


Figure 2.10: Regions of Wales according to the Wales Spatial Plan Vision (WAG 2004).

The economic vision for Wales described in the Wales Spatial Plan highlights the importance of the Knowledge Economy with focus upon the provision of opportunities that harness the skills and knowledge of the people (Wales Spatial Plan, 2004):

"We need an innovative, high value economy for Wales which utilises and develops the skills and knowledge of our people: an economy which both creates wealth and allows that prosperity to be spread throughout Wales: an economy which adds to the quality of people's lives as well as their living and working environments."

To achieve this vision, the plan lays out the need for engagement between public, business and other partners. It presents a range of actions for the region and Wales as a whole including taking forward of strategies such as the Skills and Employment Action Plan and Creative Industries Strategy along with investment in knowledge transfer initiatives such as Technium.

As part of this Spatial Planning Exercise overseen by the Welsh Assembly Government each region must select and develop themes for its future development.

In line with the Lisbon Agenda of the European Union, the region of Swansea Bay, Waterfront and Western Valleys is focusing on building upon its Knowledge Economy foundations to provide a prosperous and sustainable future for its communities. This embodies in the vision for the region described in the Wales Spatial Plan. The charge to develop the Knowledge Economy described in the Plan makes direct reference to the roles of both Swansea University and Technium:

- Retaining young people and attract well-qualified people from outside the area to provide a stimulus for improved economic performance.
- The University, FE Colleges and Technia should embed the Knowledge Economy within the area.

2.4 The 'Objective One' Era – 1999-2006

2.4.1 The Continuing Challenge

Wales entered the new millennium equipped with a new Assembly to fulfil its ambitions, but much like its devolved neighbours of Northern Ireland and Scotland was about to attempt this in the face of economic decline, poor conditions for entrepreneurship and the disinvestment caused by globalisation (Cooke and Clifton 2005).

The scale of this challenge is highlighted by the fact that Wales, with 5 percent of the UK population, only contributes 4.5 percent of total economically active persons and 3.9 percent of GDP in the UK. The Welsh Assembly Government has set itself the target of closing the gap with the rest of the UK economy by raising per capita GDP to 90% of UK levels within a generation (WAG 2001). This target is an enormous aspiration that would require national economic performance to be raised to a level not seen in a century. This is shown in Figure 2.11 presented Crafts recently to a conference in Cardiff.

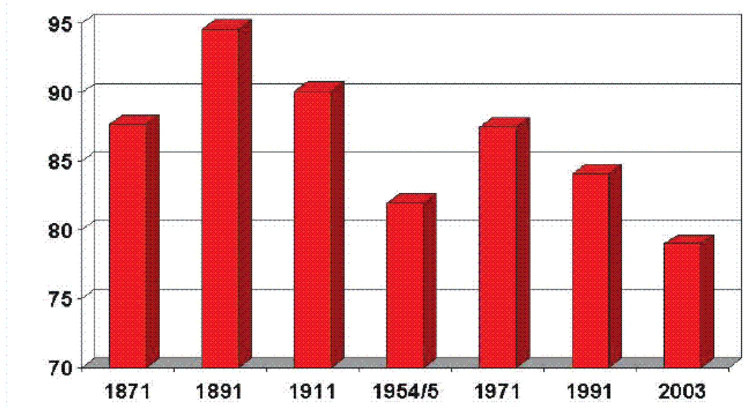


Figure 2.11: GDP/Person in Wales as % of Great Britain GDP, selected years (Crafts 2005).

The pressure on manufacturing and basic industries continued with the closure or relocation out of Wales of many inward investors and the termination of steel production at Llanwern. In the period between 1998 and 2003 Wales as a whole lost 57,000 manufacturing jobs. This has again raised the question of how 'embedded' multinationals are (or were) in the Welsh economy, with the suggestion that the presence of functions beyond assembly such as research and development would improve embeddedness (Phelps et al. 2003).

In addition to the continued pressure on manufacturing, the supply of FDI opportunities available was starting to fall during the end of the 1990s due to a slow-down in the global economy (Young et al. 1994) and the emergence of new attractions for FDI, most notably in China and India (Chen 1996). Despite the emergence of these low cost competitors it is observed that wage rate versus skills level remains an issue, working in favour of the relatively better skilled workforces of developed nations (Wei et al. 1999). Furthermore another factor which also hampers future growth for the region is an aging population, which though not a unique regional challenge, does feature worse than for the country as a whole (EU 2005).

These challenges meant the problems of the new millennium would not be fixed by the same solution of solely attracting foreign investment by cheap labour and access to markets used at the end of the last century.

2.4.1.1 Rationale

At the end of the twentieth Century much of the Welsh economy was significantly trailing behind, such that GDP was only 73% of the European average (WEFO 2004) meaning that parts Wales qualified for 'Objective One' assistance (Figure 2.12). This level of assistance represented the highest level of aid provided by the EU and was targeted at regions with GDP below 75% of the EU average (Figure 2.13).

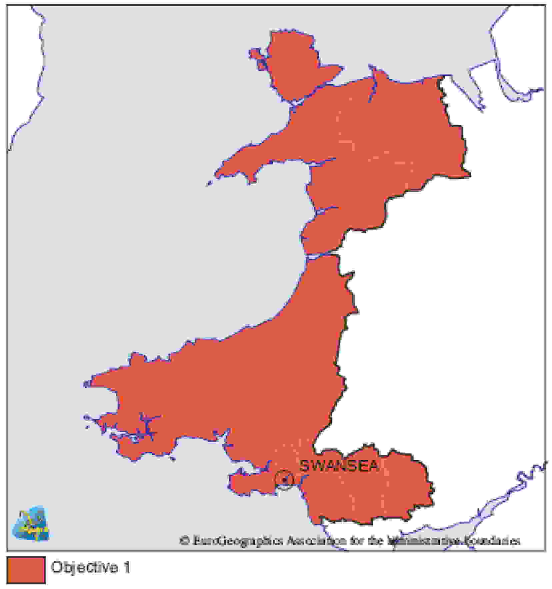


Figure 2.12: Objective One Areas in Wales (EU 2004).

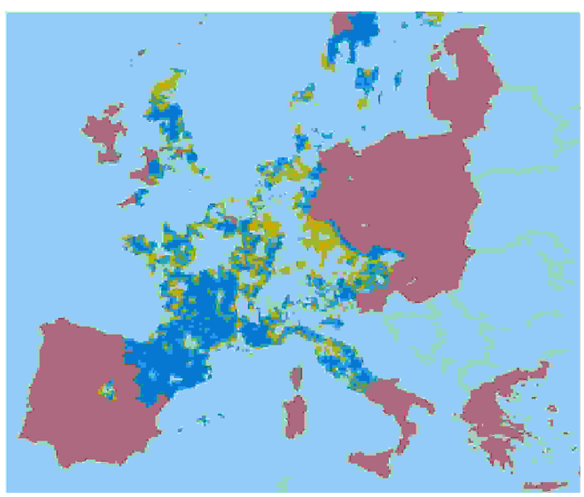


Figure 2.13: Objective One Areas in the EU (EU 2004a).

The fact that not all of Wales qualifies for such assistance reflects the variation in prosperity across the country. This is highlighted by the fact that disposable incomes in the Vale of Glamorgan are as high as those in the more affluent parts of Bath and Bristol across the bridge, while the mining communities of the Valleys just a few miles from the other side of the M4 remain as impoverished as the most deprived parts of Inner London (Lovering 1999).

The reasons for this poor relative performance were structural dependence upon low value added activities, low productivity in certain sectors and high levels of unemployment within an overall low level of economic participation. Objective One funding came about thanks to the creation of a new statistical region 'West Wales and the Valleys' that presented and highlighted the economic woes of this part of Wales (Cameron et al. 2002). The value of this assistance totalled some £1.2bn in grant aid – to be match funded from other sources.

While much effort has been made to address the economic weaknesses of much of Wales, including through use of European Objective 1 funding, the performance of parts of the Welsh economy remains significantly behind that of Europe as a whole. This is highlighted by the fact that much of Wales still qualifies for the highest level of assistance from the EU, now termed 'Convergence Funding'.

As previously described in this section WAG outlines its strategy for economic development in *'Wales: A Vibrant Economy'* (WAG 2005b). This strategy builds upon the vision of integrating national and regional policy with the vision of the European Union and the 'Lisbon Agenda' of social and economic regeneration. To achieve this Wales has the support of Convergence Funding worth £1.3bn for the West Wales and Valleys region while other areas of Wales qualify for support worth around £120m from the 'Competitiveness Fund', which was previously called Objectives 2 and 3. Most of the funding available (65%) is set for '*Lisbon related investments*' (WEFO 2006) and has been earmarked in line with 9 European Regional Development Fund (ERDF) and European Social Fund (ESF) priorities (WEFO 2006);

ERDF

- Building the knowledge based economy.
- Improving business competitiveness.
- Developing strategic infrastructure.
- Creating an attractive business environment.
- Building sustainable communities.

ESF

- Supplying young people with the skills needed for employment
- Increasing employment and tackling economic inactivity
- Improving skill levels and improving the adaptability of the workforce
- Making the connections – modernising our public services

While much effort has been made to address the economic weaknesses of much of Wales, including through use of European Objective 1 funding, the performance of parts of the Welsh economy remains significantly behind that of Europe as a whole. This is highlighted by the fact that much of Wales still qualifies for the highest level of assistance from the EU, now termed 'Convergence Funding'.

With the close of "Objective 1" funding in 2006, the West and the Valleys region of Wales were awarded the highest level of support from the European Union for the Structural Funds programming round 2007–2013 (Convergence).

Convergence, the successor to the Objective 1 programme 2000-2006, covers 15 local authority areas in the West Wales and the Valleys region (Figure 2.14).

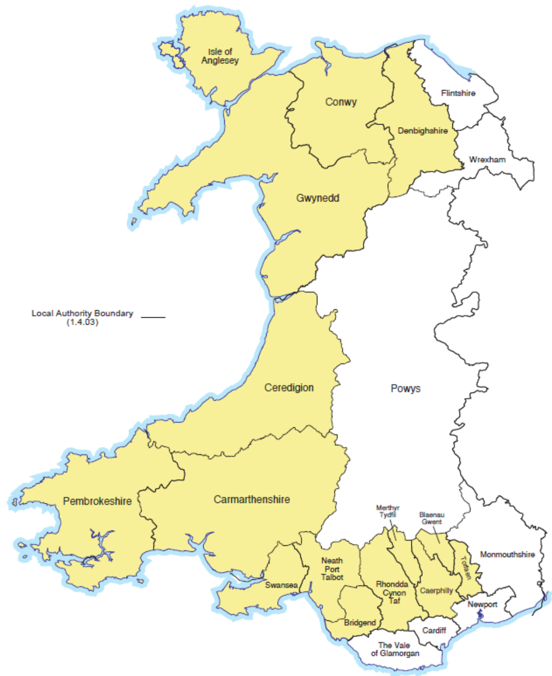


Figure 2.14: Convergence Region of Wales.

The Convergence programmes for West Wales and the Valleys comprises of funding from two separate European Structural Funds: the European Regional Development Fund (ERDF) and the European Social Fund (ESF). Around £1 billion of ERDF funds has been allocated to help progress the region's transformation into a sustainable and competitive economy by investing in the knowledge economy and helping new and existing businesses to grow. It is focused on regenerating Wales' most deprived communities, tackling climate change and improving transport. Over £690 million from the ESF has been slotted to be used to tackle economic inactivity, increase skills and employment. The aim is that together, with match funding, Convergence will drive a total investment of £3.5 billion in West Wales and the Valleys (WEFO 2009).

2.5 The Emerging BRICs

Europe, Japan and the USA have dominated the 'knowledge economy landscape' for a generation. However the world is changing and economies known as the BRICs (Brazil, Russia, India and China) are becoming significant players. Other countries are following close on their coat tails for example Mexico and Vietnam, which is now the fastest growing economy in the world (Milken Conference 2010). This is not to mention established actors in the knowledge economy drama such as Singapore that has made a conscious effort to identify the key sectors and invest to attract the best. The Biopolis project in Singapore is an example of a sovereign state deliberately and strategically seeking to build a cluster using the immense resource at its disposal to seek sustainable competitive advantage.

NOTE: Located in Singapore in close proximity to the National University of, National University Hospital and the Singapore Science Parks, Biopolis aims to be a world-class biomedical science R&D hub in Asia. Biopolis is dedicated to biomedical R&D activities fostering a collaborative culture among the private and public research communities. (http://www.one-north.sg/hubs_biopolis.aspx[2]).

Taking China as an example, for a generation or more China has sent its best young talent overseas to receive the best education in the universities of the UK, Europe, the US, Canada and Australia. The Chinese government has focussed this strategy largely on the STEM subjects and a large percentage of UK STEM postgraduates are students form China and India. The time has now come for China to reverse this trend, it is now has the economic wealth to create opportunity for this knowledge based human capital back home in China. Couple with this the fact that China is no longer seen, by global corporate executives, as an IP risk, indeed the opposite. Chris Viehbacher CEO of the pharmaceutical giant Sonofi-Aventis recently said that *'I no longer worry about IP; I will take my research to the region which offers me the best talent and best service. China now plays by the rules'* (Milken Global Conference 2010).

2.6 The Financial Crisis of 2008-2010

The issues of the participation of emerging nations in the global knowledge economy are made the more real and pertinent by the recent global financial crisis. The 2008-2010 crisis is different form others in recent history, this time it is emerging economies that leading the world out of recession. China has led the way followed by others of the 'BRIC' category. The US' emergence from recession followed some two quarters later and Europe lagged significantly further behind. The crisis in Greece has made it harder for Europe to regain economic momentum and as of Q2 2010 fears remain for the Spanish, Irish, Portuguese and even British economies. At this critical time therefore China and others BRICs are able to invest in the emerging knowledge economies and in particular in the human capital. These nations are climbing rapidly up the league tables. Their scientific citations are improving and the rate of generation of new IP is surpassing that of the established dominant players.

The US and the UK are now faced with a new competitive landscape in the context of the knowledge-based economy. What this means for a relatively small and relatively peripheral region like Wales is truly significant. Getting the strategy right is critical and every possible opportunity for seeking advantage must be taken.

2.7 Bibliography

- Almeida P. and Kogut B., 1997, "The Exploration of Technological Diversity and the Geographic Localization of Innovation", Small Business Economics, Vol. 9, pp. 21-31.
- Boddy M., 2005, "The Knowledge-Driven Economy, Regional Economic Strategy and the Regional Spatial Strategy in the South West of England", South West Regional Development Agency.
- Bresnehan T., Gambardella A. and Saxenian A, 2001, "Old Economy' Inputs for 'New Economy' Outcomes: Cluster Formation in the New Silicon Valleys", Journal of Industrial and Corporate Change, Vol. 10, No. 4, pp 835-860.
- Bresnehan T., Gambardella A., 2007, "Building High-Tech Clusters", Cambridge Press, ISBN 978-0-521-82722-5.
- Cameron G., Muellbauer J. and Snicker J., 2002, "A Study in Structural Change: Relative Earnings in Wales Since the 1970's", G Cameron, J Muellbauer and J Snicker, Regional Studies, Vol. 36, Iss. 1, pp. 1-11.
- Chen C.H., 1996, "Regional determinants of foreign direct investment in mainland China", Journal of Economic Studies, Vol. 23, No. 2, pp. 18-30.
- Clement R.M., 2004, "A Sustainable Engine for Economic Development", Presentation to Cardiff Business School.

[2] http://www.one-north.sg/hubs_biopolis.aspx

- Cooke P., 2002, “Regional Innovation Systems, Clusters & the Knowledge Economy”, European Comparisons, Conference Presentation, The Digital North Denmark Research Seminar.
- Cooke P. and Clifton N., 2005,“Visionary, Precautionary and Constrained ‘Varieties of Devolution‘ in the Economic Governance of the Devolved UK Territories”, Regional Studies, Vol. 39, Iss. 4, pp. 437-451.
- Davies G.H., Abbey J.V., Huxtable L. and Bunting G., 2007, “Using experts in the identification of the challenges to the development of a Regional Knowledge Economy”, QRM Conference Proceedings.
- De Laurentis C., Cooke P. and Williams, G., 2003, “Barriers to the Knowledge Economy- New Media Cluster in the Periphery”, Paper presented at the Regional Studies Association International Conference, Scuola Superiore Sant’ Anna Pisa 12th -15th April 2003.
- Dorfman N., 1983, “Route 128: The development of a regional high technology economy”, Research Policy, Vol. 12, pp 299-316.
- DTI, 2001, “Regional Innovation Performance in the UK”, Department of Trade and Industry, UK Government.
- DTI, 2003, “Competing in the Global Economy – The Innovation Challenge”, DTI Economics Paper, No. 7, Department of Trade and Industry, UK Government.
- DTI, 2004, “Our Competitive Future: Building the Knowledge-Driven Economy”, Department of Trade and Industry, UK Government.
- DTI, 2001, “Business Cluster in the UK – A First Assessment”, Department of Trade and Industry, UK Government.
- Edmonds T., 2000, “Regional Competitiveness & the Role of the Knowledge Economy”, Research Paper 00/73, Economic Policy & Statistics Section, House of Commons, UK Parliament.
- EU, 2003, “Final Report of the Expert Group on Enterprise Clusters and Networks”, Enterprise Directorate General, European Commission.
- EU, 2005, “Common Actions for Growth and Employment: The Community Lisbon Programme”, Communication from the Commission to the Council and the European Parliament, European Commission.
- HEFCE (2003) “Higher Education Business Interaction Survey 2000-01 and Patent Office Annual Facts and Figures2000-01”, London, UK: Patent Office.
- Hughes A., 1999, “Enterprise, Innovation and High-Tech SMEs”, ESRC Centre for Business Research and Judge Institute of Management Studies, Conference Paper, The Economics of the Knowledge Driven Economy, DTI, 1999.
- HSMO Licensing Division, 2003, “Lambert Review of Business-university Collaboration”, Norwich, UK: HM Treasury.
- K GROUP, 2006, “Knowledge Economy Theme: Interim Report, Wales Spatial Plan, Swansea Bay – Waterfront and Western Valleys”, Working Document, School of Law, Swansea University.
- Karlsson K., 2007, “Clusters, Functional Regions and Cluster Policies”, CESIS Electronic Working Paper Series, Paper No. 84.
- Keeble D. and Tomlinson F., 1999, “Collective Learning and Knowledge Development in the Evolution of Regional Clusters of High Technology SMEs in Europe”, Regional Studies, Vol. 33, Iss. 4, pp 295-305.
- Ketels C., Lindqvist G. and Solvell O., 2008, “Clusters and Cluster Initiatives”, Center for Strategy and Competitiveness Stockholm School of Economics.
- Leadbeater C., 1999, “New Measures for the New Economy”, OECD International Symposium, Technical Meeting.
- Local Futures, 2006, “A Cardiff and South East Wales City Region?”, Research Report, Local Futures Group.
- Lovering J., 1999, “Theory Led by Policy: The Inadequacies of the ‘New Regionalism’ (Illustrated from the Case of Wales)”, International Journal of Urban and Regional Research.
- Maskell P. and Malmberg A., 1999, “Localised learning and industrial competitiveness”, Cambridge Journal of Economics, Vol. 23, pp. 167-185, 1999.
- Milken Global Conference, Los Angeles April 2010.

- NAW, 2006, “Enterprise, Innovation and Networks Committee, Review of Science Policy in Wales”, National Assembly of Wales.
- OECD, 1996, “The Knowledge-based Economy”, Organisation for Economic Co-operation and Development.
- OECD, 2005, “Briefing Note for the United States”, OECD Science, Technology and Industry Scoreboard 2005, Organisation for Economic Co-operation and Development.
- Porter M.E., 1990, “Competitive Advantage of Nations”, Free Press, ISBN 0-684-84147-9.
- Porter M., 2000, “Location, Competition and Economic Development: Local Clusters in a Global Economy”, Economic Development Quarterly, Vol. 4, Iss. 15, pp 15-34.
- Porter M. and Ketels C. H. M., 2003, “Moving to the next stage”, DTI Economics Paper No.3, Department for Trade and Industry, UK Government.
- Porter M. and Stern S., 1999, “The New Challenge to Americas Prosperity: Findings from the Innovation Index”, Council of Competitiveness.
- Rocha H. O., 2004, “Entrepreneurship and Development: The Role of Clusters”, Small Business Economics, Vol. 23, pp. 363-400.
- Scot Exec, 2001, “Scottish Executive Report on the Knowledge Economy Cross-Cutting Initiative”, Scottish Executive.
- Shapira P., Youtie J., Yogeesvaran K. and Jaafar Z., 2005, “A125: Knowledge Economy Measurements: Methods, Results and Insights from the Malaysian Knowledge Content Study”, Conference Paper, Triple Helix 5 Conference, Turin.
- Steil, B., Victor, D., and Nelson, R. (2002) “Technological Innovation and Economic Performance”, Princeton, USA: Princeton University Press.
- Todtling F. and Trippl M., 2005, “One size fits all?: Towards a differentiated regional innovation policy approach”, Research Policy, Vol. 34, Iss. 8, pp. 1203-1219.
- Turok I., 1993, “Inward Investment and Local Linkages: How Deeply Embedded is ‘Silicon Glen’?’, Regional Studies, Vol. 25, Iss. 5, pp. 401-417.
- Varga A., 2000, “Local Academic Knowledge Transfers and the Concentration of Economic Activity”, Journal of Regional Science, Vol. 40, No.2, pp. 289-309.
- WAG, 2001, “A Winning Wales: The National Economic Development Strategy of the Welsh Assembly Government”, Welsh Assembly Government.
- WAG, 2003, “Wales for Innovation: The Welsh Assembly Government’s Action Plan for Innovation”, Welsh Assembly Government.
- WAG, 2003a, “A Winning Wales: Annual Report 2002-2003”, Welsh Assembly Government
- WAG, 2003b, “Wales: A Better Country: The Strategic Agenda of the Welsh Assembly Government”, Welsh Assembly Government.
- WAG, 2004, “Knowledge Economy Nexus: Role of higher Education in Wales”, Report of the Welsh Assembly Government’s Higher Education and Economic Development Task and Finish Group.
- WAG, 2004c, “People, Places, Futures: The Wales Spatial Plan”, Welsh Assembly Government.
- WAG, 2005b, “Wales: A Vibrant Economy”, The Welsh Assembly Government’s Strategic Framework for Economic Development, Welsh Assembly Government.
- WAG, 2005c, “Skills and Employment Action Plan for Wales 2005”, Welsh Assembly Government.
- WAG, 2006, “A Science Policy for Wales 2006: The Welsh Assembly Government’s Strategic Vision for Sciences, Engineering and Technology”, Welsh Assembly Government.
- Wei Y., Parker D. and Vaidya K., 1999, “The Regional Distribution of Foreign Direct Investment in China”, Regional Studies, Vol. 33, Iss. 9, pp. 857-867.
- WEFO, 2004, “Single Programming Document including Mid-term Review Changes”, West Wales and Valleys, Objective 1, Welsh European Funding Office, Welsh Assembly Government.
- WEFO, 2006, “Frameworks and Projects: An overview of implementation arrangements”, WEFO Programme Management Division, Welsh European Funding Office.
- Work Foundation, 2006, “The Knowledge Economy in Europe: A Report prepared for the 2007 EU Spring Council, The Work Foundation.

- Young S., Hood N. and Peters E., 1994,"*Multinational* Enterprises and Regional Economic Development", Regional Studies, Vol. 28, No. 7, pp. 657–677.

Chapter 3

21st Century Economic Development[1]

"Innovation has become the new theology, reports Nicholas Valéry. Yet there is still much confusion over what it is and how to make it happen" The Economist (US), [2] *February, 1999* [3]

Innovation has become the industrial religion of the late 20th century. Business sees it as the key to increasing profits and market share. Governments automatically reach for it when trying to fix the economy. Around the world, the rhetoric of innovation has replaced the post-war language of welfare economics.

"It is the new theology that unites the left and the right of politics", Gregory Daines, Cambridge University.

3.1 Innovation: nothing new?

Recent years have seen much focus on how innovation can lead to improvements in productivity assisting in economic development (DTI 2003). However, while the term innovation often conjures up images of electronics, test tubes and new products the much wider-reaching nature of the concept has been understood for some time (Schumpeter 1934) to include:

- The introduction of a new good – one with which consumers are not yet familiar, or the quality of a good.
- The introduction of a new method of production – which is not necessarily founded upon a new scientific discovery but can be a new way of handling an existing commodity.
- The opening of a new market.
- The conquest of a new source of supply – such as raw materials or half-manufactured goods.
- The carrying out of the new organisation of any industry – such as creation or breaking up of a monopoly position.

Attempts to understand the effects of technological progress on economic growth pay homage to Joseph Schumpeter, an Austrian economist best remembered for his views on the "creative destruction" associated with industrial cycles 50-60 years long. Arguably the most radical economist of the 20th century, Schumpeter was the first to challenge classical economics as it sought (and still seeks) to optimise existing resources within a stable environment - treating any disruption as an external force on a par with plagues, politics and the weather. Into this intellectual drawing room, Schumpeter introduced the raucous entrepreneur and his rambunctious behaviour. As Schumpeter saw it, a normal, healthy economy was not one in equilibrium, but one that was constantly being "disrupted" by technological innovation.

[1] This content is available online at <http://cnx.org/content/m43441/1.1/>.
[2] http://findarticles.com/p/articles/mi_hb5037
[3] http://findarticles.com/p/articles/mi_hb5037/is_199902

3.1.1 Innovation at the Macro and Firm Levels

Innovation is described more succinctly as the '*the transformation of knowledge into new products, processes, and services...*' (Porter and Stern 1999) and in the definition provided by the DTI in the Innovation Review as:

"*...the successful exploitation of new ideas...*"

Information and knowledge (though of varying value and exclusiveness) are relatively abundant. However its potential is limited by '*the capacity to use them in meaningful ways*' (OECD 1996). The knowledge-based economy therefore applies 'Innovation' to turn knowledge into wealth.

Innovation is central to driving up productivity and delivering economic growth. Porter and Stern (1999), outlining how innovation not only provides a mechanism for improving productivity through efficiency, but also creates higher value goods for which businesses (subsequently amalgamated to industries and economies on a national scale) can command higher prices in comparison to the inputs required. If unskilled labour and land are cheaper in Asia and access to markets from these locations is relatively easy then it is through *innovation*, and the development of *higher value-added* goods and services that developed nations can compete (Porter 2000).

Innovation has often been approached as a linear process taking an idea through development and production to market, as in Figure 3.1 (OECD 1996). Each of the phases in this model itself draws upon a variety of disciplines as illustrated in the 'Innovation Bridge' representation of Clement (2004) (Figure 3.2).

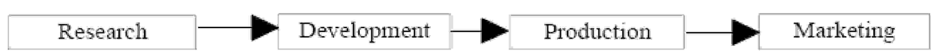


Figure 3.1: 'Linear' model of innovation (OECD 1996).

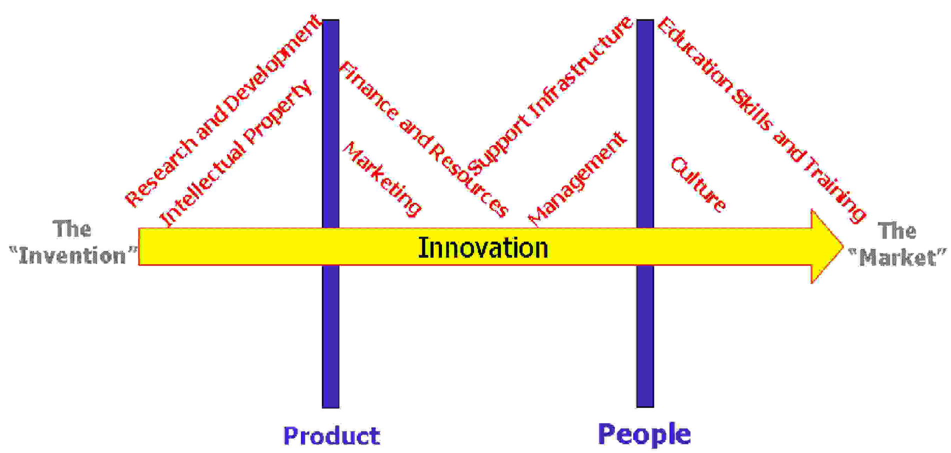


Figure 3.2: 'Innovation Bridge' linear model of innovation presenting disciplines involved (Clement 2004).

Such a model implies that innovation is only 'initiated' by invention or discovery (OECD 1997). This sits at odds with von Hippel's observation that the most important source of innovation is '*end-user innovation*' (von Hippel 1988) where users' needs rather than supply side factors drive the development and exploitation of knowledge. The 'chain-link model' of innovation by contrast allows for numerous stimuli and feedback to be incorporated from various stages between identifying market potential and actual sale (Figure 3.3).

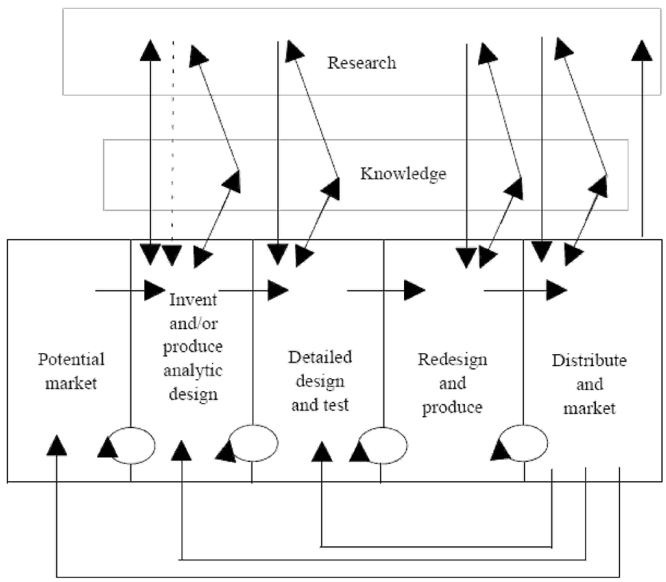


Figure 3.3: 'Chain-link' model of innovation (OECD 1996).

3.1.1.1 Innovation at the Firm Level

Innovation has been cited as a key determinant of macroeconomic growth, but does it relate to the microeconomic level? It has been shown by various studies that innovative firms outperform their peers who do not engage in the activity (Geroski and Machin 1992, Heunks 1996, Leadbeater 1999, Freel 2000).

This improved performance relates to growth in employment, turnover and profitability. Each of the studies listed above supported this broad linkage between innovation and performance, though each shed further light on different aspects. Freel (2000), in a survey of 228 small firms, found that innovation created growth in employment though not necessarily in profitability. This, as Freel explains, is understandable for the sunk costs of innovation will impact upon young firms prior to them enjoying returns on route to becoming larger firms. The earlier work of Geroski and Machin (1992) focused on larger companies. An interesting result from this study was that the fortunes of innovative firms were less cyclic than those of other firms. This runs against the hypothesis that cyclical introduction of new products would have a corresponding cyclical effect on performance.

Innovation can be difficult for businesses as it often involves change, the scale of which is generally related to how radical the innovation may be. This makes it especially challenging for larger businesses where practices are more embedded and changes more difficult to effect (Keeble and Tomlinson 1999, Todtling and Trippl 2005).

3.1.1.2 Research and Development (R&D)

R&D is often used as a proxy measure for innovation activity (Leadbeater 1999, WAG 2001) though it is in effect simply an input to the process. Outputs require inputs and this measure has readily available data for comparison at national and international levels. The importance of R&D in driving innovation and economic development cannot be overstated. In 2002, at least a quarter of the UK productivity gap with the US was linked to lagging investment in R&D (DTI 2003).

The importance of public R&D activity should not be overlooked, particularly in developing new technologies. As pointed out by Porter and Stern (1999), information technology, telecommunications, weather satellites, sensors, passenger jets and many other technologies have come about from defence research. The private sector will understandably focus efforts where it can find returns, i.e. at the market, leading to greater interest in the development end of R&D. In the US for example, 70% of R&D expenditure is for Development, while 22% goes into exploratory and applied research, with the remaining 8% spent on basic research (OECD 1996).

3.1.1.3 Intellectual Property

Intellectual Property Rights (IPR) represents the mechanism through which individuals and organisations aim to protect and manage their knowledge. As described by Nelson (1986) IPR has the role of balancing the public and private interests of innovation providing "*...enough private incentive to spur innovation, and enough publicness to facilitate wide use...making public those aspects of technology where the advantages of open access are greatest*". The strength of the IPR instrument is also a challenging issue in fostering the optimal level of competition. Monopoly capitalism feared earlier in the century was broken by competition, through constant new entrants to markets and innovation itself (World Bank 1999). However, IPR is intended to present a barrier to entry, allowing monopolistic positions to be established. The accessibility of levering IPR is also an important issue as costs of protection and enforcement are a particular challenge for smaller innovative companies (DTI 2003).

While R&D expenditure is an 'input' of the innovation process, patents are best regarded as an 'intermediate product'. At a macroeconomic level patent statistics generate an interesting picture of comparative productivity. Despite being by far the largest spender on R&D (42% of OECD R&D expenditure), the US produces relatively few patents compared to some of its competitors. France, Germany, Japan and the UK together create 83.6% of triadic (US, EPO and Japan patent office filed) patent families (OECD 2005). While this is an observation of the OECD, the researchers do not discuss whether this is a bias caused by attitudes of US companies towards overseas markets or whether it is simply that overseas countries need to access the significant US market.

3.1.2 Open Innovation

Companies including leading multinationals can no longer satisfy their need for innovation internally and are therefore looking outside their own organisations for sources of innovation that will provide future growth. Traditionally, businesses used their own internal resources and capabilities to innovate, and jealously protected their results achieved in what is termed *Closed Innovation*. However, it has become increasingly difficult for companies to satisfy their innovation needs from internal resources. This has come about as markets become increasingly dynamic and global, disruptive technologies arrive, and opportunities require diverse multidisciplinary approaches – often involving completely new capabilities.

To address this challenge, many large firms have adopted a strategy of acquisition, buying innovative small firms to assimilate into their own product/service offerings. Meanwhile, others have looked to collaborate with partners, including academia, in order to support their innovation activity.

During recent years, collaborative approaches have received increasing interest, particularly within the paradigm of *Open Innovation*, which not only embraces openness in sourcing of innovations, but also in how they are developed and taken to market. As shown in Figure 3.4 this Open Innovation approach significantly expands innovation potential by increasing opportunity flow in terms of markets as well as ideas.

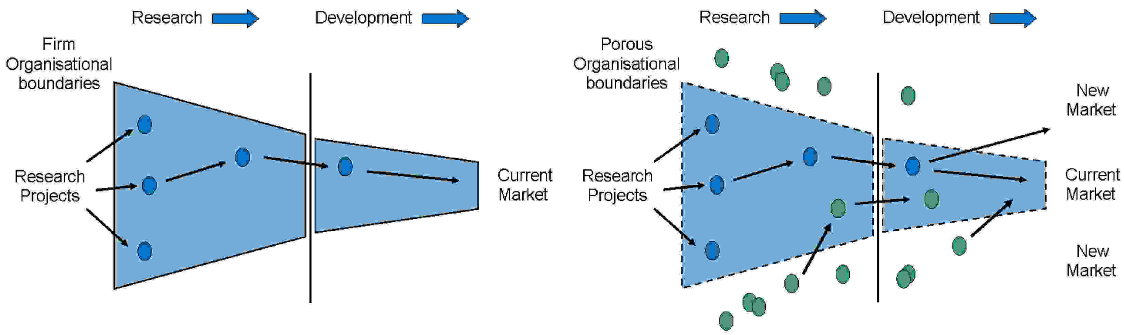


Figure 3.4: A representation of closed (left) and open (right) innovation paradigms (Chesbrough 2006).

Open Innovation is a concept developed by Henry Chesbrough (Chesbrough 2003, Chesbrough 2006) recognising a change in how businesses innovate. The concept is defined by Chesbrough as:

"*. . . the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology.*"

As the definition implies, Open Innovation is not only about where companies source knowledge for their own innovations but ways in which they manage innovations that arise which may not fit with the conventional strategy. Examples of both these strands may include licensing in IP to develop, while licensing out IP, which may not fit with the core business.

Chesbrough outlines how the development of this concept is highlighted by the challenges faced by many major companies who are struggling to sustain their innovation performances. To address this they have to look beyond their (often global) internal capabilities and engage in innovation with a variety of partners. Whereas internal R&D could produce sufficient innovation he describes how this has been challenged by '*erosion factors*' including:

- *The increasing availability and mobility of skilled workers* – i.e., the precious human capital they enjoyed is no longer exclusive and therefore a competitive advantage
- *The venture capital market* – i.e., the increased availability of investment has removed (or at least reduced) a barrier to entry for new competitors
- *External Options for Ideas Sitting on the Shelf* – i.e., the ability to 'spin-out' new products or services through alternative and/or new channels
- *The Increasing Capability of External Suppliers* – i.e., if the inputs to the company include more 'value-add' then the company can add less value

Many of the concepts in Open Innovation are not new. For example, earlier models of innovation describe how '*firms search for linkages to promote inter-firm learning and for outside partners to provide complementary assets*' (OECD 1996), which ties in with the paradigm described by Chesbrough. Furthermore, the pressure of the Knowledge Economy in challenging hierarchical structures and replacing them with flatter alternatives, often involving semi-autonomous teams is an effect that was apparent before Open Innovation (World Bank 1999).

The challenge for businesses to exploit external knowledge sources while 'protecting' their own knowledge is observed by Doring and Shnellenbach (Doring and Shnellenbach 2006) in their work examining knowledge spillovers.

The transition of multinationals to Open Innovation strategies is not only shown by high-profile endeavours such as Proctor and Gamble's 'Connect and Develop' strategy (Huston and Sakkab 2006) but also through observations of phenomena such as "*creation of new technological competencies through the international dispersion of corporate activities*" (Cantwell and Piscitello 2005), whereby firms seek access to knowledge and opportunities in other localities.

The Procter and Gamble '*Connect and Develop*' strategy is particularly interesting as it uses an Open Innovation system to provide "*more than 35% of the company's innovations and billions of dollars in revenue*" (Huston and Sakkab 2006). Having previously focused on the internal efforts of its 8,600 scientists the company looked outside to capitalise on the 1.5 million who worked elsewhere (Chesbrough 2003).

3.2 Sustainable Innovation

3.2.1 Economic Cycles

Above we have introduced the concept of business and technology cycles as developed by Joseph Schumpeter. The concept of economic cycles including those involving technological change has also been developed by other economists such as Kondratieff, who in 1925, drew attention to the ~60 year cycles which bear his name. While his research clearly did not examine modern technologies such as ICT or Genetics, the phenomena he observed from analysis of data relating to the technology sectors of his time can still be used as a basis for contemporary analyses.

In his view, each of these long business cycles was unique, driven by entirely different clusters of industries (Figure 3.5). Typically, a long upswing in a cycle started when a new set of innovations came into general use - as happened with water power, textiles and iron in the late 18th century; steam, rail and steel in the mid-19th century; and electricity, chemicals and the internal-combustion engine at the turn of the 20th century. In turn, each upswing stimulated investment and an expansion of the economy. These long booms eventually petered out as the technologies matured and returns to investors declined with the dwindling number of opportunities. After a period of much slower expansion came the inevitable decline - only to be followed by a wave of fresh innovations, which destroyed the old way of doing things and created the conditions for a new upswing. The entrepreneur's role, as Schumpeter saw it, was to act as ferment in this process of creative destruction, allowing the economy to renew itself and bound onwards and upwards again (McDaniel, 2005).

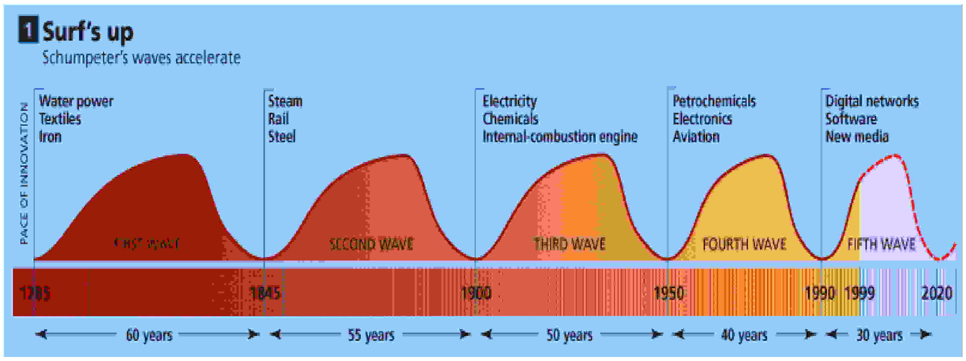


Figure 3.5: Schumpeter's wave (Copyright: The Economist, 1999).

By the time Schumpeter died in 1950, the third cycle of his "successive industrial revolutions" had already run its course. The fourth, powered by oil, electronics, aviation and mass production, is now rapidly winding down, if it has not gone already. All the evidence suggests that a fifth industrial revolution - based on semiconductors, fibre optics, genetics and software - is not only well under way but even approaching maturity. This may explain why America shrugged off its lethargy in the early 1990s and started bounding ahead again, leaving behind countries too preoccupied with preserving their fourth-wave industries. If so, then Schumpeter's long economic waves are shortening, from 50-60 years to around 30-40 years.

There is good reason why they should. It was only during the third wave, in the early part of the 20th century, that governments and companies began to search for new technologies in a systematic manner. One of the oldest, Bell Laboratories at Murray Hill in New Jersey, was founded in 1925. Rather than leave the emergence of "new-wave" technologies to chance, all the major industrial countries nowadays have armies of skilled R&D workers sifting the data in pursuit of blockbuster technologies capable of carving out wholly new markets. The tools they use - computer analysers, gene sequencers, text parsers, patent searchers, citation mappers - are getting better all the time, speeding up the process. The productivity of industrial laboratories today is twice what it was a couple of decades ago (McDaniel, 2005).

So the fifth industrial revolution that started in America in the late 1980s may last no more than 25-30 years. If, as seems likely, we are already a decade into this new industrial cycle, it may now be almost too late for the dilatory to catch up. The rapid-upswing part of the cycle - in which successful participants enjoy fat margins, set standards, kill off weaker rivals and establish themselves as main players - looks as though it has already run two-thirds of its course, with only another five or six years left to go. Catching the wave at this late stage will depend on governments' willingness to free up their technical and financial resources, invest in the infrastructure required and let their fourth-wave relics go (The Economist, 1999). Failing that, latecomers can expect only crumbs from the table before the party comes to an end - and a new wave of technologies begins, once again, to wash everything aside (Table 3.1 and Figure 3.6).

Cycle/Wave Name	Years
Kitchen/inventory	3-5
Juglar/fixed investment	7-11
Kuznets	15-25
Bronson/asset allocation	~30
Kondratiev wave	45-60

Table 3.1: Economic wave series.

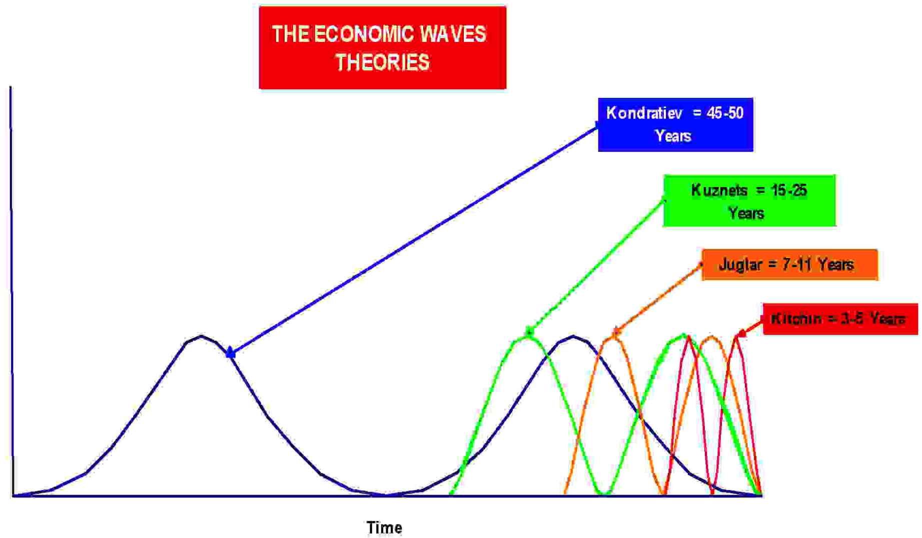


Figure 3.6: The Economic wave theories.

The knowledge that is created in the market allows for the cycles to shorten, this is not done in isolation there are other factors such as government and policy that aid or impede the shortening of these cycles.

In the Juglar cycle, that is often called the business cycle, recovery and prosperity are associated with increases in productivity, consumer confidence, aggregate demand and price. In the cycles before World War II or that of the late 1990's in the United States, the growth periods usually ended with the failure speculative investments built on a bubble of confidence that bursts or deflates. In these cycles, the periods of contraction and stagnation reflect a purging of unsuccessful enterprises as resources are transferred by market forces from less productive uses to more productive uses. Cycles between 1945 and 1990's in the United States were generally more restrained and followed political factors, such as fiscal policy, and monetary policy.

If one lays the idea of knowledge over this cycle; as the growth period ended and the failures occurred the knowledge of those people involved in the cycle and enterprises utilise knowledge of lessons learned before into the new emerging cycle to create value and opportunities in new cross over emerging technologies and enterprises (Figure 3.7).

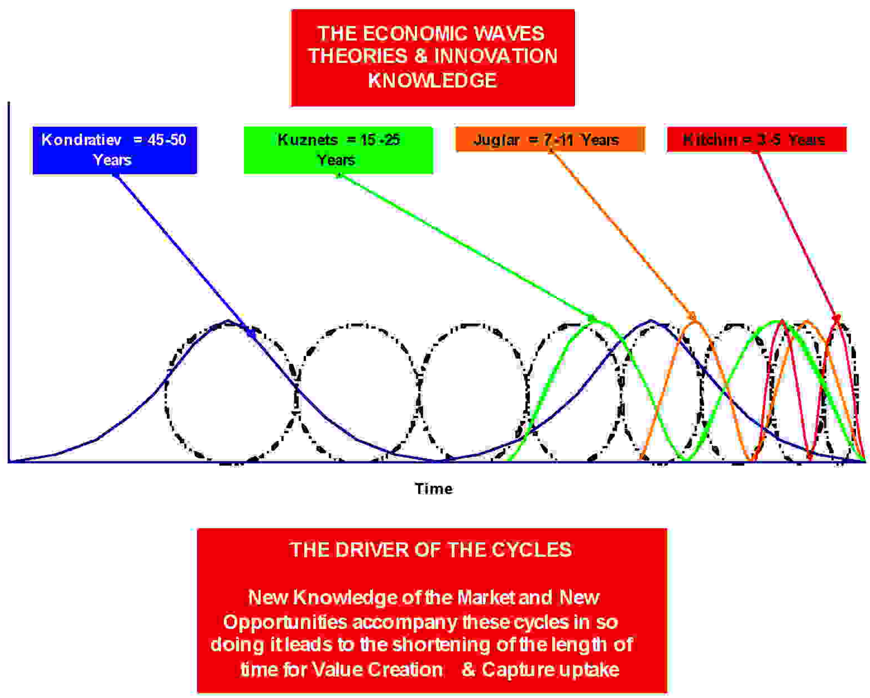


Figure 3.7: Economic wave theories and innovation knowledge.

3.3 Collaboration

"If you think you have all the answers internally, you are wrong." The Power of Many, 2006

Earlier chapters and sections have presented the complexities and challenges of innovation in increasingly rapid moving markets and technology sectors. Linkages with firms within clusters have been shown to be a key attribute in sustaining economic development, demonstrating the role and impact of collaboration within a cluster.

Collaboration is defined as a structured, recursive process where two or more people work together toward a common goal; typically an intellectual endeavour that is creative in nature by sharing knowledge, learning and building consensus" (www.encyclopediabrittanica.com 2007). Collaboration does not require leadership and can sometimes bring better results through decentralization and egalitarianism (Leydesdorff and Wagner 2005) In particular, teams that work collaboratively can obtain greater resources, recognition and reward when facing competition for finite resources (Mithas et al. 2009). Collaboration is not just valuable among peer groups, but among all members of an organization (Rosenberg 2006, Gannon-Cook 2008).

Over the past decades, there has been exceptional growth in enterprise partnering and dependence on different forms of external collaboration (Hergert and Morris 1988, Mowery 1988, Hagedoorn 1990, Badaracco 1991, Hagedoorn and Schakenraad 1992, Gulati 1995). Historically, firms organized research and development (R&D) internally and relied on outside contract research only for relatively simple functions or products (Mowery 1983, Nelson 1990). Today, companies in a wide range of industries are executing nearly every step in the production process, from discovery to distribution, through some form of external collaboration. These various types of collaborative alliances take on many forms, ranging from R&D partnerships to equity joint ventures to collaborative manufacturing to complex co-marketing arrangements. The most common rationales offered for this upsurge in collaboration involve some combination of risk sharing, obtaining access to new markets and technologies, speeding products to market, and pooling complementary skills (Kogut 1989, Kleinknecht and Reijnen 1992, Hagedoorn 1993, Mowery and Teece 1993, Eisenhardt and Schoonhoven 1996, Park et al. 2004).

Figure 3.8 shows the cycle of innovation. The key features being:

- "Death Valley" A major chasm that must be navigated in the early stage of any innovation process.
- "Bowling Alley" where early adopters support the highest rate of growth for product adoption.
- "Main Street" where product market penetration is driven by commercial strategies.
- "Elastic/Plateau" where the innovation achieves steady state before it commences a decline due to market or technological changes.

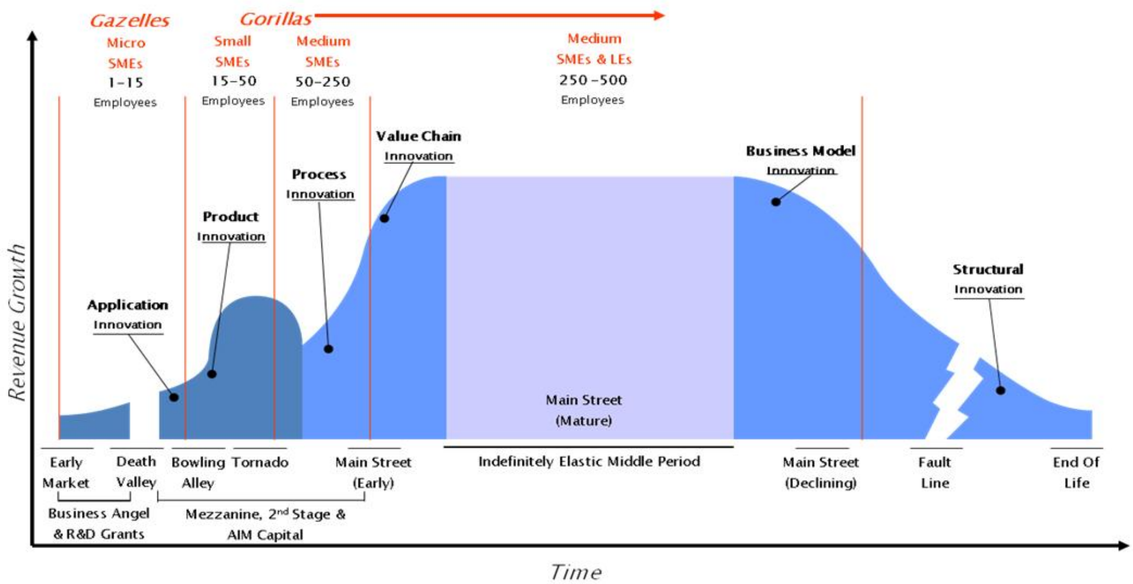


Figure 3.8: The "Dead Mouse" (Moore 2005).

Figure 3.9 shows a development of Schumpeter's thinking, the diagram describes the hypothesis that in order to create a sustainable cluster in a region there are three key requirements. Firstly, the active sector must itself be one that is emerging and has growth potential. The sector's location on the development cycle of the mouse is shown on the green portion of Figure 3.9. Secondly the region must have product innovation capacity in the chosen sector. This is illustrated by the orange portion of Figure 3.9. There has to be sufficient innovation capacity in the defined in the sector in the region in order for that innovation capacity to be itself sustainable. The third essential requirement, shown in purple on Figure 3.9 is the need for a critical mass of knowledge enterprise in the sector in the region. Each of these requirements has to navigate its own 'dead mouse' obstacle course in order to arrive at the relatively calm waters at the plateau of the mouse. Each has to navigate death valley an this requires commitment from all stakeholders who need to work collaboratively to achieve a common goal but above all there needs to leadership and vision. If this can be achieved then a sustainable cluster may be created. The blue portion of the figure illustrates the goal of moving a cluster across "Death Valley" and onto the plateau. This is challenging, takes time, partnership, vision, commitment and perspiration but the rewards and the impact can be substantial. It could be argued that a region like Wales has little alternative in the current global knowledge economy landscape. It has the great advantage of being a small, coherent region but the disadvantage of being at times a collection of fiefdoms that prefer to compete rather than collaborate. Leadership, from wherever it comes is critical.

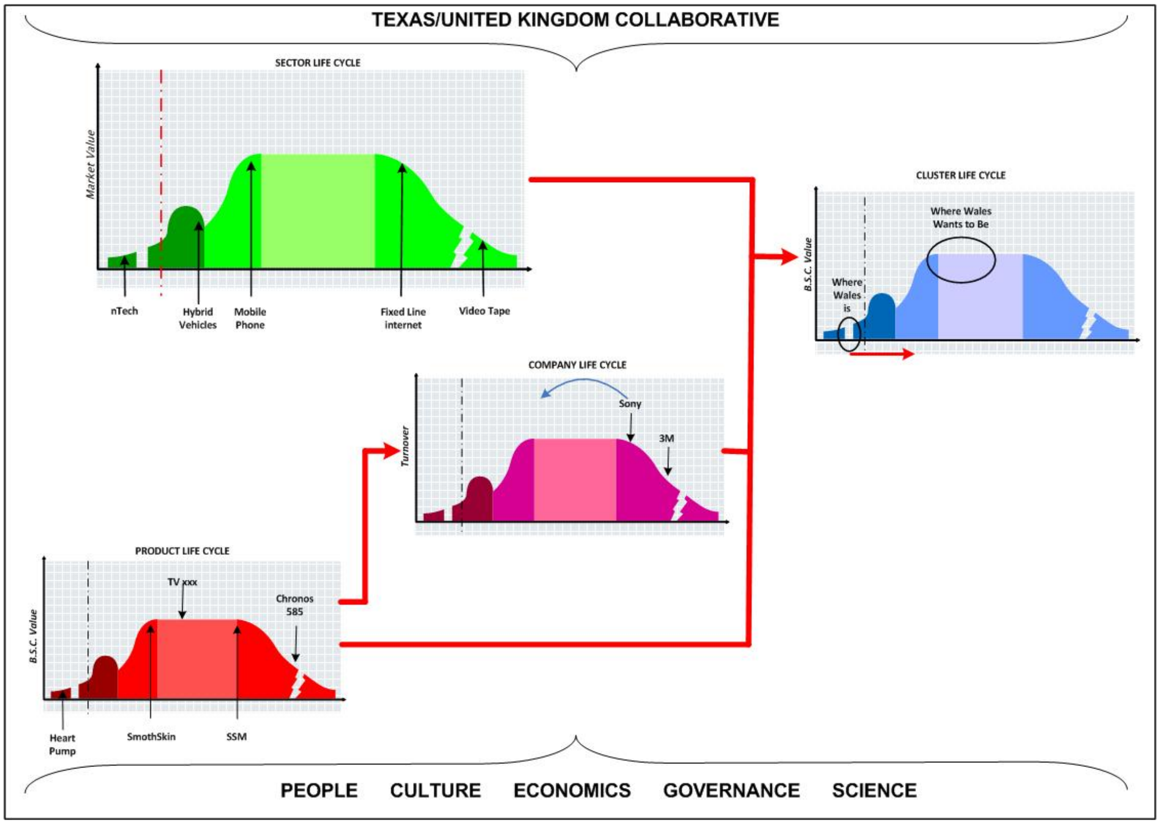


Figure 3.9: Innovation cycle in product, company, sector, and cluster.

3.4 Triple Helix

The triple helix of industry, academia and government is relatively mature concept in regional knowledge based economic development. The role of universities has been championed by many as playing a vital role in developing the knowledge economy (Goh 2005, Dreyer and Kouzmin 2009, Nasto 2009). This is important both in regions with strong universities and knowledge clusters (e.g., MIT/Cambridge), and regions in a more developmental stage (e.g., Southwest Wales)

3.4.1 Universities: Knowledge Cluster Anchor Tenants

The linkages between academia and industry have received much interest over recent years by governments (WAG 2004, Lambert 2003), academics (Nelson 1986, Varga 2000) and other organisations including the private sector, though many commentators observe that it is the private sector that will deliver the fruits of innovation in the knowledge economy (Porter and Stern 1999).

The above studies recognise the importance of universities and academic knowledge in driving innovation and the knowledge economy. Nelson (1986) was one of the earliest to clearly demonstrate the positive effect of university on industry and technological advance, based on research undertaken in the US. This came at a time when American academia was undergoing the start of a seismic shift in technology transfer following the Bayh-Dole Act. This important pieced of legislation is regarded as a paradigm shift in US academia-industry relations for it clarified ownership of IP developed during research, and incentivised and charged universities to exploit its value.

Higher education institutions (HEIs) and public research facilities play a variety of roles in supporting the Knowledge-Based economy including '*knowledge production*' developing new knowledge, '*knowledge transmission*' – in developing human capital, and '*knowledge transfer*' – by disseminating knowledge and supporting industry (OECD 1996, WAG 2004). HEIs are also recognised as important knowledge businesses that are often 'anchor tenants' in regional knowledge economies (WAG 2004). The importance of HEIs in supporting knowledge-based industrial clusters in their regions is acknowledged by the UK and Welsh Governments (DTI 2001 and WAG 2003b).

3.4.2 Challenges to collaboration

The opportunities and challenges for each region and individual collaboration are unique to its ambition, environment and the efforts invested. This context includes for example: the existing vibrancy of knowledge-based enterprise within the region; the presence of research activity allied to growth sectors; and the mobilisation of collective efforts within the region to develop the initiative.

It is possible to identify key factors that can affect the likelihood and potential extent of success for collaboration. These include individual and organisational factors as well as broader issues such as funding availability. For example, a first weakness lies in the way that the United Kingdoms Research Assessment Exercise (RAE) operates. The *Research Assessment Exercise* (RAE) is intended to recognise world-class research undertaken with business partners, as well as other forms of academic excellence. In practice, however, the assessment panels tend to concentrate on purely academic benchmarks, such as output in important journals. This may be partly because this kind of output is what most interests the people who sit on the peer review panels. It is also because such work is easier to measure than business collaboration. An article in an academic journal has by definition been through a rigorous process of assessment even before it appears, and can be judged against similar work from other sources. It is much harder to define what constitutes world-class research undertaken with business partners (Lambert 2003).

This bias has an impact on the way that research departments operate. Given the choice between producing an academic paper and working with industry, an ambitious academic is more likely to take the former option: that way lies extra funding for the department, and an increased chance of promotion. The Review came across a number of cases where departments had deliberately decided not to work with business in order to concentrate all their efforts on raising their RAE rankings.

In addition, the importance attached to Quality-related Research (QR) funding has tended to homogenise the research efforts of the university system. Less research-intensive universities invest large amounts of time and money in preparing for the RAE even though they may have very little hope of gaining significant extra funding as a result. Instead of concentrating on their own areas of comparative advantage – which may be of real value to their local and regional economy – they strive to be measured against a world-class benchmark.

Another criticism by business of the RAE is that it fails to give sufficient weight to multidisciplinary research. Because the assessment is undertaken by a large number of panels divided up on the basis of subject areas or units of assessment, it can be difficult to reward work that cuts across different disciplines – precisely the kind of research that is of increasing importance to business.

There are broadly similar concerns about the ways in which the Research Councils operate. One of them, the Engineering and Physical Sciences Research Council (EPSRC), has made a particular effort to develop collaborative projects with business. It says that such work represents around 40 per cent of its current research programmes, up from just 13% a decade ago. Other Research Councils have much less exposure to the business sector, with relatively few active business people on their boards.

There is no doubt it is easier for the EPSRC, which covers the engineering sectors, to develop collaborative links than it is for, say, the Particle Physics and Astronomy Research Council. All the Councils have mechanisms for funding research in collaboration with industry. These include set piece schemes which are often funded jointly with the DTI, such as LINK and Knowledge Transfer Partnerships; network-type projects such as the Faraday Partnerships; funding for joint business university projects; and the financing of PhD students in the workplace (Lambert 2003).

Over the past decade growth in Research Council funding has significantly outstripped the growth in QR funding. The increasing imbalance between the two funding streams has led some observers to question the present dual support system. Business has a real interest in the sustainability of strong university departments, and in public funding which supports creative and innovative research (Lambert 2003).

3.4.2.1 Universities as Knowledge Businesses in Wales

The most notable contribution of Higher Education to the Knowledge Economy is the graduates it produces. The graduate outputs of Welsh Universities are a significant source of knowledge and skills. The Welsh HE sector employs over 17,000 people and is currently educating over 120,000 students, including some 45,000 in Science and Engineering. Additionally, the Welsh HE sector also supports a further 23,600 jobs in the wider community (HEFCW 2006).

3.4.2.2 Welsh Graduate Output – Welsh Economy Input?

However, the challenge exists, as described in the Welsh Assembly Government's Knowledge Economy Nexus (WAG 2004), to provide opportunities for these skills, preventing them from being lost to other regions of the UK. This outflow of graduates from most regions is something seen across the UK with young talent attracted to the opportunities of London and the South East of England. This problem is particularly acute in science and technology. While Europe (and our region) performs well in producing science and technology graduates we perform poorly in the number of researchers that we employ (EU 2006), thereby failing to capitalise on this investment in intellect.

3.4.3 Supporting Innovation – Knowledge and Technology Transfer

Universities are being increasingly recognised as a source of ideas for new commercial products and services (Siegel et al. 2003). University research produces new knowledge and builds upon existing knowledge. This makes it valuable for fuelling innovation, through both incremental improvements to existing technology and by major fundamental breakthroughs.

Forms of technology and knowledge transfer that are simple to measure and compare include: contract research; new company spinout; (Di Gregorio and Shane 2003); patenting and licensing activity. Each of these activities is easily numerated, be it by research income, number of new companies founded, patents filed or licenses executed. Studies in many countries, including extensive national surveys, have quantified and analysed these outputs of technology transfer (AUTM 1995, 2005, HEFCE 2003).

3.4.3.1 Consultancy, Contract Research and Licensing

As described above there exists a host of mechanisms for universities to transfer knowledge to the industrial community. Consultancy can provide businesses with the opportunity to appraise what a university could offer before embarking upon larger research contracts, leading to a different type of interaction, plus it can provide SMEs with university expertise for relatively low fees. Other fields of technology transfer could also benefit such as licensing, where more than 50% of licenses go to companies already known by the academic concerned (Lambert 2003).

The manner in which universities manage their IPR portfolios and anticipate revenues is an important issue. Using a portfolio of patents (patent pooling can be within and between institutions) (Parish and

Jargosch 2003) in a targeted manner rather than relying on individual patents is a strategy advocated and applied by the Association of University Technology Managers (AUTM) in the United States. This strategy helps facilitate successful licensing and commercialisation. This strategy also helps balance revenues, as revenues from all patents are not equal. During 2002 only 0.6% of licenses negotiated by U.S. universities (N.B. licences not patents) provided revenues of over $1million (Pressman 2002). When considering the possible revenues it must be born in mind that on average it takes six years to commercialise university research, thereby putting much of the onus of risk and investment onto the shoulders of the licensee.

Management of IP raises many issues before embarking upon the patent application process and searching for potential licensees. The appropriateness of patent protection and to what extent is important considerations along with ensuring freedom to operate. 70% of R&D in the U.S. infringes IPR of another party (WAG 2004), which can place substantial obstacles in the path of continued the development, let alone eventual commercialisation. The importance of the right of freedom to operate in the university case has been highlighted by high-profile cases such as Madey versus Duke University (Guttag 2003) in the U.S. and has led to much discussion about the legal position of educational institutions.

Historically Welsh Higher Education Institutions (HEIs) have engaged in a limited amount of licensing activity with more focus given to development of spin-out companies. However, there have been instances where inventions have been licensed for significant sums. The most notable example concerns a life science technology relating to fluorescence technology used in genetic research, which was licensed by the University of Wales, College of Medicine for £710,000 (WAG 2004).

While licensing activity has been modest other mechanisms such as consultancy have been growing consistently since the mid 1990's as shown in Figure 3.10.

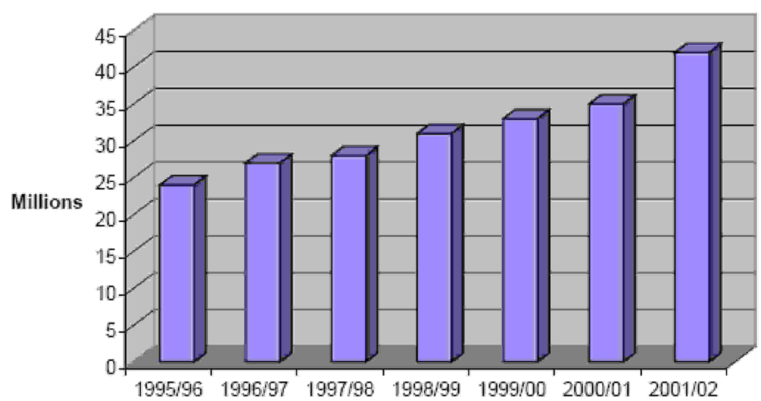


Figure 3.10: Consultancy income of Welsh HEIs 1995-2002 (WAG 2004).

3.4.3.2 Spin-out Companies

Furthermore companies located in university incubators have been found to be more productive (Siegel et al. 2003) along with the sense of vibrancy and catalysing effect they have for associated companies. This can assist in long-term economic development supporting the establishment and growth of successful clusters (Tornatzky 2000).

Welsh HEIs have been performing well in terms of creating spin-out companies. During 2001/02, supported by the Wales Spin-out Programme, 22 spin-outs were produced (10% of the UK total) together with a further 64 businesses started by graduates (19% of the UK total). This performance is particularly encouraging considering Wales represents 6% of the UK population.

The rate of spin-out development in Wales stuttered following this period, as it did across the whole of the UK, following changes in capital gains tax rules in 2003. These rules saw academics being liable for immediate taxation at a rate of 40% on the value of their share of equity in a spin-out company. This issue is now being addressed by the Treasury together with professional bodies representing academic commercial activity such as The University Companies Association, UNICO (2004).

3.5 Sustainable Innovation System Components

Previously we have explored the concepts of economic development, regional cluster theory and innovation. The concept of sustainable innovation has also been introduced considering the cyclical nature of economies and technologies, and how this impacts upon economic and firm development. Sustainability is also a topic of significant current interest due to the environmental and societal challenges faced across the world such as climate change and aging populations. This has drive governments and other organisations to consider how sustainable development in economic societal and environmental contexts can be effectively combined. The work of Jorna (2006) is a prime example of how this broader consideration of sustainability in innovation can be applied her work dovetails the concepts of Schumpeter's creative destruction and economic cycles with technology cycles and the central role of knowledge creation and dissemination. Also demonstrated earlier in previous sections is how the ethos of open, collaborative, multidisciplinary and global working is critical in developing and sustaining vibrant knowledge economy clusters, this thinking was recently articulated by Nick Donofrio (Figure 3.11).

"Innovation resides at the intersection of invention and insight leading to the creation of social and economic value" Nick Donofrio, IBM Executive VP, Innovation and Differentiation.

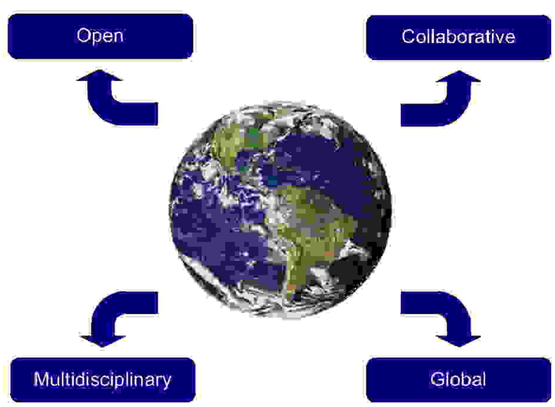


Figure 3.11: Innovation and differentiation, Nick Donofrio, IBM (2008).

While the above provides the ethos and modus operandi of sustainable innovation, its components can be considered as being People, Culture, Economics, Governance, and Science. These are used as the organising principles for the UK governments Sustainable Development Strategy – Securing the Future (DEFRA, 2005). Considering each of these in turn in the context of a Sustainable Regional Innovation System.

3.5.1 People

Providing the talent to generate harness and exploit new knowledge and opportunities is critical for the success of a region. The correlation between regional economic performance and the quality of human capital has been clearly demonstrated in numerous studies. (ONS 2004, Work Foundation 2006) The mobility of talent between regions is a key feature in the European Union's Knowledge Economy Strategy and is underpinned by actions ranging from ERASMUS through to FP7: People. In addition it must be stressed that human capital perspective is equally important with regard to the commercial and entrepreneurial perspectives, as it is to the scientific. It could be argued strongly that this is where the Universities have a major role to play. Do regional education programmes deliver the training that the knowledge economy needs? Is there sufficient business skills development in all undergraduate programmes? Are there policy instruments in place, particularly in the HE system to encourage entrepreneurial activity? Many observers fear that the answer to these questions is a very firm NO but that subject is another matter for discussion. A major US think tank Faster Cures in a recent publication entitled 'The Critical Need for Innovative Approaches to Disease Research' (April 2010) observed that a critical issue affecting progress in the traditional academic research system was:

3.5.2 Infrastructure

- Institution stakeholders' resistance to changing infrastructure and rewards systems in areas such as publication, tenure, and intellectual property to promote collaboration and innovation.
- Lack of institutional communication and data exchange between basic and clinical researchers.
- Inadequate opportunities for cross-disciplinary training and practice (Michael Milken, 2010).

Whatever the situation, for reasons already argued is critical. Other regions have identified the nanotechnology field as the 'next big thing'

3.5.3 Culture

The transition from closed to open innovation paradigms is a prime example of the need for cultural change within organisations and amongst individuals in order to harness the opportunities of collaborative, open and multidisciplinary working. Activities such as KTN and KTP aim to support development of such a culture within and between academic and industrial sectors. Building upon the people component as described above the culture of successful regional clusters supports "serial entrepreneurs and innovators", retaining their talents and supporting the transfer of their skills to and development in to in others.

3.5.4 Economics

In essence, for a region and cluster to prosper and maximise impacts of its resources it cannot swim against the tide and must harness opportunities to reinvent enterprises operating in declining sectors and support new firms in emerging sectors. A region must have and intelligent, patient and informed funding infrastructure. So often early stage funding is either absent or very difficult to access. The concept of building value in ideas or enterprises is little understood and hardly ever taught to Science, Technology, Engineering and Maths (STEM) students (Abbey and Lane 2005). This establishes a chasm between the entrepreneur and the source of finance one failing to understand why the financier cannot see how brilliant the idea is and other failing to explain to the inventor why a return on investment has to be calculated and convincingly articulated. The key performance indicators, kpi's used must be meaningful, so often for example patents filed are used as a metric when all practitioners know that the majority of patents lead to no value and represent a major financial burden. The interplay between economic benefit and the technical knowledge generators is key and must interface using the language of value generated.

3.5.5 Governance

Above we described the models of planned versus spontaneous clusters and how a common factor in successful regions is the good governance that facilitates rather than micromanages development. This chimes with supporting the ethos of collaborative, open global and multidisciplinary working, embedding a culture described above. Governance is key to agenda. It is the governance process that sets, protects, sustains and refreshes the vision, mission and core values. It the governance that defines the kpi's and monitors progress against plan holding the executive to account. More importantly still it is the governance that allows the executive to deliver, protecting it form the 'short-termism' an influence so often embedded in the political system due to the priorities imposed by the need to be re-elected. Good governance facilitates partnership and collaboration and mitigates against vision drift.

3.5.6 Science

The generation and development of new knowledge and opportunities is vital to spawn new enterprise through commercialization of academic output, attraction of inward investment and retention of talent. As will be discussed in the next chapter the increasing complexity of science and innovation requires greater multidisciplinary working often requiring collaboration on a global scale. Drilling down into any opportunity in emerging technologies demonstrates a convergence of scientific and technological disciplines, and commercial acumen. There is a need for pockets of 'world class' science within the cluster, but also a need to recognise limitations, identify weaknesses and to be prepared to work with others in open, collaborative, multidisciplinary and global partnership.

3.6 Bibliography

- Abbey G. and Lane N., 2005, "United States Space Policy: Challenges and Opportunities", American Academy of Arts and Science, Policy Report.
- AUTM, 1995, FY 1991-1995 Five Year Licensing Survey, Association of University Technology Managers.
- AUTM, 2005, FY 2005 U.S. Licensing Survey, Association of University Technology Managers.
- Badaracco J., 1991, "The Knowledge Link: How Firms Compete through Strategic Alliances", Boston, Harvard.
- Cantwell J. and Piscitello L., 2005, "Recent Location of Foreign-owned Research and Development Activities by Large Multinational Corporations in the European Regions: The Role of the Spillovers and Externalities", Regional Studies, Vol. 39, Iss.1, pp. 1-16.
- Chesbrough H., 2006, "Open Innovation: Researching a New Paradigm", Oxford University Press.
- Clement R.M., 2004, "A Sustainable Engine for Economic Development", Presentation to Cardiff Business School.
- DEFRA, 2005, "Securing the Future – UK Government Sustainable Development Strategy", www.defra.gov.uk, Accessed 2007.
- Di Gregorio D. and Shane S., 2003, "Why do some universities generate more start-ups than others?", Research Policy, Vol. 32, pp 209-227.
- Donofrio, N. 2008, "Innovation and Differentiation", Presentation at IBM New York.
- Doring T. and Shnellenbach J., 2006, "What Do We Know about Geographical Knowledge Spillovers and Regional Growth?: A Survey of the Literature", Regional Studies, Vol. 40, Iss. 3, pp. 375-395.
- Dreyer W. and Kouzmin A., 2009, "The Commodification of Tertiary Education within a Knowledge Economy", Journal of Economic and Social Policy, Vol.13, Iss. 1.
- DTI, 2003, "Competing in the Global Economy – The Innovation Challenge", DTI Economics Paper, No. 7, Department of Trade and Industry, UK Government.
- Eisenhardt K. and Schoonhoven C., 1996, "Strategic alliance formation in entrepreneurial firms: Strategic needs and social opportunities for cooperation", Organization Science, Vol. 7.

- EU 2006, “Mobilising the brainpower of Europe: enabling universities to make their full contribution to the Lisbon Strategy”, Communication from the Commission, European Commission.
- Freel M.S., 2000, “Do Small Innovating Firms Outperform Non-Innovators?”, Small Business Economics, Vol.14, pp195-210.
- Gannon-Cook R. and Crawford C., 2008, “Combining Quality and Expediency with Action Research in ELearning Instructional Design”, Journal of Educators Online, Vol. 5, No. 2.
- Geroski P. and Machin S., 1992, “Do Innovating Firms Outperform Non-Innovators?”, Business Strategy Review, Vol. 3, Iss. 2, pp. 79-90.
- Goh A., 2005, “Harnessing Knowledge for Innovation: an integrated management framework”, Journal of Knowledge Management, Vol.9, No. 4, pp.6-18.
- Gulati R., 1995, “Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances”, Academy of Management Journal, Vol. 38, pp. 85-112.
- Guttag E.W., 2003, “Immunizing University Research from Patent Infringement: The Implications of Madey v. Duke University”, Journal of the Association of University Technology Managers, Vol. XV, pp. 1-21.
- Hagedoorn J., 1990, “Inter-firm partnerships and co-operative strategies in core technologies”, New Explorations in the Economics of Technical Change, pp. 3-37.
- Hagedoorn J., 1993, “Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences”, Strategic Management Journal, Vol. 14 pp. 371-385.
- Hagedoorn J. and Schakenraad J., 1992, “Leading companies and networks of strategic alliances in information technologies”, Research Policy, Vol. 21, pp. 163-190.
- HEFCE, 2003, “Higher Education-Business Interaction Survey – 2001-2002”, Higher Education Funding Council for England.
- Hergert M. and Morris D., 1988, “Trends in international collaborative agreements”, Cooperative Strategies in International Business, Lexington Books, pp. 99-109.
- Heunks F.J., 1996, “Innovation, Creativity and Success”, Small Business Economics, Vol. 10, pp263-272.
- Huston L. and Sakkab L., 2006, “Connect and Develop: Inside Procter and Gamble’s New Model for Innovation”, Harvard Business Review, Vol. 84, Iss. 3, pp58-66, Mar 2006.
- Jorna R., 2006, “Knowledge creation for sustainable innovation”, The KCIS Programme, Greenleaf Publishing.
- Keeble D. and Tomlinson F., 1999, “Collective Learning and Knowledge Development in the Evolution of Regional Clusters of High Technology SMEs in Europe”, Regional Studies, Vol. 33, Iss. 4, pp 295-305.
- Kleinknecht A. and Reijnen J., 1992, “Why do firms cooperate on R&D? An empirical study.” Research Policy, Vol. 21, pp. 347-360.
- Kogut B., 1989, “The stability of joint ventures”. Journal of Industrial Economics, Vol. 38, pp.1-16.
- Lambert R., 2003, “Lambert Review of Business-University Collaboration – Final Report”, HM Treasury, UK Government.
- Leadbeater C., 1999, “New Measures for the New Economy”, OECD International Symposium, Technical Meeting.
- Leydesdorff L., Wagner S., 2005, “Network structure, self-organization, and the growth of international collaboration in science”, Research Policy, Vol. 34, Is. 10, pp. 1608-1618.
- McDaniel, B., 2005, “A contemporary view of Joseph A. Schumpeter’s theory of the entrepreneur”, Journal of Economic Issues, Vol. 39.
- Milken Global Conference, Los Angeles April 2010.
- Mithas S., J., Khuntia R., Agarwal, 2009, “Information Technology and Life Expectancy: A Country-Level Analysis”, Conference Paper, International Conference on Information Systems, Proceedings.
- Mowery D., 1988, “The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900-1940”, Explorations in Economic History, Vol. 20, pp. 351-374.

- Mowery D. and Teece D., 1996, "Strategic alliances and industrial research", W.J. Spencer and R.S. Rosenbloom, eds., Engines of Innovation: U.S. Industrial Research at the End of an Era, Harvard Business School Press.
- Nasto B., 2008, "Chasing biotech across Europe", Nature Biotechnology Vol. 26, pp. 283-288.
- Nelson R. 1986, "Institutions Supporting Technical Advance in Industry", American Economic Review, No. 76, No. 2, pp.186-189.
- OECD, 1996, "The Knowledge-based Economy", Organisation for Economic Co-operation and Development.
- OECD, 1997, "National Innovation Systems", Organisation for Economic Co-operation and Development.
- OECD, 2005, "Briefing Note for the United States", OECD Science, Technology and Industry Scoreboard 2005, Organisation for Economic Co-operation and Development.
- ONS, 2004, "Social Trends Report 34: Proportional effect on earnings of a degree level qualification: by sex and degree subject", 1993-2001, Dataset ST340510, UK National Statistics.
- Parish R. and Jargosch R., 2003, "Using the Industry Model to Create Physical Science Patent Pools among American Institutions", Journal of the Association of University Technology Managers, Vol. XV, pp 65-81.
- Park N., Mezias J., and Song J.,2004, "A Resource-based View of Strategic Alliances and Firm Value in the Electronic Marketplace", Journal of Management, Vol. 30, No. 1, pp. 7-27.
- Porter M., 2000, "Location, Competition and Economic Development: Local Clusters in a Global Economy", Economic Development Quarterly, Vol. 4, Iss. 15, pp 15-34.
- Porter M. and Stern S., 1999, "The New Challenge to Americas Prosperity: Findings from the Innovation Index", Council of Competitiveness.
- Rosenberg M., 2006, "Beyond E-learning", San Francisco, CA: Pfieffer, an Imprint of Wiley.
- Pressman L., 2002, "What is Known and Knowable about the Economic Impact of University Technology Transfer Programs?", Council on Research Policy and Graduate Education, Chair AUTM.
- Siegel D., Westhead P. and Wright M., 2003, "Assessing the impact of university science parks on research productivity: exploratory firm-level evidence from the United Kingdom", International Journal of Industrial Organization, Vol. 21, pp. 1357-1369.
- Schumpeter J., 1934, "The Theory of Economic Development", 13th Print, Harvard University Press, 0-87855-698-2.
- Todtling F. and Trippl M., 2005, "One size fits all?: Towards a differentiated regional innovation policy approach", Research Policy, Vol. 34, Iss. 8, pp. 1203-1219.
- Tornatzky L. G., 2000, "Building State Economies by Promoting University-Industry Technology Transfer", US National Governors' Association.
- Varga A., 2000, "Local Academic Knowledge Transfers and the Concentration of Economic Activity", Journal of Regional Science, Vol. 40, No.2, pp. 289-309.
- von Hippel E., 1988, "The Sources of Innovation", E von Hippel, Oxford University Press, ISBN 0-19-509422-0.
- WAG, 2001, "A Winning Wales: The National Economic Development Strategy of the Welsh Assembly Government", Welsh Assembly Government.
- WAG, 2003b, "Wales: A Better Country: The Strategic Agenda of the Welsh Assembly Government", Welsh Assembly Government.
- WAG, 2004, "Knowledge Economy Nexus: Role of higher Education in Wales", Report of the Welsh Assembly Government's Higher Education and Economic Development Task and Finish Group.
- Work Foundation, 2006, "The Knowledge Economy in Europe: A Report prepared for the 2007 EU Spring Council, The Work Foundation.
- World Bank, 1999, "Public Policy for Knowledge Economy", World Bank, 1999.

Chapter 4

Nanotechnology: It's the Little Things that Matter[1]

4.1 What is Nanotechnology?

There exists the popular misconception that nanotechnology is a discreet industry or sector. Rather nanotechnology is a set of tools and processes for manipulating matter that can be applied to virtually any manufactured good. Nanotechnology is an emerging and promising field of research, loosely defined as the study of functional structures with dimensions in the 1-1000 nanometer range (Figure 4.1). During the last decade, however, developments in the areas of surface microscopy, silicon fabrication, biochemistry, physical chemistry, and computational engineering have converged to provide remarkable capabilities for understanding, fabricating and manipulating structures at the atomic level (Adams, 2007).

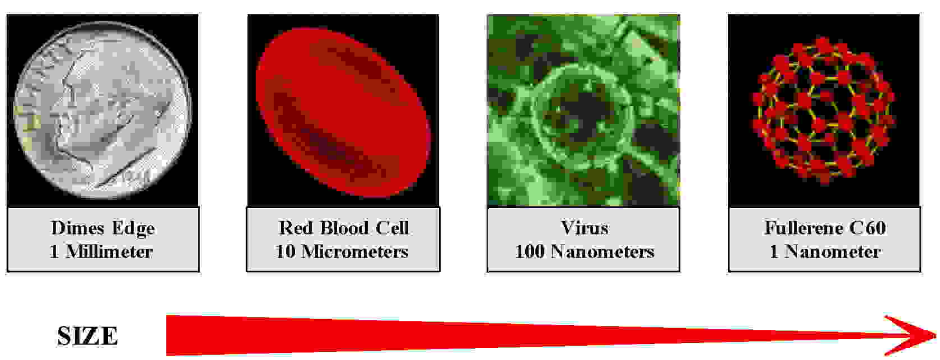


Figure 4.1: Scale of nano; Adapted from: The Scale of things (Source: Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy (www.nano.gov 2009).

[1]This content is available online at <http://cnx.org/content/m43446/1.1/>.

4.1.1 Sizing up Nanotechnology

Research in nanoscience has gained momentum, due to the intellectual attraction and the potential societal impact and with the forecasted global market impact across several sectors it lends nanotechnology to be a dominant and enabling technology in the 21st century. Nanotechnology is not an industry or a sector rather a set of tools and processes for manipulating matter that can be applied to virtually any manufactured good.

Nanotechnology as an emerging and disruptive force has already faced the initial challenges of public acceptance globally. Notable commentators such as HRH Prince of Wales famously commented on a potential of "Green Goo" while numerous academics examine the toxicology of the technology to guard against the next "asbestos" (Figure 4.2). Despite this often high-profile cautiousness, the technology has already found its way into the mainstream through products such as antimicrobial refrigerators.

Figure 4.2: Launch of Prince of Wales Innovation Scholars Program: HRH the Prince of Wales (right), Professor Andrew R. Barron the first Prince of Wales Visiting Innovator (center) and Professor Marc Clement Vice Chancellor of the University of Wales (far right).

4.1.2 Emergence of "nano" as a commercial opportunity

The commercial interest in nanotechnology can be tracked back over significant period. For example, the first trademarks incorporating "nano" was registered in 1965 though this has grown rapidly over recent years. (Lux Research, 2006) Nanotechnology is a disruptive technology crossing many industrial sectors and at the middle of the last decade had already become incorporated in over $50 billion worth of products sold worldwide. The growth of scale has been matched by the growth of scope, with products ranging from nano-formulated drugs through to high performance nanophosphate batteries. A key breakthrough was the discovery of fullerene by Harry Kroto (University of Sussex, United Kingdom), Bob Curl and Richard Smalley (Rice University, Texas), which has become a major enabler in numerous technologies for sectors across the board. The discovery of fullerene helped put the then-emerging field of nanotechnology, which involves making products from designer molecules, into the limelight. Besides the 1996 Nobel Prize in Chemistry, Smalley was awarded the Irving Langmuir Prize, the Franklin Medal, and the Ernest O. Lawrence Memorial Award (Kanellos 2005).

4.2 Nano Applications and Technology

Growth and development of nanotechnology has exploded over recent years, though as shown in Figure 4.3, below this trend was lead by the United States with a massive increase in patenting activity starting in the mid 1990s (Huang et al. 2004).

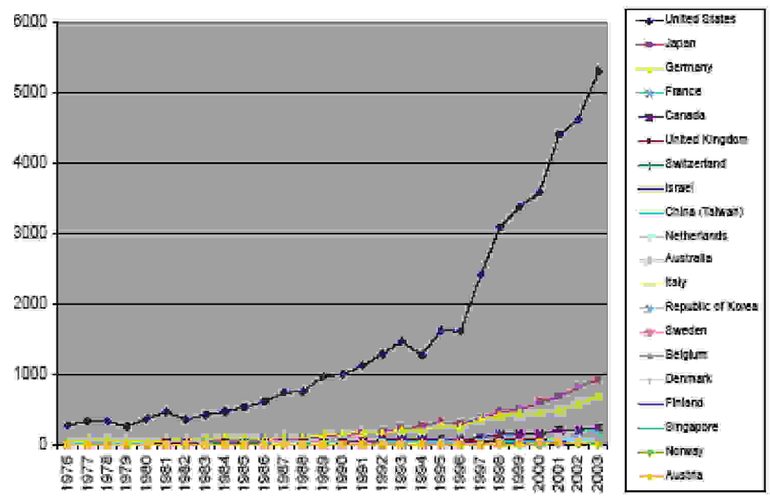


Figure 4.3: A plot of the publications from the top nanotechnology countries by year (Huang et al. 2004).

To date, nanotechnology has seen selective application in high-end products, most of which is within high-performance applications for the automotive and aerospace sectors.

Having established this presence in performance engineering applications, nanotechnology is now becoming embedded within IT applications such as microprocessors and memory chips built using new nanoscale processes (Lux Research, 2004). By 2014 it is projected that 50% of electronics and IT will incorporate nanotechnology (Lux Research 2004).

Although Bio-Life Science is currently the leading sector in nanotechnology development, the rate of innovation across all sectors is significant. Other technological fields that experienced rapid growth in patenting activity in 2003 were those relating to transistors and other solid-state devices, semiconductor device manufacturing, optical waveguides, and electric lamp and discharge (Huang et al. 2004). Figure 4.4 shows an overview of sectoral breakdown of nanotechnology. It is worth noting that sectors such as Materials and Chemicals are in effect enablers for broader sectors, and integrate into the supply and value chains of other sectors. (OSTP 2005). Examples of such materials are carbon nanotubes and quantum dots, which have applications in all sectors.

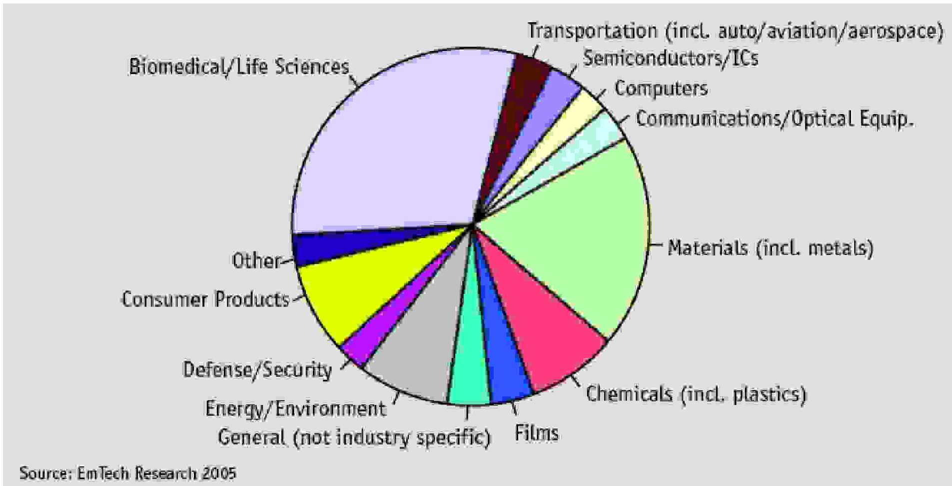


Figure 4.4: Target industries for companies involved in R&D, manufacture, sale, and use of nanotechnology in 2004 (total number of companies = 599). Source (EmTech 2005).

Industrially it has been shown that the leading participants in nanotechnology development are the large-scale industrial actors such as IBM, Intel, and L'Oreal, reflecting the complex and expensive nature of development (EmTech 2005).

In terms of economic impact it is projected that 11% of total manufacturing jobs worldwide will involve manufacture of products incorporating nanotechnology. This will have a result in a paradigm shift in requirements upon supply chains and shift the nature of competition by introducing radical new entrants. This shift is set to accelerate as mass production processes are developed and the cost of materials is driven down, making product opportunities more viable.

4.3 Nano Market Growth

Although the most ambitious, potentially world-changing nanotechnology applications are still in development, marketplaces associated with nanotechnologies are already forecasted to be worth billions and are projected to exceed $2.6 trillion within 15 years (Texas Nanotechnology Report, 2008).

4.3.1 Global

Due to the potential impacts of nanotechnology, there has been, and is, a strong global interest across governments, business, venture capitalists, and academic researchers. From the period of 1997 to 2005, approximately $18 billion were invested globally in nanotechnology by national and local governments (Cientifica 2006). Governments in the United State, Japan, and Western Europe are among top global nano technology spenders, with global collective governmental spending annually some ~$4.6 billion. This represents just under 50% of total expenditure with the remainder coming from major corporations including a minor proportion from venture capitalists (Lux Research, 2008). However, despite the initial lead of the United States in nanotechnology investment it is now been overtaken by Europe for government expenditure and by Asia for corporate investment (Nano Report, 2006).

The global nanotechnology market has been examined in great detail by a range of academic and commercial organisations. A particularly detailed and comprehensive ongoing study by Lux Research Corporation

(2004, 2006, and 2008) provides a useful breakdown of existing activity together with projections of future trends. This work presents growth in nanotechnology manufacturing as a sector towards a global value of some $2.6 trillion dollars by 2014. This is broadly equivalent to the current size of the ICT sector and ten times larger than Biotechnology.

4.3.2 Regional

Countries across the world, including China, Japan, and several European countries, have made nanotechnology leadership and a national priority, working to catch up with the lead established by the United Sates in the field. Even developing countries in areas like Africa, South America, and Malaysia have established government-funded nanotechnology programs and research centres (Cientifica 2006).

Regionally, the U.S. is forecast to remain the largest nanomaterials market due to its large, technologically advanced economy and is top 4 in ranked positions in most major nanomaterials areas, including electronics, consumer goods, pharmaceuticals, and construction materials. (Europe is currently competitive with 31% on the materials market, however there is a clear gap in government spending). The report indicates that Japan is the leading nanomaterials investor in R&D on a per capita basis (Freedonia Group, 2003).

Previous sections have outlined the breadth and growth potential of market sectors in nanotechnology. The transformational nature of endeavour in the field can support establishment of clusters spanning numerous sectors. An example of this is the development of a nanotechnology cluster in the State of Texas. Table 4.1 highlights leading firms within the cluster from a range of sectors.

Company	**City**	**Sales**	**Industries**
LynnTech Inc	College Station	$14.3	Healthcare, Semiconductors, Energy, etc.
Southern Clay Products	Gonzales	$12.2	Construction
Applied Optoelectronics Inc.	Sugarland	$10.0	Telecom, Cable TV, Semiconductors, etc.
Zyvex Corporation	Richardson	$10.0	Aerospace, Defense, Healthcare, Semiconductors, Telecom, etc.
Molecular Imprints	Austin	$8.0	Healthcare, Semiconductors, etc.
Introgen Therapeutics Inc.	Austin	$1.9	Biopharmaceuticals
Applied Nanotech Inc.	Austin	$1.4	Communications, Semiconductors, etc.
Advanced Bio Prosthetic Surfaces	San Antonio	$1.3	Medical Devices

continued on next page

Nanospectra Biosciences	Houston	$1.0	Medical Devices

Table 4.1: Revenues (in millions) for selected Texas early stage nanotechnology companies (Source: Nanotechnology Foundation of Texas, 2008).

4.3.3 Bio-Nano Life Science

It is projected that by 2014 Healthcare and life sciences applications will finally become established as nano-enabled pharmaceuticals and medical devices emerge from lengthy human trials (Lux Research 2004). Within the sector pharmaceuticals alone will represent an annual global market worth ~ $180 billion (Hobson 2009).

Available research shows that using 2003 figures the biomedical / life science industry was the largest sector involved in the R&D, manufacture, sale and use of nanotechnology. In 2003, four of the five top assignees for nanotechnology patents in 2003 were electronics companies, although the field of chemistry (molecular biology and microbiology) had the greatest number of nanotechnology patents both in 2003 and in previous years (Freedonia Group, 2003).

Considering Life Science as the "Leading" sector for nanotechnology applications, it could be asked why the apparent throughput of products remains low. It is worth stressing that due to the extensive development and rigorous regulatory pathways involved, this creates a particularly long time to market for innovations in the sector. In addition this is compounded by the need for framework to catch up with and effectively accommodate nanotechnology advances. It was highlighted by the US FDA in 2008 and again in 2009 that there was a lack of qualified people within the agency to be able to properly facilitate nano through approvals (ANH 2008, 2009)

Within the combined sectors of Bio and Life Science exist numerous segments and markets which represent significant opportunities themselves. For example, the Medical Devices market is growing at ~9% each year presenting opportunities for nanotechnology applications. Meanwhile, other segments such as in-vitro diagnostics and medical imaging represent markets of ~$18 billion and ~$14 billion respectively (EPT 2005). It was highlighted by the Chairman of the Wellcome Trust, Sir William ('Bill') Castell in 2010 that "it is the low hanging fruit of diagnostics and imaging that will bring nano into forefront of healthcare" (Castell 2010). Within each of these sectors nanotechnology has the potential to be immensely disruptive. For example, within the field of drug delivery systems, a market worth ~$43 billion, there is significant potential for technologies such as Au (gold) particles (Cientifica 2008) and micro-needles (www.belasnet.be 2008), Figure 4.5 and Figure 4.6, respectively.

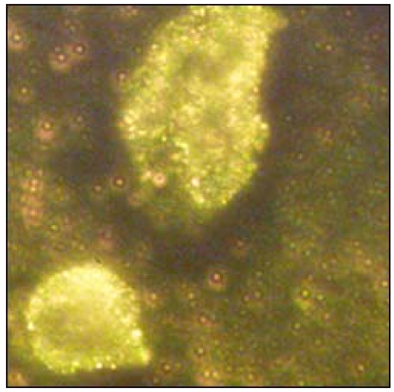


Figure 4.5: Image of gold nanoparticles (Source: Cientifica 2008).

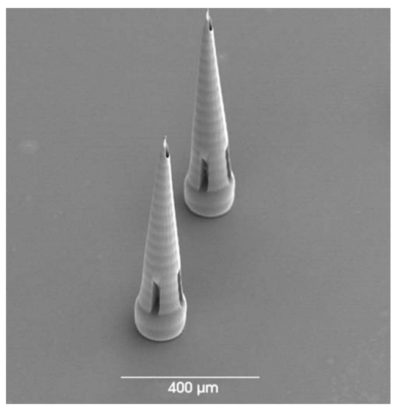


Figure 4.6: SEM image of micro-needles (Source: www.belasnet.be[2]).

4.4 Regional Nanotechnology Initiatives

The Southwest Wales Region has seen significant investment over recent years into its Knowledge Economy infrastructure. These investments have come from European Structural Funds, Welsh Assembly Government, academia, and the private sector. These initiatives include specific actions to support key growth sectors such as Life Science, Performance Engineering and ICT. Examples include:

- **Technium**: A network of incubation/innovation centres across Wales to support new enterprise and inward investment. The initiative has been considered as a component within a sub-regional innovation system (Abbey et al., 2008) and its economic impact appraised by external commentators.

[2]http://www.belasnet.be/

- **Institute of Life Science (ILS)**: The ILS represents collaboration between the University of Wales Swansea, the NHS and IBM to support the emerging regional Life Science Cluster. Combined with the parallel initiatives of the "Blue-C" Supercomputing facility and activities in Health Informatics, ILS has now entered a second phase to expand its interactions with the NHS and crate new facilities for business incubation, clinical trials and imaging.
- **Other academic-industrial Research Centres**: A number of specialist research centres have been established over recent years with a focus on industrial engagement. For example, the National Centres for Mass Spectrometry, and Printing and Coating have effectively combined leading research groups with an agenda of collaborating between academic research areas and industry. A further and directly relevant major example of such an initiative is the Multidisciplinary Nanotechnology Centre, this discussed in more detail in the following section.

4.4.1 Multidisciplinary Nanotechnology Centre

In 2002 University of Wales, Swansea led a partnership involving UW Aberystwyth, UW College of Medicine and Cardiff University to create an infrastructure for development of cutting edge nanotechnology research. The Centre, which remains in operation, is multi-faceted, focusing on "boundary projects" operating in multidisciplinary fields. Core components of the initiative include:

- Specialist laboratories focused around a central hub at UW Swansea.
- State of the art research equipment with particular focus on imaging and fabrication.
- A team of over 50 researchers leading in their respective fields.
- A portfolio of "boundary projects" drawing in further support from Research Councils and industry.

The initiative has established itself as a leading research centre the success of which was recently reflected in the excellent outcome of the School of Engineering in the 2008 Research Assessment Exercise (RAE).

4.4.2 Centre for NanoHealth "Son of MNC"

One of the prime foci of the Centre for NanoHealth (CNH) is the field of "Nanomedicine". The reasons for specific interest in the field include the facts that:

- It is an extremely large field ranging from in vivo and in vitro diagnostics to therapy including targeted delivery and regenerative medicine.
- It has to interface nanomaterials (surfaces, particles, etc.) or analytical instruments with "living" human material (cells, tissue, body fluids).
- It creates new tools and methods that impact significantly existing conservative practices
- It builds upon established and emerging academic and commercial strengths within the cluster such as the MNC and Schools of Medicine and Engineering.

In the near future, the second and the third points represent the biggest challenge for developing nano-medical tools and devices, because due to the novelty of the field no infrastructures of European scale have evolved yet, which create the necessary close proximity between experts and facilities of different areas. This is essential for innovations in this field, and to create the condition of the fast translation of research results to the clinic for patients.

To overcome this problem a distributed infrastructure of specialised European poles of excellence of complementary expertise is a necessary first step. Each centre or node should already have: excellence in one area of nano-technology (surfaces, particles, analytics, integrated systems, etc.), a biological and/or medical research centre and hospital, and (most importantly) companies, which have access to and knowledge of the relevant markets. The missing expertise should be quickly and very easily accessible within this network of distributed infrastructures and expert pools:

- ‘Dedicated clinics or hospital units developing and testing nanotechnology based tools, devices and protocols should be supported in the key places across Europe.’
- ‘In fact, a few technological/ clinical centres will have to specialise on the transfer of nanomedical systems from the bench to the patient’s bed – the “clinicalisation” of the nanomedical devices – to take into account its specificities.’
- ‘Testing patient’s bio-samples on nanobio-analytical systems, implanting an in vivo nanobio device or injecting a nanotech based drug carrier require a specific environment in dedicated clinics as close as possible to nanotechnology centres, which is not currently found in the usual university hospitals.’
- ‘These places will also be key support facilities for joint training of medical doctors and technology developers.’
- ‘A European infrastructure based on such places with complementary nanotechnological and biomedical excellences will have the capacity to build up scientific and technical expertise at the interface between “nano” and “bio” to speed up the development of tools and devices for the market.’
- ‘Upgrading and combining these places therefore is crucial for effective market oriented developments in nanobiotechnology, because speed is the most critical key factor of success for bringing nanomedical devices or methods to the market in a competitive situation.’

In August of 2002 the University of Wales Swansea (Swansea University) made a bold step in development of collaboration within Wales for Nanotechnology. Combining University of Wales Swansea (UWS), University of Wales Aberystwyth (UWA), University of Wales College of Medicine (UWCM) and Cardiff University (CU) with the objective to create the infrastructure for the development of a cutting-edge nanotechnology research centre at UWS. The centre brought together internationally-leading scientists, and achieved added value by creating new opportunities for research in emerging area of acknowledged importance. By definition, the centre is multi-faceted, focussing effort into new ‘boundary’ projects where the synergy of three key groups of staff from the School of Engineering (Chemical and Biological Process Engineering, and Electronic Engineering) and the Department of Physics, form the broad knowledge base; these groups, totalling over 50 researchers. Furthermore, inclusion of complementary research groups that were established in the newly created Clinical School, Biological Sciences, and the EPSRC Mass Spectrometry Unit based in the then Chemistry Department and the Welsh Centre for Printing and Coating have also be prioritised. The realisation of this centre was achieved through:

- The creation of a coherent physical space, housing specialist laboratories and research personnel acted as a ‘central hub’ to foster research interaction in a multidisciplinary environment where cross fertilisation of ideas, techniques and technologies flourish.
- The purchase of state of the art equipment to support nanotechnology research in several ‘boundary areas’. The new equipment, which had capabilities not presently available in Wales, or indeed internationally, brought together microscopy and spectroscopy and had applications in nano-fabrication. Scanning probe microscopes that allow structural, mechanical, electronic, optical and chemical properties of surfaces and interfaces to be probed on the nano-length scale under a variety of environments formed a powerful platform. High-speed cameras that permit the observation of processes on the nano-time scale in conjunction with scanning probe microscopes were required. The equipment complemented the existing instruments at Swansea.
- The appointment of talented research staff and research students working within the new, shared laboratories created the multidisciplinary environment and helped facilitate skill and knowledge transfer.
- Initiation of ‘boundary projects’ in the fabrication of nano-functional materials and devices, for example, bio-electronic systems, biological units, membranes, sensors, tissue engineering and biomedical materials. Manipulation of chemical, structural, electronic and optical properties of such systems on the nanoscale formed a central theme.
- Securing a long-term growth strategy for the Multidisciplinary Centre of Nanotechnology by continuous innovation leading to enhanced support from Funding Councils and Industry.
- Bringing international experts in nanotechnology to Wales to visit the new Centre and to work there for extended periods. Reciprocal visits of Centre staff and students to internationally leading nanotechnology laboratories.

- Creating a pan-Wales Centre for Nanotechnology where the instrumentation and facilities are open to researchers from all institutions of Higher and Further Education.

Collaboration, including joint project work, was undertaken with research teams from the UWCM, CU and the Physics Department at UWA built on successful collaborations that were already underway. They anticipated that the Centre's scanning microscopy-and-spectroscopy and nano-fabrication laboratories would be of particular interest to groups working in the fields of dermal wound healing and biomaterials (UWCM), organic thin films (UWA), nano-modelling and semiconductor and bio-chip technologies (UC). Furthermore, smaller groups who do not have critical mass or developing groups with potential in the field of nanotechnology were encouraged to participate.

The lead organization was the University of Wales Swansea a research-led institution. Of particular relevance to the proposal were its areas of strength and international recognition in Engineering and the Physical Sciences, which housed the nanotechnology expertise. The University recognised the need to support research selectively through the promotion and development of Centres with a critical mass of personnel and resources and an international profile. The University physically reorganized its Departments on campus to promote this strategy. The proposal was well-suited to take advantage of these developments. The proposed Centre for Nanotechnology resonated with the establishment of the Swansea Clinical School, in which there were recent staff appointments at senior levels in cognate biomedical areas. The University participated in forming all-Wales Networks of Excellence and the Centre for Nanotechnology forming a pivotal role acting as one of those networks. The development of a Multidisciplinary Centre of Nanotechnology on the UWS campus feeds into this strand of activities. Along with opportunities for interactions with local industry, through the established Technium project for knowledge exploitation, consistent with UWS' stated goals.

Links of the proposed programme with external schemes and initiatives are exemplified by the work of the two key strands, the Centre for Complex Fluids Processing (Chemical and Biological Process Engineering) and the Semiconductor Interface Group (Electronic Engineering). The former has been endorsed and funded by an EPSRC Platform Grant; an award given only to world leading groups to provide continuity for longer term research and international networking. The latter has been successful in attracting EPSRC and industrial funds to support nanotechnology projects within the electronics and sensing sector; research carried out by this group and the Power Electronics Centre (Electronic Engineering) was seen to be instrumental in attracting International Rectifiers and PureWafer, SMEs to set-up in Swansea. Both strands of research are also in receipt of a Higher Education Funding Council of Wales (HEFCW) funding, which has been awarded on the basis of technical excellence and a proven track record of successful collaboration with industry.

The rapidly developing area of nano-technology research area at the time was certain to be a growth area within Wales. At the time Cardiff University planned to create a multidisciplinary Research Institute for Micro and Nano-science (IMNOS) and it was seen that it would be vital for Swansea and the Cardiff centres to work closely together and co-ordinate their activities, based on their previous solid record of collaboration.

The MNC set up four key panels to govern over specific areas for the Centre:

- A core management panel that comprises of three senior academics with international research reputations at the highest level and extensive experience of programme that is responsible for programme management, finance and staffing.
- Multidisciplinary Research Panel responsible for shaping research strategy across the breadth of activities.
- Research Forum to allow creative input to the research direction and projects from all Centre participants including the Panel members, research staff and research students.
- International Expert Panel appointed to advise on scientific direction. Advice from interested industrial parties will be continuously sought at an early stage using existing mechanisms. Research Officers employed on the programme will be required to formally report their work bi-monthly and the UWS Graduate School Postgraduate Student Monitoring Scheme will be adopted for PhD students. These formal measures will be accompanied by Centre Seminar Days, where progress on all fronts can be monitored and discussed by all members of the Centre.

The aim of the recently funded (2009) Centre for NanoHealth (CNH) aim is to deliver the next generation of Healthcare via the application of Nanotechnology as described above. CNH will achieve this through research & development, demonstration and deployment, and Skills innovation system. In doing so, the goal of CNH is to underpin the development of skills and enterprise people required for Wales to realise its potential in an emerging nanotechnology sector.

CNH has identified that future healthcare lies in new novel technologies that permit early disease intervention, supported by new diagnostics and treatments in non-hospital environments e.g., the home, community clinic or local General Practitioners (GP) surgery. With the key being rapid intervention at the earliest possible instance for disease detection and treatment through the use of therapeutic devices, sensors, diagnostics and other applications.

The £20 million CNH project will firmly establish the region as a world leading interdisciplinary centre offering a Research and Development, Demonstration and Deployment, and Skills innovation system for NanoHealth, where basic research is fed into the Centre from the MNC and ILS in Swansea (see Figure 4.7).

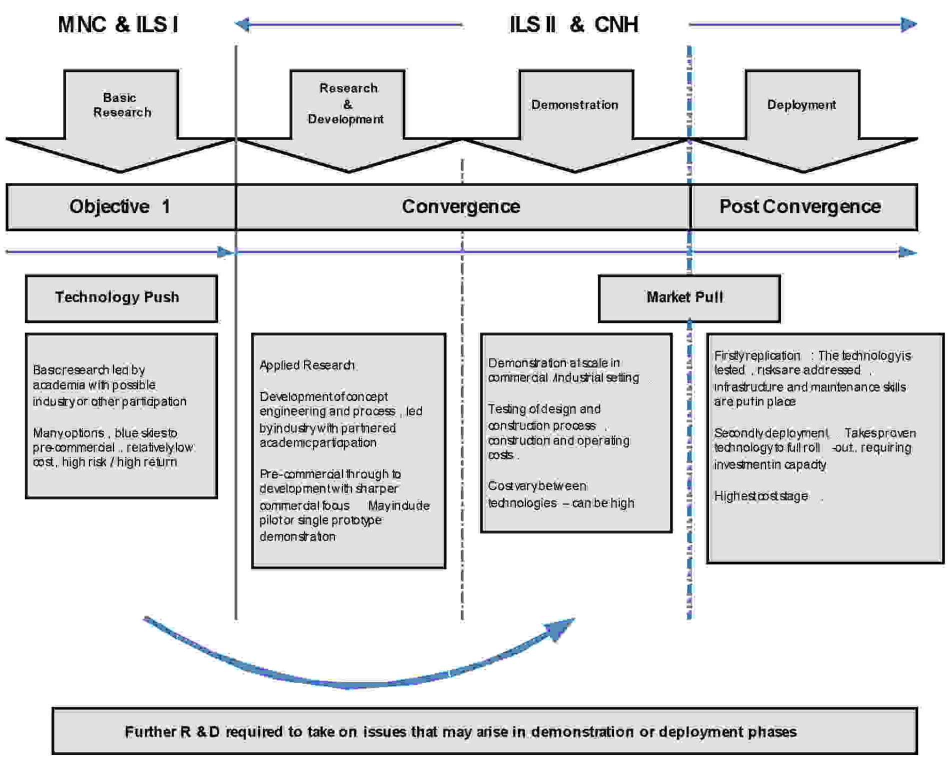


Figure 4.7: Innovation system adapted from: The Research and Development, Demonstration and Deployment and Skills Innovation System (DTI 2007).

CNH brings together, within a single physical and state of the art facility, Clinicians from the local Trust Hospital, Life Scientist Researchers from Swansea University's School of Medicine and Engineers/Physical Researchers from Swansea's School of Engineering to work closely with business to deliver innovations in healthcare. The CNH goal is to be a multidisciplinary environment integrating specialist facilities for nano-fabrication, nano-characterisation, and biomedical development, coupled with the added benefit of business incubation space, which is adjacent to a clinical research unit and hospital. The Centre aspires to support the ambitions of the Science Policy by delivering personalised medicine solutions and enhanced diagnostics capabilities, for treatment in the home and community outlets, not only support the economic development agenda but also transform the way in which healthcare is delivered.

The Centre for NanoHealth (Figure 4.8) is funded through Convergence funding and is tasked with not only research but also to assist Welsh SMEs to work on the development of new healthcare technologies from initial concept to the point where they can be deployed commercially. Within Wales the private sector, and in particular Welsh SMEs, are not likely to be able to invest adequately in the initial R&D area due to the lack of funds, preventing them from capitalising on any returns relative to the costs and risks involved. The role of the CNH is to address this failure by providing the region with the required infrastructure to facilitate a level of investment from the private sector to develop new technologies in the area of NanoHealth; ultimately returning wider economic, health and environmental benefits to the Southwest Wales region.

Figure 4.8: Institute of Life Science II and Centre for NanoHealth, Swansea University.

CNH will provide a world-class infrastructure for the commercialisation of science based around one of the three key themes targeted by the Science Policy: Health. It will actively attract inward-investing R&D activity and create a pipeline of opportunities, which it can incubate and develop. Adding to developing a regional 'critical mass' of activity, supporting an emerging life science cluster and linking directly to healthcare provision in Wales.

4.5 Bibliography

- Abbey JV, Mainwaring L. and Davies G.H. 2008, "Vorsprung durch Technium: building a System of Innovation in South West Wales', Regional Studies, Vol. 42, Iss.2, pp. 281 – 293.
- Adams W., 2007, Discussion of the Smalley Institute, Meeting at Rice University.
- Cientifica, 2006, "VCs to Nanotech: Don't Call Us!" EU Venture Capital Report, www.cientifica.eu[3] . Castell W., 2010, "Welcome Address Nano4Life Conference", Wellcome Trust London.

[3] http://www.cientifica.eu/

- Cientifica, 2008, "Gold for good; Gold and nanotechnology in the age of innovation", Gold Council Report, www.cientifica.eu[4] .
- DTI, 2007, "Energy White Paper: Meeting the Energy Challenge", Department of Trade and Industry, UK Government.
- EmTech Research, 2005, "2005 Nanotechnology Industry Category Overview" Ann Arbor, MI: EmTech Research (a division of Small Times Media).
- Freedonia Group, 2003, "Nanomaterials to 2008 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders", Study No. 1887, pp. 122-217.
- Hobson D., 2009, "Commercialization nanotechnology", John Wiley & Sons, Inc., WIREs Nanomed Nanobiotechnol, Vol. 1, pp. 189–202.
- Huang Z., Chen H. and Roco M., 2004, "International nanotechnology development in 2003: Country, institution, and technology field analysis based on USPTO patent database", Journal of Nanoparticle Research Vol.6, pp. 325–354.
- Kanellos M., 2005, "Nano visionary Richard Smalley dies", CNET News, www. news.cnet.com.
- Lux Research, 2004, "Sizing Nanotechnology's Value Chain - New Report", New York: LuxResearch, Inc.
- Lux Research, 2006, "Statement of Findings: Benchmarking U.S. States in Nanotech", New York: Lux Research, Inc.
- Lux Research, 2008, "Nano Tech Report", 5th Edition, New York: Lux Research, Inc.
- The State of Texas Office of the Governor, 2008, "Texas Nanotechnology Report 2008", www.texaswideopenforbusiness.com, Accessed 2008.
- www.belasnet.be, Accessed 2009
- www.nano.gov, Accessed 2009.

[4] http://www.cientifica.eu/

Chapter 5

Research Methodology[1]

5.1 The Hypothesis

Can a Region Lever Participation in a Global Network to Accelerate the Development of a Sustainable Technology Cluster.

The aspiration of participation in the Texas/UK Collaborative is not solely to produce a regional innovation engine but a sustainable innovation system. The thesis sets out a definition of a sustainable innovation system i.e., a triple helix with the key strands of People, Culture, and Environment bound together with good Science and Governance as cross cutting themes in Figure 5.1. The purpose of the research is to objectively measure the impact of participation of the Texas/UK Collaborative on an emerging knowledge culture in the Southwest Wales region on and around the Swansea University campus.

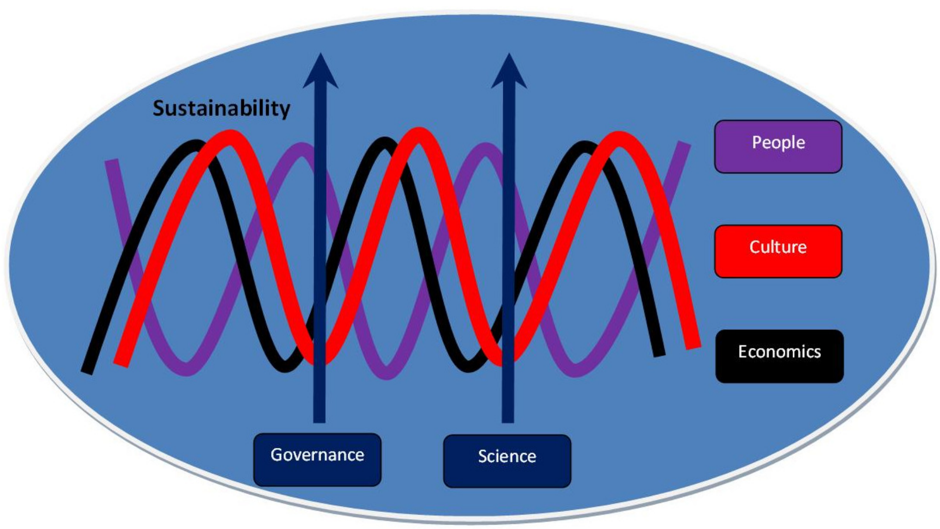


Figure 5.1: Sustainable innovation system.

[1]This content is available online at <http://cnx.org/content/m43449/1.3/>.

This thesis is a study of how a region can lever participation in a global network to accelerate the development of a sustainable technology cluster Figure 5.1 captures the dynamics that influence the strategic development of a cluster.

The key dynamics are considered to be a global sector, product innovation capacity in the sector in the sub region and knowledge company activity in that sector in that region. Each of these dynamics evolves with time and each has stages of development. The "Dead Mouse" analogy has been used to illustrate the phases of development of the three key dynamics.

Any emerging sector has itself to bridge "Death Valley". Figure 5.2 illustrates products and sectors at various stages of their life cycle. Video tape (VHS) is clearly at the end of the cycle and is now only used by a few enthusiasts; fixed line internet is at the cusp of its decline. Indeed mobile phones are arguably stating to plateau, where hybrid vehicles could be said to have past "Death Valley" and are posed for rapid growth. Nanotechnology and NanoHealth as a technology and a sector is probably yet to successfully navigate "Death Valley" but many commentators predict that it will have dramatic impact on a range of markets and sector.

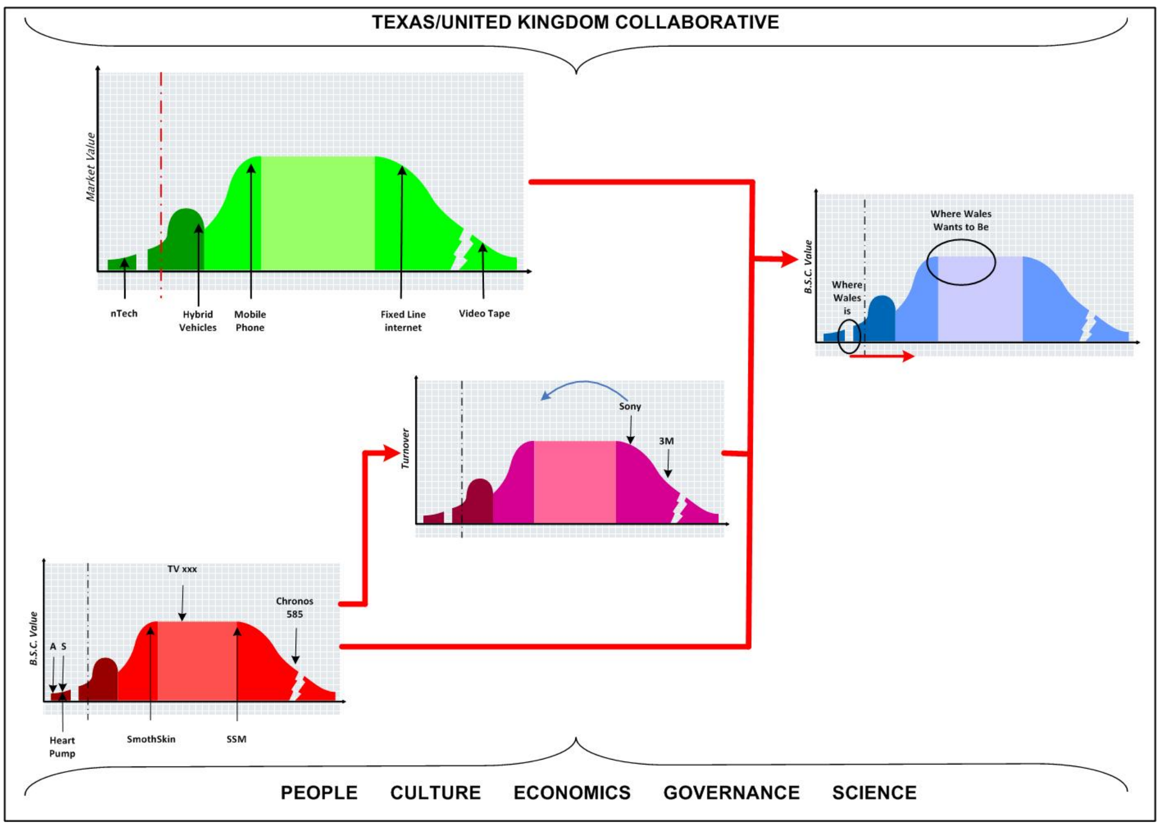


Figure 5.2: The "Dead Mouse" sector, product, company life cycles based on Moore (2005).

The hypothesis here assumes that Wales has identified Nanotechnology and NanoHealth as a sector that it is targeting. Major infrastructure investments have been made for example; Higher Education Funding Council of Wales (HEFCW) has invested in the Multidisciplinary Nanotechnology Centre (MNC) focused at Swansea University but involving a number of research led institutions. In 2009 the CNH was funded using European Regional Development Funds (ERDF) through the Convergence Program. Wales as a small region has therefore wagered a great deal on the fact that Nanotechnology as a sector will safely navigate "Death Valley" and will emerge creating major new markets feeding the regional economy.

The purpose of this thesis is to study whether participating in a global network thereby linking to other world class centres will assist the development of the NanoHealth in the region. The thesis as already discussed assumes that there are five key components that essential prerequisites namely, people, culture, economy, good science and good governance and the following sections seek to measure how these five components have been influenced by participation in the Texas/United Kingdom Collaborative in this context to the emerging sector.

The second dynamic in the creation of a sustainable cluster is the product innovation capacity. This is again dependent on the five key components, People, Culture, Economics, Governance and Science. The "Dead Mouse" is again used to illustrate the phases of any product innovation life cycle. It has its "Death Valley", rapid growth phase followed by plateau and decline. A sustainable cluster is dependent on a constant flow of product innovation, which in turn relies on the five key components. This chapter seeks to identify how participation in a global network, the Texas/United Kingdom Collaborative, has influenced product innovation capacity. The third dynamic is that of knowledge company activity these companies again have phases of development they themselves are confronted with "Death Valley" can themselves grow rapidly plateau and any company is always confronted with the possibly of decline. It is the function of a board of directors to strategically manage these companies thorough these troubled waters. The Chapter seeks to measure the influence of participation in a global network on knowledge company activity. It looks at companies of all sizes from the sole inventor to the multi national and also considers the dynamic between these organizations.

The hypothesis is that a sustainable cluster needs to select its sector carefully it needs to have excellent product innovation capability and a wide range of knowledge company activity. All of these are totally dependents on the five key components. People are critical they have to be appropriately skilled and those skills need to be constantly refreshed they need to be motivated and rewarded, recruited and retained. The culture even though difficult to measure is all important, success has to be recognised and celebrated, failure forgiven and the ability to learn from mistakes embedded. The economic considerations allow value to be grown and reinvested in the agenda to ensure that today's success fuels tomorrow's activity. All of this is based on aspects of the science base that is truly world class whilst recognising that no one can be expert in all and that partnership of mutual benefit on the global basis is essential. All of this will not deliver optimally without good governance. The public sector and the private sector must recognise their roles, strengths and weaknesses and work together to allow good people to flourish.

This section is intended to study and measure the influence of the TX/UK Collaborative on the above thereby testing the thesis of how a Region can lever participation in a global network to accelerate the development of a sustainable technology cluster.

5.2 Methodology

The methodology used to generate the data to investigate the research question was a combination of qualitative and quantitative research supported and supplemented by semi-structured interviews. A mixed methodology approach was applied as the research question could be most comprehensively informed by drawing together the widest possible range of data from across the samples.

Opinion Data derived from questionnaire responses from actors who are components of a member group active in the Texas/UK Collaborative compared with responses to the same questionnaire from a non-member control group who are not active in the collaborative. These member and non-member groups exist in the same university and on the same campus and indeed the same departments. They therefore undertake their activities in the same environment with the significant difference of participation or non-participation in the Texas/UK Collaborative initiative. The qualitative data generated reflected the opinions relating to value benefits of participation in a global network such as the Texas/UK Collaborative, from the perspective of individual academic/researcher actor. The non-member group acted as a control group to allow unbiased comparison. In addition questionnaires responses were collected from participants from Texas that engaged in the Swansea related initiatives within the Texas/UK Collaborative. Whether or not the data shows the participation in the collaborative to be a success from a Swansea perspective it will be short lived unless it is similarly regarded from a Texas perspective. The Texas questionnaires were evaluated with particular regard to their perceived derived value from the Swansea participation. All of these questionnaires analyzed the impact of the Texas/UK Collaborative on and from the perspective of the individual.

A second category of questionnaire was designed to collect different but supportive data. A group of 68 knowledge based companies were identified subject to the criteria of being active in the nanotechnology field; Nanotechnology being one sector where the Texas cluster is recognised as world leading. The purpose of this study being to identify the needs of the UK based nanotechnology companies and their perception of value that participation in the Texas/UK Collaborative could deliver.

Along side the qualitative data generated by the questionnaires quantitative data was harvested to reflect the academic entrepreneurial and economic impact of participation in the Texas/UK Collaborative. Traditional Key Performance Indicators (KPI's) were used to measure impact similar to those that might be applied to the RAE or in economic impact analysis. Traditional KPI's such as employment, patents filed, new start ups, increasing profits and turnover are of course important and the impact of the collaborative were measured. However efforts were made to measure other changes reflecting the development of an open innovation culture of the region critical to a sustainable innovation system.

A subset of the membership of the four constituencies was interviewed in a semi structured manner i.e., the member group, non member group, partners based in Texas and the representatives of knowledge industries relevant to nanotechnology. The purpose of these interviews was to validate data derived from the questionnaires and secondly and possibly more importantly to further develop dialogue relating to the positive evolution of an open innovation philosophy in individuals, organisations and the region. In particular were the experiences of working within the collaborative leading to a more open global collaborative and multidisciplinary approach.

e-inform software program was used to create two surveys. The first was a 47 question Likert scale survey to measure the opinions and level of agreement to the survey questions of academic participants of the Texas/UK Collaborative. The second was a 37 question Likert scale survey of a control group of non-participants of the Texas/UK Collaborative initiative. The Likert scaling was chosen as it is widely used scale in survey research.

NOTE: Methods in educational research: from theory to practice, 2006, Marguerite G. Lodico, Dean T. Spaulding, Katherine H. Voegtle.

The e-inform software was also chosen due to the ease of analysis and breakdown of survey respondents and ability to distribute online on a secure server.

In addition to the two surveys conducted on participants and non-participants of the Texas/UK Collaborative initiative, a 21 question Likert scale survey was distributed online to the Nanotechnology Technology Transfer Network a United Kingdom based network of both national and international companies engaged in nanotechnology development. The survey questions focused on the assessment of individual companies strategic needs for competing in emerging nanotechnology market and their strategic view of the importance of innovation.

The results provide a qualitative comparative analysis obtained from data field surveys. The sizes of the samples are presently limited and no attempt has been made to draw any statistical inference on uncertainty at this early stage. However, the data provides a powerful indication of the comparative judgements exercised by the various survey groups. In the fullness of time it would be appropriate to consider an extension of the survey sample, but for the present purposes it was judged to be sufficient to draw comparative conclusions.

The use of semi-structured interviews was chosen due to the fact that they enhance the data that were derived from survey respondents in this study. These were conducted on a random sampling of Texas/UK Collaborative academic participants. This allowed for considerable flexibility about how and when questions were raised, thusly allowing for considerable amount of additional topics to be built in to the responses, inclusive to this, all interviews were transcribed.

NOTE: A Rationale for the Use of Semi-structured Interviews, 1990 Volume: 28, Issue 1, p63-68, Journal of Educational Administration, John Carruthers.

5.2.1 Knowledge Transfer Network (KTN) Questionnaire

A knowledge transfer network's primary mission is to put firms and innovators in contact with the knowledge and funding that they need to bring new products and processes to market (www.ktn.com 2009).

The UK government has set up Knowledge Transfer Networks which are single over-arching national networks in a specific field of technology or business application which brings together people from businesses, universities, research, finance and technology organisations to stimulate innovation through knowledge transfer. They are funded by government, industry and academia bringing together diverse organisations and providing activities and initiatives that promote the exchange of knowledge and the stimulation of innovation in these communities (www.innovateuk.org 2009). These networks have been created to steer the flow of knowledge within, in and out of specific knowledge areas.

The objective of a Knowledge Transfer Network is to improve the UK's innovation performance by increasing the breadth and depth or the knowledge transfer of technology into UK-based businesses and by accelerating the rate at which this process occurs. The Network must, throughout its lifetime, actively contribute and remain aligned to goals of the Technology Strategy Board.

Within the overall objective of accelerating the rate of technology transfer into UK business, the specific aims of a Knowledge Transfer Network include the following:

- To deliver improved industrial performance through innovation and new collaborations by driving the flow of people, knowledge and experience between business and the science-base, between businesses and across sectors;
- To drive knowledge transfer between the supply and demand sides of technology-enabled markets through a high quality, easy to use service;
- To facilitate innovation and knowledge transfer by providing UK businesses with the opportunity to meet and network with individuals and organisations, in the UK and internationally;
- To provide a forum for a coherent business voice to inform government of its technology needs and about issues, such as regulation, which are enhancing or inhibiting innovation in the United Kingdom.

The mission of the Nanotechnology Knowledge Transfer Network (NanoKTN) is to accelerate innovation in nanoscale technologies, encouraging and supporting organisations to collaborate and share knowledge with key partners in attractive end user markets to achieve growth of the UK nanotechnology sector. With the end aim of leading to a dynamic, vibrant, application focussed nanotechnology based industry that gains competitive advantage by transferring and sharing knowledge with key end user sectors to develop and commercialise products.

The key objectives of this sector network are to:

- Improved industrial performance through adoption of nanotechnology.
- Increased knowledge transfer between companies and the research base.
- Enabling interactions through networking and event organisation.
- Providing thought leadership and industry input into UK policy and strategy.

5.2.1.1 The UK position

Within recent years in the UK there has been significant investment into both infrastructure and R&D, through the Government's Micro and Nano-Manufacturing initiative, with £150m joint investment split approximately 50:50 in micro (including micro fluidics and micro electro mechanical systems) and nanoscale development. The NanoKTN forms part of the Technology Strategy Board's nanoscale technologies strategy for 2009-2012 and plans to build on, and be complementary to, the existing nano infrastructure and knowledge networks (www.innovateuk.org 2009).

5.2.1.2 KTN Questionnaire

The KTN questionnaire was published on the NanoKTN website for a period of one month, at the end of the month there were 63 respondents all of whom are companies working in the scope of nanotechnology physically located within the United Kingdom. The key component of this questionnaire was what does industry want and perceive to need in regards to driving forward their innovation capacity.

Small and medium enterprises (SMEs) account for 97% of businesses and over 50 % of employment worldwide. A thriving SME sector can drive growth and jobs in developing countries. (www.ifc.org, 2009) Small to Medium Enterprises (SME's) drive the economy reference OECD. Within this study a definition of a small company has been adopted as being an undertaking employing fewer then 100 employees with annual revenues of £10m or less (Figure 5.3). While it is acknowledged that the European Commission has a specific SME definition, as presented in Figure 5.4(Europa 2009) however for the purpose of this study a specific focus on small enterprises was required, hence the alternative definition as above. This provided a dichotomy of small and large companies.

Company Catagory	Headcount: Annual Work Unit (AWU)	Annual Revenue
Large	>100	£10 million – > £20 million
Small	<100	< £1 million - £10 million

Figure 5.3: Definition of Small and Large Companies for this Study.

THE NEW THRESHOLDS *(Art. 2)*

Enterprise category	Headcount: Annual Work Unit (AWU)	Annual turnover		Annual balance sheet total
Medium-sized	< 250	≤ €50 million (in 1996 € 40 million)	or	≤ €43 million (in 1996 € 27 million)
Small	< 50	≤ €10 million (in 1996 € 7 million)	or	≤ €10 million (in 1996 €5 million)
Micro	< 10	≤ €2 million (previously not defined)	or	≤ €2 million (previously not defined)

Figure 5.4: European Union Threshold Indicators of an SME, Europa, 2009 (www.ec.europa.eu 2009).

5.2.2 Tools and Approaches

Figure 5.5 shows the primary thrust of each of the research tool used. The primary purpose of the secondary data research was to identify the relevant scientific research and in particular pockets of world class activity. Despite the primary focus on science useful information was generated on the four components People, Culture, Economics, and Governance. The knowledge transfer questionnaire was primarily focused on generating information relevant to the economic component and in particular, how nanotechnology companies felt that their quest to create value could be assisted by collaboration with university. The collaborative questionnaire was designed to study aspects relating to people and culture in the context of Swansea University whilst also mapping the scientific strengths of the activity. Following completion of the collaborative questionnaire and studying its results short comings were identified and it was recognised that an opportunity had been lost in generating information relevant to the economic component. A supplemental questionnaire was designed with a specific purpose of harvesting that economic data. Following completion of the first four studies, semi structured interviews were conducted to create greater granularity of the issues relating to governance.

	Secondary Data	Knowledge Transfer Networ Questionnaire	Texas United Kingdom Collaborative Questionnaire	Supplemental Questionnaire	Interviews
People	★	★	★★★	★	★
Culture	★	★	★★★	★	★
Economics	★	★★★	★	★★★	★
Governance	★	★	★	★	★★★
Science	★★★	★	★★	★	★

Figure 5.5: Component relevance by research approach. Legend: 1 star = Relevant; 2 stars = highly relevant; 3 stars = extremely relevant.

5.2.3 Nanotechnology Knowledge Transfer Network Questionnaire

The details of the questionnaire are available upon request from the author; however, the cover page is shown in Figure 5.6.

Centre for NanoHealth Questionnaire

One of the biggest challenges facing the future of healthcare is enhancing early intervention in diagnosing and treating diseases in non-hospital environments; in the home, community clinic or local doctor's surgery, and in the development of personalised medicine.

The collaboration between Swansea University's Schools of Engineering and Medicine in partnership with industry and Abertawe Bro Morgannwg University Trust (ABMUT), the largest NHS Trust in Wales, to apply Nanotechnology to Healthcare offers a unique opportunity to make a step change in the way healthcare is approached. Nanotechnology has an increasingly important and strategic role to play in furthering our ability to detect and treat disease, and this has been central to the work of the University's Multidisciplinary Nanotechnology Centre (MNC) in the School of Engineering. Through a strategic alliance with the School of Medicine's Institute of Life Science (ILS), research using Nanotechnology is underway that is planned to lead to novel devices, processes and sensors essential for the earliest detection of disease onset, developed for point of care, near-patient and in vivo application.

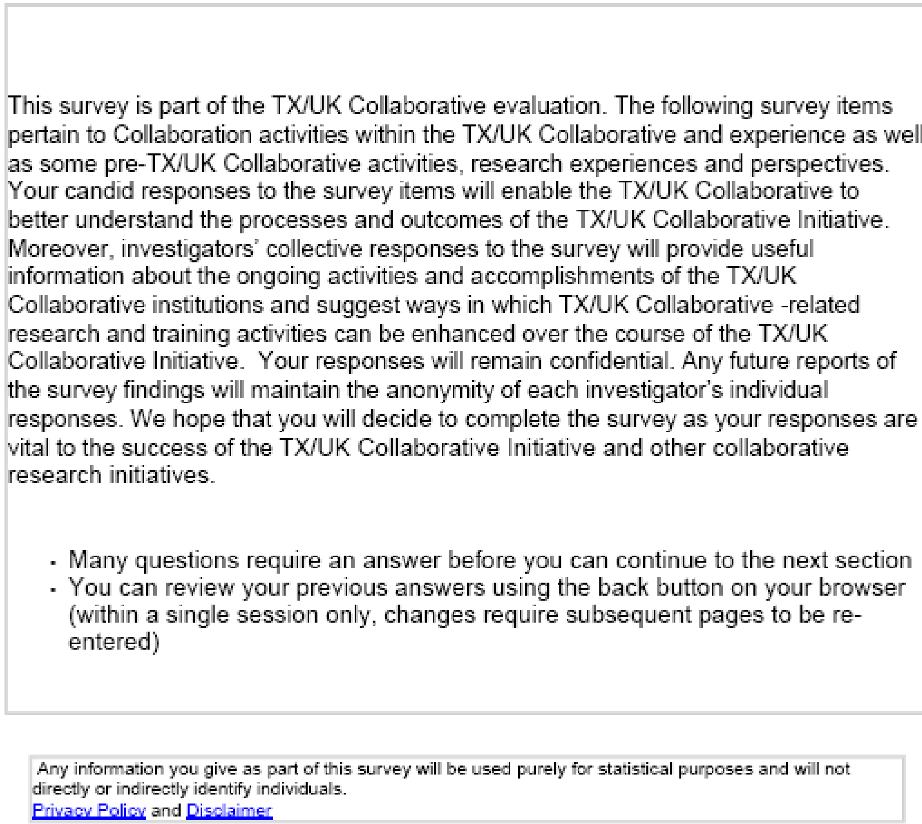
Nano-devices and Nano-biosensors will permit the detection and measurement of biomarkers present in fluid or tissue samples at a level of sensitivity far beyond current detection methods; in the parts per billion range. Through an alliance between the MNC, ILS, NHS and industrial partners we aim to develop the Centre for NanoHealth (CNH), a unique concept co-locating engineers and biomedical scientist in a single Centre, with access to patients and clinical materials to create a pioneering, integrated facil ity for delivery of Research and Development in NanoHealth.

The CNH will be an open access centre, with state of the art nano-fabrication, nano-manipulation and nano-characterisation resources, together with cell and molecular discovery, characterisation and production laboratories, and high-volume printing and coa ting facilities for manufacturing scale-up. The CNH will also offer business and IP support, with facilitated access to UK and Global networks.

Figure 5.6: KTN questionnaire cover page.

5.2.4 Texas – United Kingdom & Collaborative Questionnaire

The details of the questionnaires are available upon request from the author; however the cover pages were as shown in Figure 5.7 and Figure 5.8.

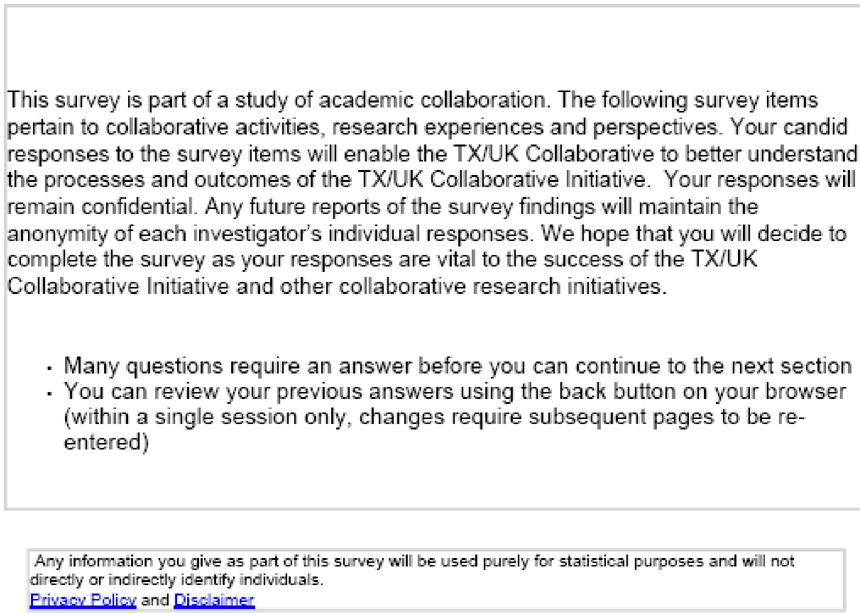


This survey is part of the TX/UK Collaborative evaluation. The following survey items pertain to Collaboration activities within the TX/UK Collaborative and experience as well as some pre-TX/UK Collaborative activities, research experiences and perspectives. Your candid responses to the survey items will enable the TX/UK Collaborative to better understand the processes and outcomes of the TX/UK Collaborative Initiative. Moreover, investigators' collective responses to the survey will provide useful information about the ongoing activities and accomplishments of the TX/UK Collaborative institutions and suggest ways in which TX/UK Collaborative -related research and training activities can be enhanced over the course of the TX/UK Collaborative Initiative. Your responses will remain confidential. Any future reports of the survey findings will maintain the anonymity of each investigator's individual responses. We hope that you will decide to complete the survey as your responses are vital to the success of the TX/UK Collaborative Initiative and other collaborative research initiatives.

- Many questions require an answer before you can continue to the next section
- You can review your previous answers using the back button on your browser (within a single session only, changes require subsequent pages to be re-entered)

Any information you give as part of this survey will be used purely for statistical purposes and will not directly or indirectly identify individuals.
Privacy Policy and Disclaimer

Figure 5.7: TX/UK collaboration questionnaire cover page.



This survey is part of a study of academic collaboration. The following survey items pertain to collaborative activities, research experiences and perspectives. Your candid responses to the survey items will enable the TX/UK Collaborative to better understand the processes and outcomes of the TX/UK Collaborative Initiative. Your responses will remain confidential. Any future reports of the survey findings will maintain the anonymity of each investigator's individual responses. We hope that you will decide to complete the survey as your responses are vital to the success of the TX/UK Collaborative Initiative and other collaborative research initiatives.

- Many questions require an answer before you can continue to the next section
- You can review your previous answers using the back button on your browser (within a single session only, changes require subsequent pages to be re-entered)

Any information you give as part of this survey will be used purely for statistical purposes and will not directly or indirectly identify individuals.
Privacy Policy and Disclaimer

Figure 5.8: Collaboration questionnaire cover page.

5.2.5 Supplemental Questionnaire

During the study it was identified that more in depth information was needed to better understand the collaborations, nature of the researchers involvement in the identified collaboration, the nature of the researchers interest of the collaboration, the type of partnership of the collaboration whether it's a one to one or multi partner collaboration, the local of the collaboration and finally the resulting outcome of the collaborations that occurred within the control researchers and the Texas United Kingdom Collaborative researcher. An equal proportion of fourteen of the control researchers and fourteen of the Texas United Kingdom Collaborative researchers were selected to complete these questions, of the two groups of fourteen, an equal number of professors (6 each) and researchers/lecturers (8 each) were selected.

5.2.6 Interviews

As presented in Table 5.2 and Figure 5.5 (theme mapping and tools & approaches) the primary thrust of the interviews was exploration of governance in establishing and developing regional knowledge based clusters. Prior to commencement of the study Dr. Malcolm Gillis, the former President of Rice University, Houston, Texas and Chair of the Texas/United Kingdom Collaborative was interviewed at length. The purpose of this interview was to gain an in-depth understanding of both the history and reasons for establishing the collaborative and the aspirations held by the stakeholders for the collaborative in particular the interview focused on the key question" what would success look like?" in the opinion of the chairman of a major international knowledge based collaborative.

Following the desk-based and questionnaire study, semi-structured interviews were conducted with individuals who played a leading role in the Collaborative. Six key participants were interviewed in Texas and

6 from Wales. The purpose of these interviews was twofold; firstly to validate conclusions derived from the harvested data and clarify issues of ambiguity and detail; and secondly to tease out opinions related to issues of governance. Many of these governance issues are sensitive in nature and can be political with both a big P and small p. These governance issues are arguably even more important in a small community of Wales where politicians and opinion formers are very accessible. This offers both strengths and weaknesses and the questionnaires had identified strengths, weaknesses, opportunities, and threats in the context of issues related to governance.

The approach taken to structure these interviews involved consideration of three stakeholder groups within each region: "Political" Observer, Academic Facilitator, and Coalface Researcher. The nature of these roles and rationale for this breakdown is shown in Table 5.1.

Stakeholder	**Nature**	**Rationale**
Political Observer	Stakeholder involved in the knowledge life of the region, providing strategic influence across regional actors, though with no institutional ties.	To explore the governance issues affecting strategic development of the regional cluster.
Academic Facilitator	Senior institutional stakeholder capable of influencing strategic direction of the research agenda, though with no/limited individual academic activity	To explore issues of aligning institutional imperatives and operational delivery with regional objectives.
Coalface Researcher	The individual academic involved within the activities delivering discreet projects, though may have some institutional influence and responsibility for research group(s).	Explore the boundaries of institutional facilitation and hindrance.

Table 5.1: Stakeholder rationale.

5.2.7 Deconstructing the Components

As described in star Table 5.2 particular aspects of the thesis were the focus of individual studies in the context of the five components. The following figure explains how and where sub-hypothesis was tested.

Components	**Sub - Hypothesis**	**Primary Research Approach**	**Questions TX/UK & Control Group**	**KTN Questionnaire**
			continued on next page	

Science	Science is Multi-disciplinary	Questionnaire/RAE	Graph C	NONE
Science	There has to be World Class Science	Questionnaires	Graph A	Q4, Q10j, Q14a, Q17b
Science	Facilities are both relevant to Science & Industry	Questionnaires	Graph G	Q7a, Q7b, Q7d, Q7e, Q7f,Q7i, Q7n, Q7o
Science	Relevance	Questionnaires	Graph D	Q7h, Q9a, Q9e, Q10a
People	Openness to academic and commercial domains (Openness)	Questionnaires	Graph D, E, I, P	Q7i, Q10d, Q10i, Q12-All
People	Need to be themselves collaborative (Collaborative)	Questionnaires	Graph D, E, I, P	Q 9b
People	Do they work in networks (Local, National, International) (Global)	Questionnaires	Graph H, L	Q7j, Q10j, Q17a
People	Need to engage & Value Multidisciplinary work. (Multidisciplinary)	Questionnaires	Graph C, I, P	Q 9c, Q9d
People	Supply of Talent	Questionnaires	Graph A, Q	Q7c, Q7g, Q10e
Culture	Research Environment supports and values Multidisciplinarily	Questionnaires	Graph C, I , N	Q9h, Q11-All, Q13-All
Culture	Colleagues recognize mutual beneficial collaboration (Institution & Away)	Questionnaires	Graph F, H, N, O	Q9d, Q9e, Q10d

continued on next page

Culture	Within the Institution the opportunity in the Wider World is Recognized	Questionnaires	Graph G, J, N	Q7j, Q9f, Q9j, Q17a
Economics	Science is in Growth Sector	KTNQ/Interview	Graph B	Q5, Q7m, Q10a, Q20
Economics	Chrysalis of Regional Sectoral Activity (Deal Flow)	KTNQ/Interview	None	Q1,Q2,Q3,Q6
Economics	Strategic Governmental Support	KTNQ/Interview	None	Q7k, Q10k
Economics	Access to Markets	KTNQ/Interview	None	Q3,Q4, Q7l, Q10f
Governance	Regional coherence (Access to Player)	Interviews/Questionnaires	Graph L	Q10f, Q14g, Q15
Governance	Institutional Responsiveness and ability to evolve	Interviews/Questionnaires	Graph J	Q10a, Q10c, Q10g, Q10h,
Governance	Embedded in Institutional Strategic Plan	Interviews/Questionnaires	Graph E	Q14b-f, Q15, Q9k

Table 5.2: Theme mapping.

The five components were broken down into sub-hypothesis then the primary research approach was identified i.e., Knowledge Transfer Questionnaire (KTNQ), the Texas/United Kingdom Questionnaire, Control Questionnaire, or interviews then tagged to the relevant data collected.

5.3 Bibliography

- Carruthers J., 1990, "A Rationale for the Use of Semi-structured Interviews", Volume: 28, Issue 1, p63-68, Journal of Educational Administration.
- Lodico M. G., Spaulding D. T., Voegtle K. H., 2006, "Methods in educational research: from theory to practice".
- www.ec.europa.eu[2] , Accessed 2009.
- www.ktnetworks.co.uk[3] , Accessed 2007.
- www.ifc.org[4] , Accessed 2009.
- www.innovateuk.org[5] , Accessed 2009.

[2]http://www.ec.europa.eu/
[3]http://www.ktnetworks.co.uk/
[4]http://www.ifc.org/
[5]http://www.innovateuk.org/

Chapter 6

Results[1]

6.1 Secondary Data

By looking at the regional academic publications output, bibilometrics and expertise that are accessible to companies. Kostoff et al. 2007 looked at the breakdown of nanoscience/nanotechnology article production by countries in percentage shares for the same three selected years Figure 6.1. The numbers in parentheses above the bars are actual numbers of papers produced for the year in question. Kostoff argues that over the time period of 1991 to 2005, the United States' and Japan's shares of global nanotechnology/nanoscience publications dropped (the US from 36% to 23%, and Japan 16.5% to 12.5%), as countries that were not as prolific at the beginning of the 1990s grew rapidly over the course of the decade, notably, China and South Korea both published about forty times more research articles in 2005 than in 1991 (Kostoff et al. 2007). The other leading countries increased their output by at most five times, although quantity of publications is a metric the quality of the publications and relevance is key to both small and large companies as can be seen in Figure 6.6 and the locations that were chosen as areas of operation.

[1] This content is available online at <http://cnx.org/content/m43450/1.1/>.

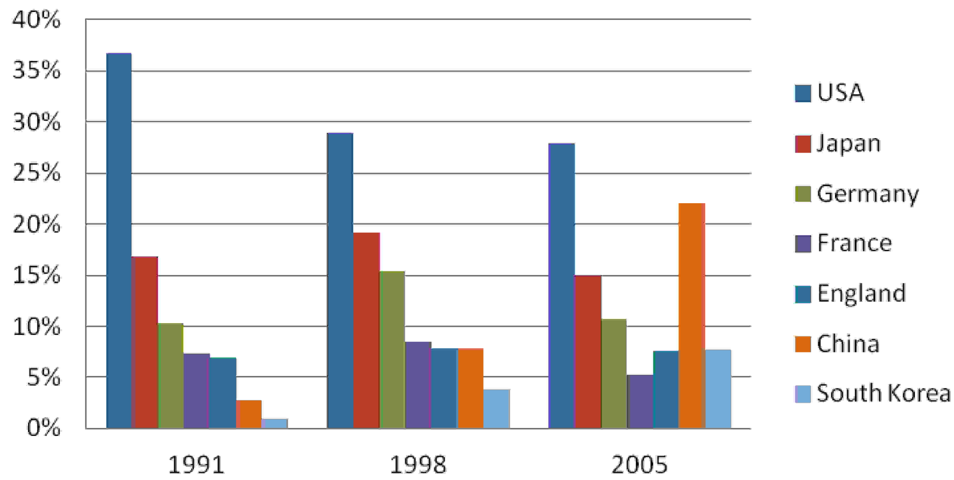


Figure 6.1: Percentage of total nanotechnology papers by country (Global nanotechnology research metrics (Kostoff et al., 2007).

At the global level, analyses have already been undertaken, usually in the context of global competitiveness, of which nations are assuming leadership in nanotechnology publications and patenting (Huang et al. 2003, NMAB 2006, and Kostoff et al. 2007). For example, Youtie et al. (2008) find that Europe, the US and Japan, as might be expected, are prominent in terms of the number of nanotechnology publications (Figure 6.2). However, nanotechnology publications in several other Asian countries is growing at rapid rate, especially in China, which is now the world's second largest producer of nanotechnology research publications after the United States (Shapira and Wang 2009). The rise of China in the new domain of nanotechnology represents a significant change in the global technology development landscape, especially as institutional, regulatory, commercialization, and socio-economic frameworks differ in China from those typically found in fully developed economies. Nanotechnology R&D is also emerging in selected other developing countries, including in Latin America (Kay and Shapira 2009), although generally most developing countries have limited capabilities not only to undertake R&D in nanotechnology but also to manage and regulate its deployment (Burgi and Pradeep 2006).

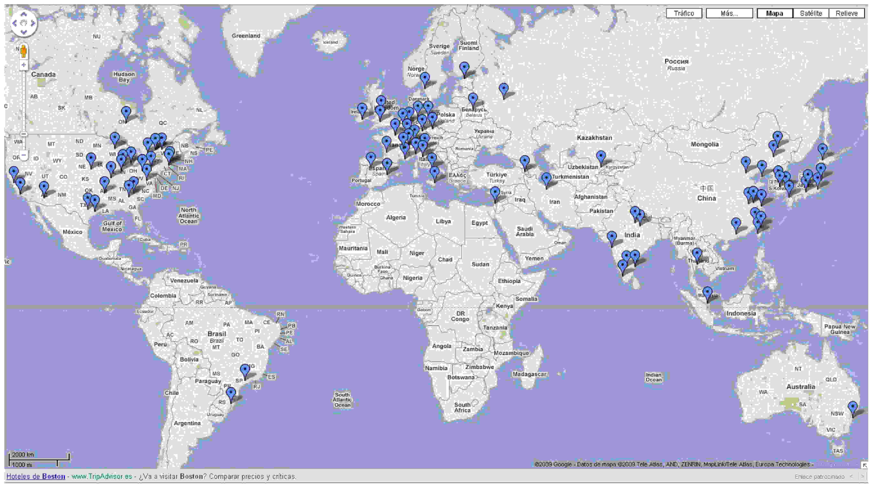


Figure 6.2: Worldwide overview of the places where there are research groups working in the field of nanotechnology based on 1,200 abstracts of 355 authors that have published since 1999 (www.nanopaprika.eu 2010).

6.1.1 Peeling the "Nano" Onion

For the purpose of this study it is important to peel the layers back to reveal the core local and academic Key Performance Indicators (KPIs) for this study. Although there has been work done in relations to identifying bibilometrics and citations of singular universities and in the context of the USA; States with publications in nano; little work has been done to look at Swansea University and in particular Wales in the context of the United Kingdom over a period of time. Though Swansea University is located within Wales and that Wales is within the United Kingdom it is important to identify these relevant outputs.

It can be seen in Figure 6.3 that at the onset during the period of 2002 – 2004 Swansea made up 22% of Welsh and 25% of the United Kingdom publications in "nano" interestingly at the same period of time Swansea University was awarded funding for the Multidisciplinary Nanotechnology Centre. It can also be seen that over the following periods 2004-2006 and 2006-2008 that the journal article outputs in Swansea, Wales and the United Kingdom increased, identifying "nano" as a research growth area. Also within the following period of and 2008 – present there was an increase in the journal article outputs for Wales and the United Kingdom.

Journal Publication within Science Direct Key Word Search "Swansea", "Wales", "United Kingdom" and "nano" over 2 Year Periods from 2002 - Present

2002 - 2004	No. Publications		No. Publications	% of Publications (Swansea)		No. Publications	% of Publications (Swansea)
pub-date > 2001 and pub-date < 2005 and "nano" "Swansea" [All Sources(- All Sciences -)]	34	pub-date > 2001 and pub-date < 2005 and "nano" "Wales" [All Sources(- All Sciences -)]	153	22%	pub-date > 2001 and pub-date < 2005 and "nano" "United Kingdom" [All Sources(- All Sciences -)]	137	25%
2004 - 2006							
pub-date > 2003 and pub-date < 2007 and "nano" "Swansea" [All Sources(- All Sciences -)]	50	pub-date > 2003 and pub-date < 2007 and "nano" "Wales" [All Sources(- All Sciences -)]	275	18%	pub-date > 2003 and pub-date < 2007 and "nano" "United Kingdom" [All Sources(- All Sciences -)]	398	13%
2006 - 2008							
pub-date > 2005 and pub-date < 2009 and "nano" "Swansea" [All Sources(- All Sciences -)]	55	pub-date > 2005 and pub-date < 2009 and "nano" "Wales" [All Sources(- All Sciences -)]	425	13%	pub-date > 2005 and pub-date < 2009 and "nano" "United Kingdom" [All Sources(- All Sciences -)]	968	6%
2008 - Present*							
pub-date > 2007 and "nano" "Swansea" [All Sources(- All Sciences -)]	54	pub-date > 2007 and "nano" "Wales" [All Sources(- All Sciences -)]	500	11%	pub-date > 2007 and "nano" "United Kingdom" [All Sources(- All Sciences -)]	1194	5%

* **Note:** It should be noted that it takes time for Journals to review and accept articles thusly this may not wholly reflect the true numbers as there are some that may be in the publishing pipeline

It can be seen from the figures above that there hasbeen an increased trend in publications within Swansea following the creation of the Multi-Disciplinary Nanotechnology Centre and the inclusion in the Texas/United Kingdom Collaborative. Yet looking in the context of Wales and the United Kingdom, Nanotechnology has become a growth Research Area and with this the number of publications has increased over time. Where Swansea once held 25% of the "nano" publications from the period of 2002-2004, in the period of 2008-present it only holds 5%. If comparing "Swansea" to a "Small Company" access to people and facilities are needed to assist Universities to be able to compete for Research Funds. Thusly participation within the Texas/United Kingdom Collaborative can assist in facilitation of publication and research outputs.

Time Period	"nano" "Swansea"	"nano" "Wales"	"nano" "United Kingdom"
2002 - 2004	34	153	137
2004 - 2006	50	275	398
2006 - 2008	55	425	968
2008 - Present*	54	500	1194

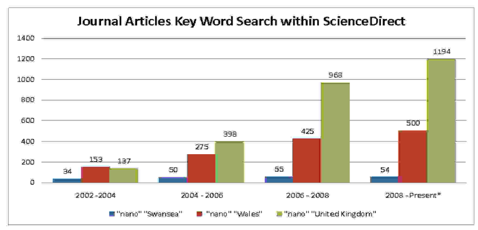


Figure 6.3: Journal Publication Search within Science Direct with key word Search "Swansea", "Wales", "United Kingdom" and "nano" over 2 Year Periods from 2002 to present.

In 2004 the NAno and MIcro -TEC SMEs in Integrate Projects and Networks of Excellence (NAoMITEC) was funded by the European Commission with the main objective of the promotion and participation of SMEs in the new instruments of Framework Project 6 with attention focusing on projects referring to nano and micro technologies and their application in key industrial sectors of ICT, Health Care, Aerospace, Transport and Environment.

In 2006 NAoMITEC put out two reports investigated the strengths of micro– and nanotechnology in Europe in a sector specific and country specific breakdown. Within the Country Report and Sector Report: Health it was seen that the University of Wales Swansea Multidisciplinary Nanotechnology Centre were capitalising and taking the lead in Wales.

The NAoMITEC reports highlight current availabilities and capacities within the European Union and identified that nanotechnology opens-up a multitude of new and improved applications in the biomedical field and that these applications would be for diagnostic or therapeutic use. They also highlighted that nanotechnology applications would also cover areas such as tissue engineering, biocompatible implants or bioactive materials. The report also identified low hanging fruit that could be quick wins within current trends as being; further biochip miniaturisation, advances of lab-on-chip applications and for longer periods of imaging techniques enhanced by nano-enabled contrast agents.

The reports went on to say that within previous years many of the start-up companies and SMEs set to work on developing ambitious new products. Yet many of them lack the funds that are needed for the lengthy phase of developments, demonstration and deployment. Therefore SMEs were recommended to concentrate on Research and Technical Development projects as a short-term step promising a sort of early return on investment.

Following a report by the House of Lords Science and Technology Select Committee on Nanotechnologies and Food, January 2009, on nano and food safety, the Department for Innovation, Universities and Skills were asked to respond. In March 2007 the Medical Research Council (MRC) issued a 'highlight notice' to encourage applications in nanotoxicology with the aim to inform policy development. The notice proved successful in stimulating a significant increase of applications and that since its launch five awards had been made at a total level of approximately £3 million. The research was focused on better understand the uptake of nanoparticles into cells and the functional consequences including oxidative stress, inflammatory response, cell death and genotoxicity, by linking this information to the physical and chemical characteristics of nanoparticles, predictive models for nanoparticle toxicity can be developed that will help risk assessment.

University of Wales Swansea was highlighted in this report as one of the five awards: *"Understanding the genotoxic potential of ultra-fine superparamagnetic iron oxide nanoparticles" (University of Wales, Swansea) - £450k/3yrs,* for studyingthe genotoxic properties of iron oxide nanoparticles with the aim to develop high-trough-put screening tests for genotoxic effects; Aims to understand dose-response relationships, to inform future in vivo studies and predictive approaches (DIUS 2009).

6.2 Nanotechnology Knowledge Transfer Network Questionnaire

6.2.1 Companies by Size and Annual Revenue

Examining the company profile by sector to identify growth trends and structure this focused on employment and revenue, the results of which are as presented above in Figure 6.4 and Figure 6.5 Small companies are key indicators of growth sectors (OECD 2005, BIS 2010) interestingly all of the sectors had a higher proportion of small companies with of those firms identifying themselves as Bio-Tech having 85% of its respondents having less than 100 employees. This was followed by firms that identified themselves as Hi-Tech/Telecom with 67% of its respondents has less than 100 employees with both Manufacturing and Other having 58% of their respondents with under 100 employees. Inclusive to this was the 70% differential between the respondents of companies with less than 100 employees and those that had over 100 employees. Where as both Manufacturing and Other had about a 15% differential between companies with less than 100 employees and companies with more than 100 employees. When looking at revenue size by sector of respondents it is interesting to find that within Bio-Tech again took the lead with 98% of the respondents who identified themselves as operating within that sector had annual revenue of less than £10m. Bio-Tech was followed by Hi-Tech/Telecom with 75% of its respondents under the threshold of £10m annual revenue yet the differential between the companies with annual revenue of over £10m was only 50%. Interestingly though was that within the companies that fell outside of Bio-Tech, Manufacturing, and Hi-Tech/Telecom, noted as Other, 57% of those respondents had an annual revenue of over £10m. Looking both at company size and annual revenue it can be said that all three of the sectors identified are growth sectors, with Bio-Tech being clearly in the lead.

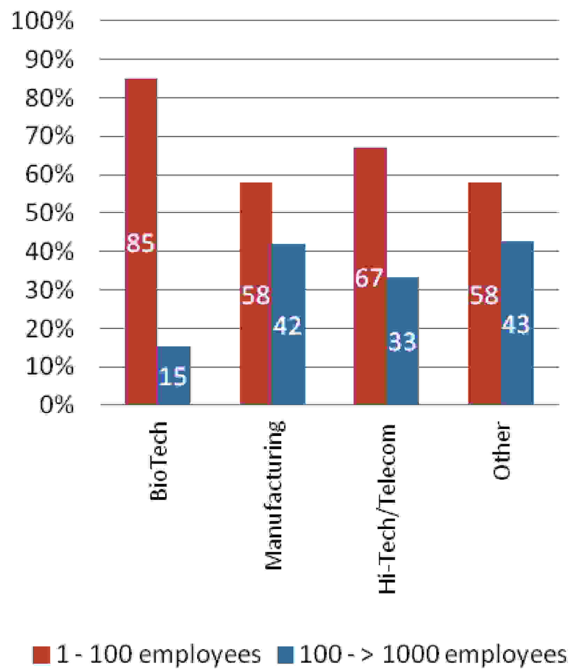


Figure 6.4: Size of companies by number of employees.

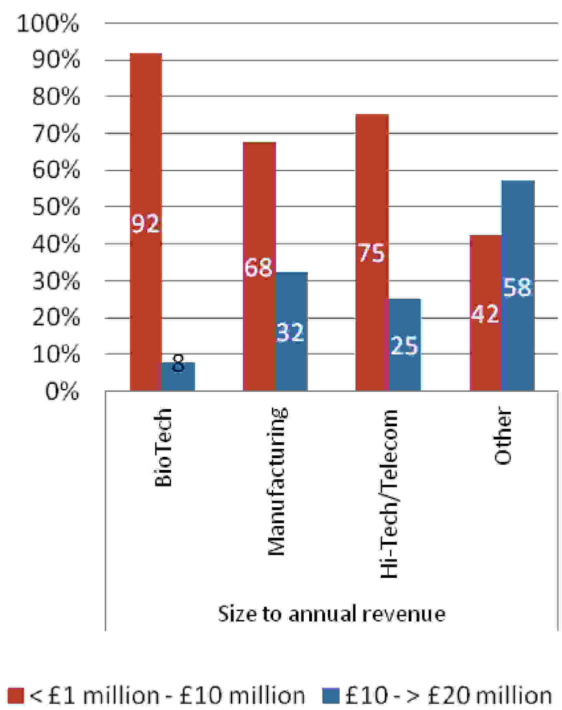


Figure 6.5: Size by companies by revenue.

Bio-Tech with 85% under 100 employees and 92% with annual revenues would be more in the areas of Application and Product Innovation at the stages of Early Market/Emerging Industry where the primary concern is raising funds to engage in early stage R&D, i.e., Application Innovation (creating differentiation by finding and exploiting a new application or use for an existing technology, the cornerstone of solution-oriented marketing (Moore 2005)) or Product Innovation (An innovation type in the product leadership zone that differentiates a growth market position by R&D to improve. (Moore 2005)), these companies are in the development stages and can be there for long periods, as the case is in pharmaceutical developments. These companies generally are high risk high return and often receive first stage investment from "Friends & Family" or Regional Funding Mechanisms. Being at the early stages of development also means that those companies are looking to innovate and seek assistance in several forms. Hi-Tech/Telecom with 67% under 100 employees and 75% under £10m in annual revenue would be more situated at a Process Innovation stage (a next generation of emerging offerings (Moore 2005)). Where as Manufacturing and Other had 58% less than 100 employees and Manufacturing had 68% with annual revenues under £10m, Other had 42% with annual revenue less than £10m and 58% with over £10m annual revenue.

6.2.2 Companies by Operating Territories

Access to markets is an important factor to any companies no mater its size or annual revenue. Davies & Weinstein 1999 argued the evidence of the importance of increasing returns, in combination with comparative advantage resulting in the importance of market access in economic geography of course included in these comparative advantages are also regulatory factors as is the case for the US and Europe in the form of the Food and Drug Administration (FDA) and the European Medicines Association (EMA). To consider access to markets of the KTN respondent's areas of operation by sector and size (both employment and turnover) were considered. 100% of all respondents indicated that they operate within the United Kingdom as can be seen in Figure 6.6 with an interesting saturation of by sectors of the US, Germany, France, Other Western Europe and China with above 50% of most sectors in operation in those regions. Within the respondents of the KTN is the Manufacturing sector that has a higher proportionality of operation within Canada, Australasia, India, Other Asia, Central/South America and Other Eastern Europe. Manufacturing traditionally is more mature in their growth phase and are more financial stability, and has slower growth, with high emphasis on spending and cost control, and less emphasis on R&D and growth strategies (Rudd 2008). These "Cost Control" may well be the reasons of choosing these locations as they historically have a low labour cost. Whereas the Bio-Tech sector, populated with more small companies (Figure 6.6) has a higher proportionality of areas of operation that have a larger market share and comparative advantage/influence as Davies & Weinstein 1999 and Hanson 2005 argue, and a more traditional decline in areas that are have less of a market advantage/influence.

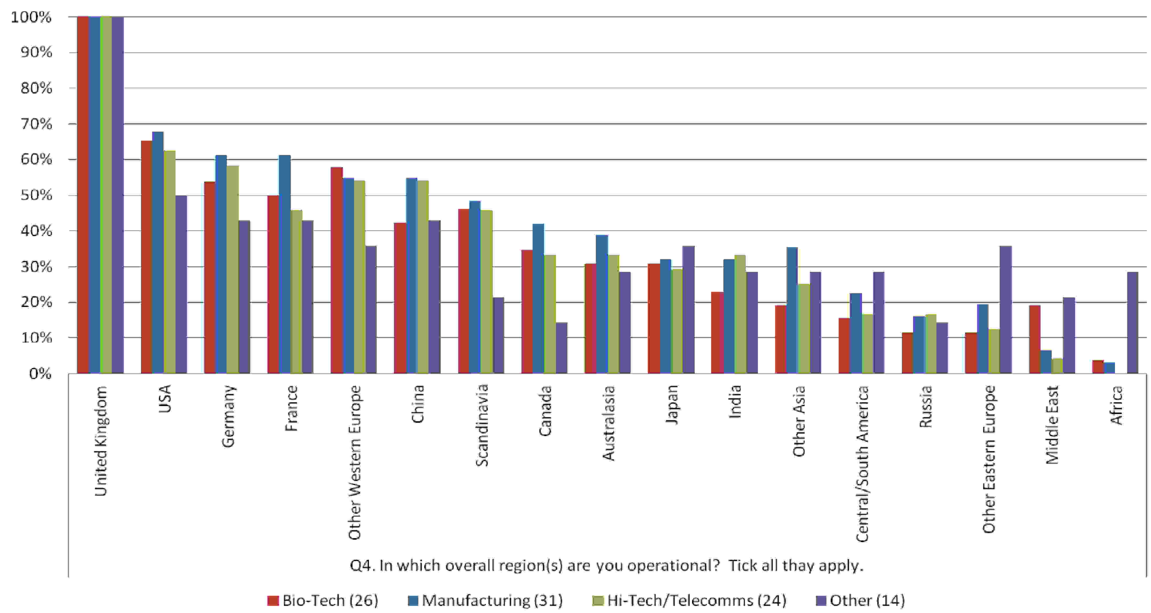


Figure 6.6: Overall region(s) operational per company sector.

For the purpose of this study location of operation cannot solely be dictated by sector alone and the dichotomy of company size and annual revenue plays a key factor on a companies abilities. As could be expected and seen in Figure 6.7 and Figure 6.8, small companies find it hard to cover more space less geographical cover than large companies. Yet small companies have a higher population in the areas that could possibly give them low cost advantages.

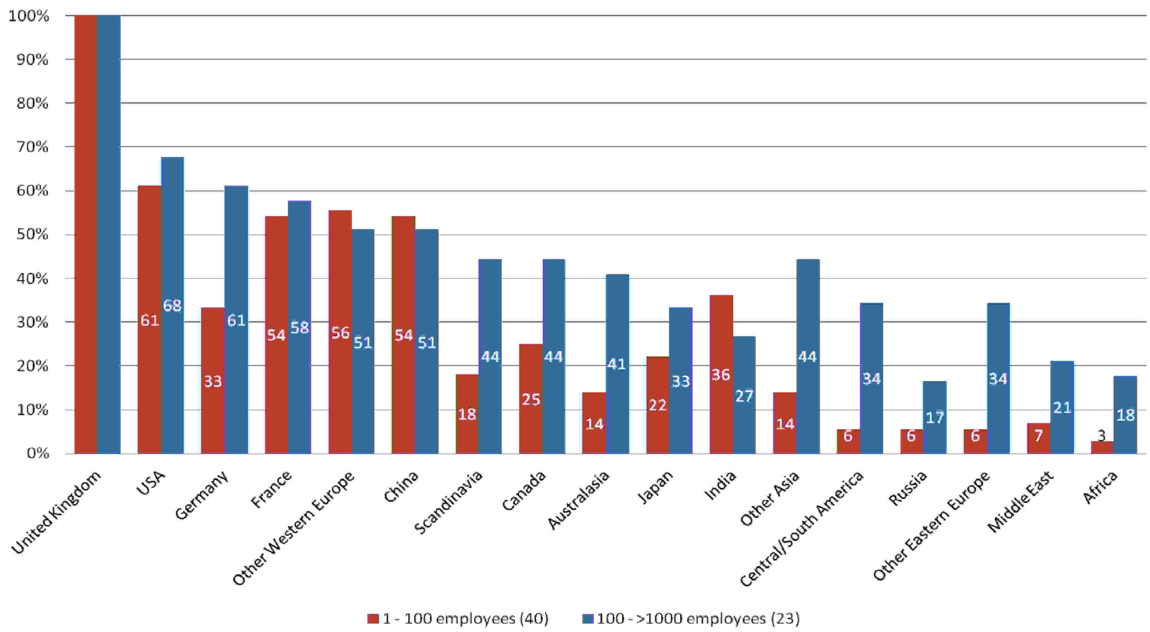


Figure 6.7: Overall region(s) operational per company size.

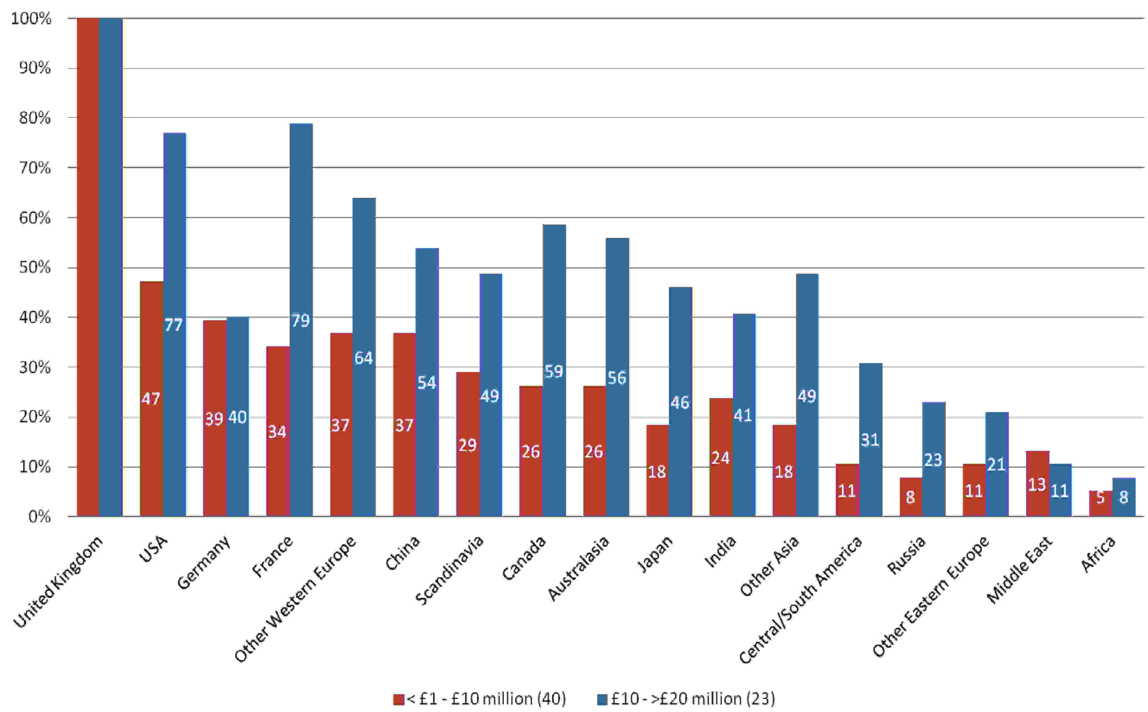


Figure 6.8: Overall region(s) operational per annual revenue size.

Interestingly though looking at areas of operation by annual revenue the companies less than £10m annual revenue are more evenly spread globally. This may be due to several factors that could leverage low cost advantage to them i.e., knowledge hubs and expertise in those locations. University expertise and knowledge, especially in the field of Nanotechnology, is important to the growth of companies and ability to innovate.

As can be seen in Figure 6.6 and Figure 6.7 that there a good proportion of both small and large companies spread through the more developed region that have a stronger ability to manage and regulate as would be expected large companies with higher annual revenue have a high percentage of global spread where those with annual revenue less than £10m have a smaller distribution globally. Yip et al. 2006 argues, "Managers of the large British companies need to be competitive internationally" (Yip et al. 2006). Yip et al. 2006 and Osegowitsch 2008 argues that revenues is a metric indicating the ability of a company to work globally, where as they are a better and more stable indicator over time because small enterprises can have very large market capitalisations (Yip et al. 2006, Osegowitsch 2008). Malbert et al. (2003) notes that companies of different sizes tended to do different things in their implementations of their resource planning and that there were differences in the outcomes and benefits attained by the enterprises. This follows suit to the regional importance to the respondents in the KTN questionnaire. In the case of China interestingly the literature argues that the Chinese Nationals educated abroad in technology fields are moving back to China as it is becoming a more Technology Economy (Bradsher 2010).

Whereas both small and large companies operate 100% in the UK it is interesting how of course due to the amount of revenue that the larger companies have they have a higher spread globally. Within the respondents of large companies, USA, France, Other Western European Countries, China and Australasia were populated over 50% by the large companies and followed by Japan, India, and Scandinavia all above

40%. Within France and Other European Countries the reason for operating in those regions may be due to the Regional Funding Assistance that is located within Europe. As for China and India, India has focused their efforts on high technology growth as a means of fuelling economic development, rather than relying only on streams of foreign aid or the more traditional approach to development in "stages of economic growth" typically advocated for developing economies (Parker 2008) as they seek to modernize through heavy investment in industrialization.

When looking at the location of where companies operate on their size Figure 6.7, the large companies have a higher percentage of wider global spread than the small companies. Large companies being more mature have a tendency in laying out extensive funds for infrastructure look for more cost savings in working in locations where labour cost is low, possibly the reason for the high proportion of the large companies with employees of over 100 employees 44%; and 49% of the large companies identified by having annual revenue of over £10m operating in Other Asia.

Interesting was to find that even with the size of the companies being under 100 people there was a global spread Figure 6.7; they appreciate the opportunities that the wider world can offer. Quinstas et al. 1997 and Davenport 2005 argues Knowledge-acquisition is one part of knowledge management which, in turn, has been defined as "the process of critically managing knowledge to meet existing needs, to identify and exploit existing and acquired knowledge assets and to develop new opportunities". Geographic proximity to the knowledge sources with which the organization is collaborating is generally assumed to assist knowledge-acquisition. Much of the advantage of such collaboration is thought to come from efficiencies in collective learning (Belussi 1999, Davenport 2005), particularly for innovative firms. Whether understood as generating economic externalities or spillovers of R&D (Krugman, 1991; Audretsch and Feldman, 1994; Feldman, 1994) or facilitating inter-organisational transmission of tacit knowledge via social capital (Powell et al., 1996), geographic proximity is thought to be important for innovative activity. "Since knowledge is generated and transmitted more efficiently via local proximity, economic activity based on new knowledge has a high propensity to cluster within a geographic region"(Audretsch, 1998). Davenport 2005 states that, "Any exploration of geographic proximity leads directly to studies of successful knowledge sharing clusters".

"Today's economic map of the world is dominated by what are called clusters" Michael Porter, 1998

Localisation, regional innovation systems, industrial districts, learning regions, local production systems and agglomeration economies are other labels given to the trend of geographically co-located firms in a value chain collaborating in some way in order to gain efficiency (Rabellotti and Schmitz 1999). The observation of regional cluster economies is not new with most writers referring back to Marshall's work *Principles of Economics*, originally published in1890 (Marshall 1986, Keeble and Wilkinson 1999). A rise in the number of studies of industrial districts and small-firm led economic growth in the 1980s combined with the increase in interest in 'networks' and social aspects of inter-organisational interaction (Granovetter 1985, Burt 1987, and Gulati, 1999) is the result of renewed activity on the part of scholars in such disciplines as economics, planning, sociology, strategic management, organisational behaviour and business history (Harrison 1991). The seeming paradox of the rise in "importance of local proximity and geographic clusters precisely when globalization seems to dominate the economic activity" has been attributed to the fact that more innovative activity is associated with high-tech SME clusters than with "footloose multinational corporations" (Audretsch 1998).

Definitions of clusters range from those that defer mainly to the geographic collectivity (*"geographic concentrations of interconnected companies and institutions in a particular field"* (Porter, 1998)) to those that emphasise the knowledge sharing aspects of such groupings: *"Firms and organisations involved in clusters are able to achieve synergies and leverage economic advantage from shared access to information and knowledge networks, supplier and distribution chains, markets and marketing intelligence, competencies, and resources in a specific locality"*, (Davenport 2005). Yet these respondents as previously identified as SMEs are not interested in certain aspect of access to specific equipment or sector specific material such as access to Biologic material for Biotech companies or "certified" procedures for regulatory approval. Yet they all identified a magnitude of importance of over 60% for access to testing and validation facilities for their products.

Figure 6.9 presents the importance of facilities and support by Sector. This addresses a range of the sub-hypotheses presented key observations of the response are as follows:

- **Broad Alignment with focus on "Soft" Support**: The importance of individual facilities and support mechanisms was broadly aligned across all sectors, with greater importance upon "Softer" support such as People and Finance, than for specialist facilities. These softer support mechanisms had ~80% of respondents citing them as important, compared to ~10-20% for many specialist facilities.
- **Facility Alignment with Sector**: It is clear that facilities of a Bio Specific nature are clearly of moiré importance to companies in the Bio-Tech Sector. More generic manufacturing facilities as well as R&D equipment is of greater importance across the wider sectors. Bio-specific facilities are of an importance to the Bio-Tech sector broadly in line with more generic facilities for other sectors.
- **Funding Business not Running it**: Across all sectors there is significantly greater importance upon the availability of regional public and venture funding than upon in-house business centres. However, the sector most interested in all of the above is Bio-Tech. Access to funding is roughly twice as important amongst respondents as in-house business support for all the sectors.
- **People Power**: By far the most important support mechanisms for all sectors are the access to international networks and availability of collaboration opportunities. Respondents citing such support as 'important' are over five times as numerous as for some specialist facilities.

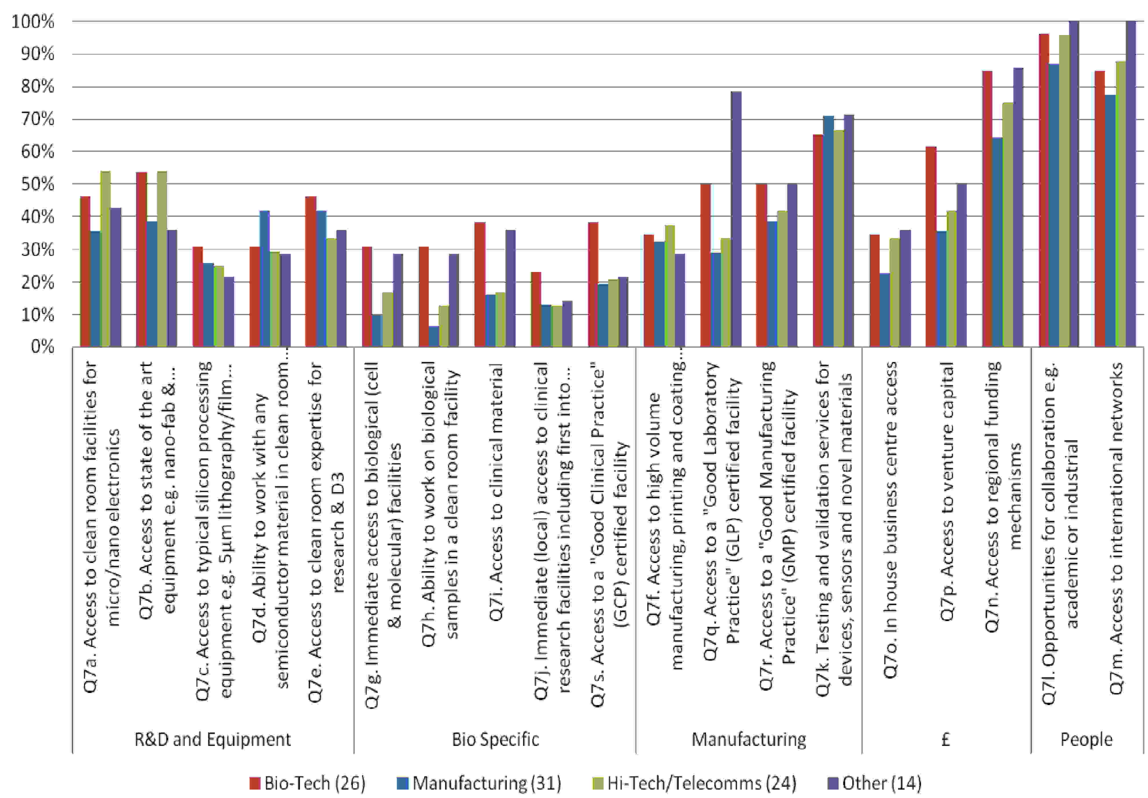


Figure 6.9: Magnitude of importance facilities/support per sector.

Figure 6.10 present the importance of facilities/support by Revenue. This presentation highlights the different needs of small and large enterprises. The following are key observations from these data:

- **Small Companies Need Different Help**: Small companies demonstrate significantly more interest in funding and more basic facilities than larger counter parts. For example within the scope of R&D facilities and equipment, it is more generic offerings such as clean room facilities, which are of most importance.
- **Big Toys for Big Boys**: Larger enterprises demonstrate significantly greater interest in specialist facilities, especially those relating to complex processes and manufacturing. While this presentation of this data does not give a sectoral breakdown, there is clearly more importance for Bio-specific facilities amongst larger companies.
- **Everyone wants Money**: One of the most sought after supports is access to regional funding, and to a lesser extent venture capital. In both cases it is significantly more important to smaller enterprises.
- **Large Companies need less Networking**: The most important support mechanisms for companies large and small are access to international networks and collaboration opportunities. However, the importance is less amongst large enterprises, though remains significantly greater than for any of their other support needs.

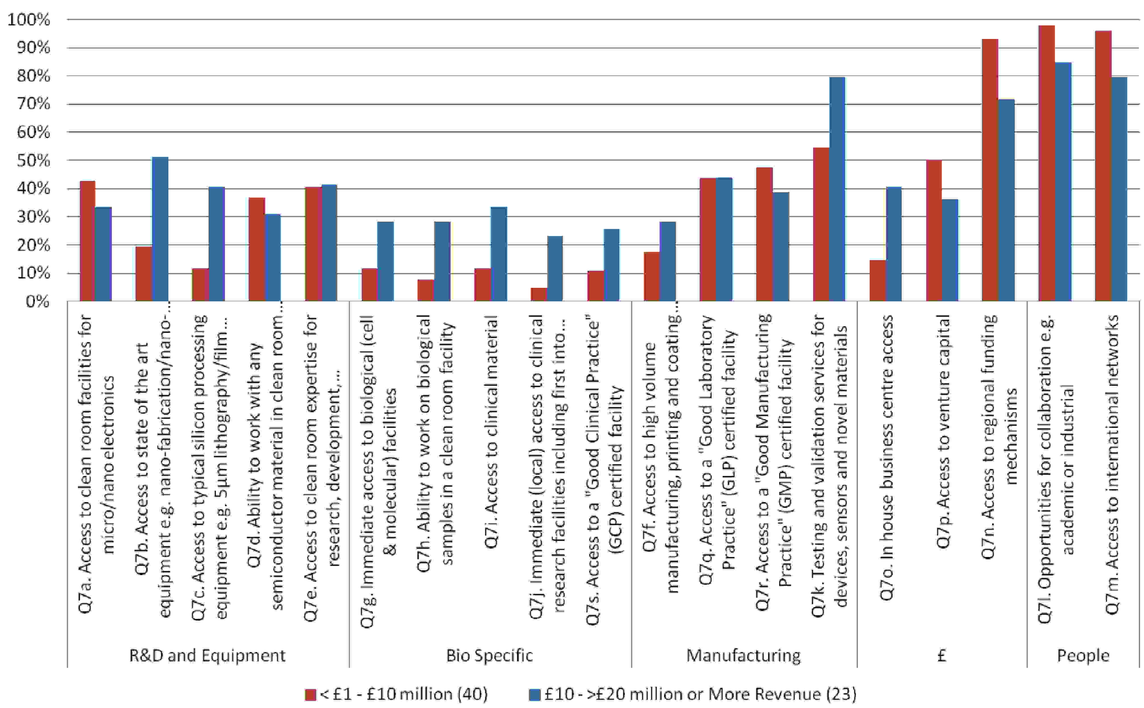


Figure 6.10: Magnitude of importance facilities/support per company revenue.

6.3 Texas – United Kingdom Collaborative Questionnaire

6.3.1 The Academic Respondents

Figure 6.11 above presents weighted proportions of "Junior" (Lectures & Researchers) and "Senior" (Readers & Professors) Academic respondents from the Control and TX/UK cohorts. These cohorts involved (24 and 21) academics respectively. It can be seen that there was just over twice as many "Senior" Academics amongst the TX/UK respondents. This point is of note for subsequent sections to give consideration regarding the nature of the respondents including their propensity to engage and effects from their age, experience, etc.

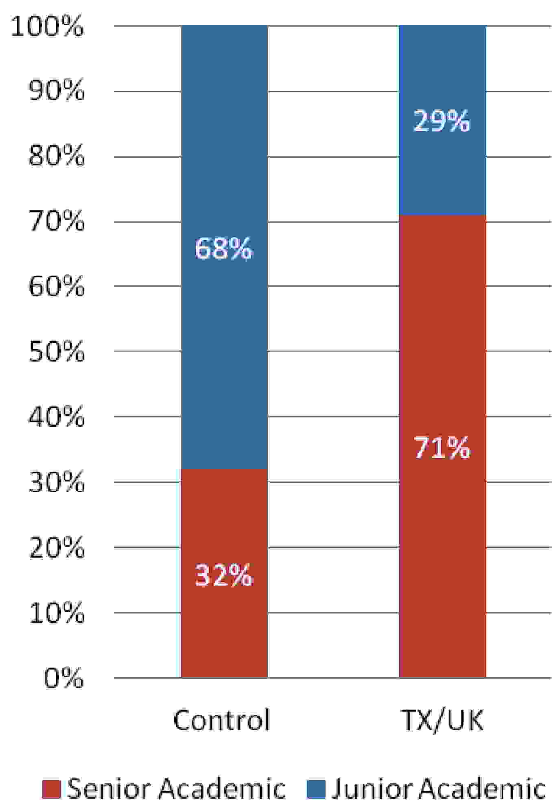


Figure 6.11: Academic rank.

Figure 6.12 presents, for the same cohorts, the academic disciplines of the respondents. It can be seen that the majority from both cohorts are based within the Schools of Engineering and Medicine. It can also be seen that the proportions representing each discipline are broadly similar for the two cohorts and wholly represent growth sectors.

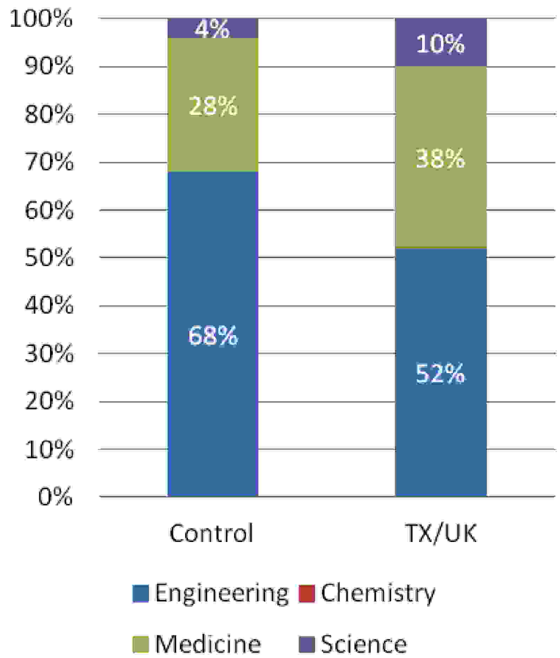


Figure 6.12: Academic respondent discipline focus.

Figure 6.13 and Figure 6.14 highlights both the primary and secondary areas of research for both the Control and the TX/UK cohorts. The profiles of primary research areas for both cohorts are broadly similar, with slightly more variety amongst Texas/UK participants. It can be seen that both cohorts show greater diversity in Secondary areas, though the diversity, by both number and split of fields for Texas/UK participants indicates a more multidisciplinary group of academics.

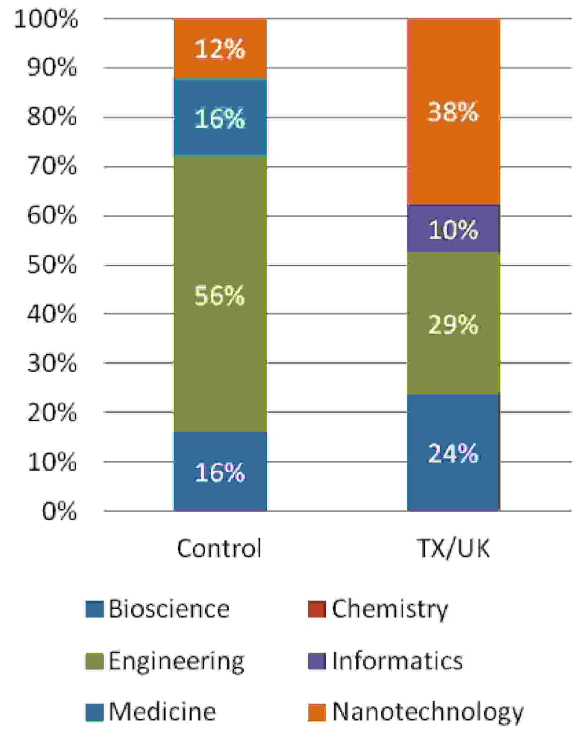


Figure 6.13: Primary area of research.

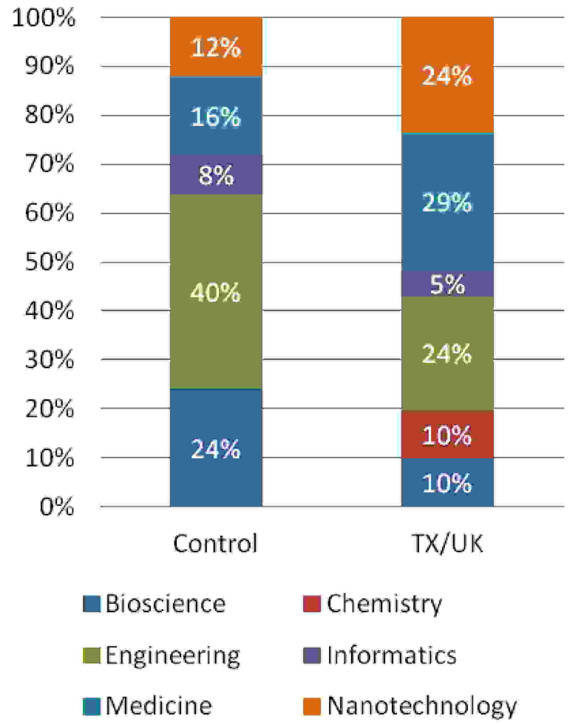


Figure 6.14: Secondary area of research.

Training is an important factor when trying to enshrine the benefit of collaboration in younger researchers. The respondents within the TX/UK Collaborative recognise difficulty in conducting multi-disciplinary training; however they do recognise its importance to enhancing activities, whereas the Control cohort see multi-disciplinary training activities as diluting focus. Overall, the participants within the TX/UK Collaborative see a high level of benefit in teaching the value of multi-disciplinarily amongst earlier-stage researchers (Figure 6.15).

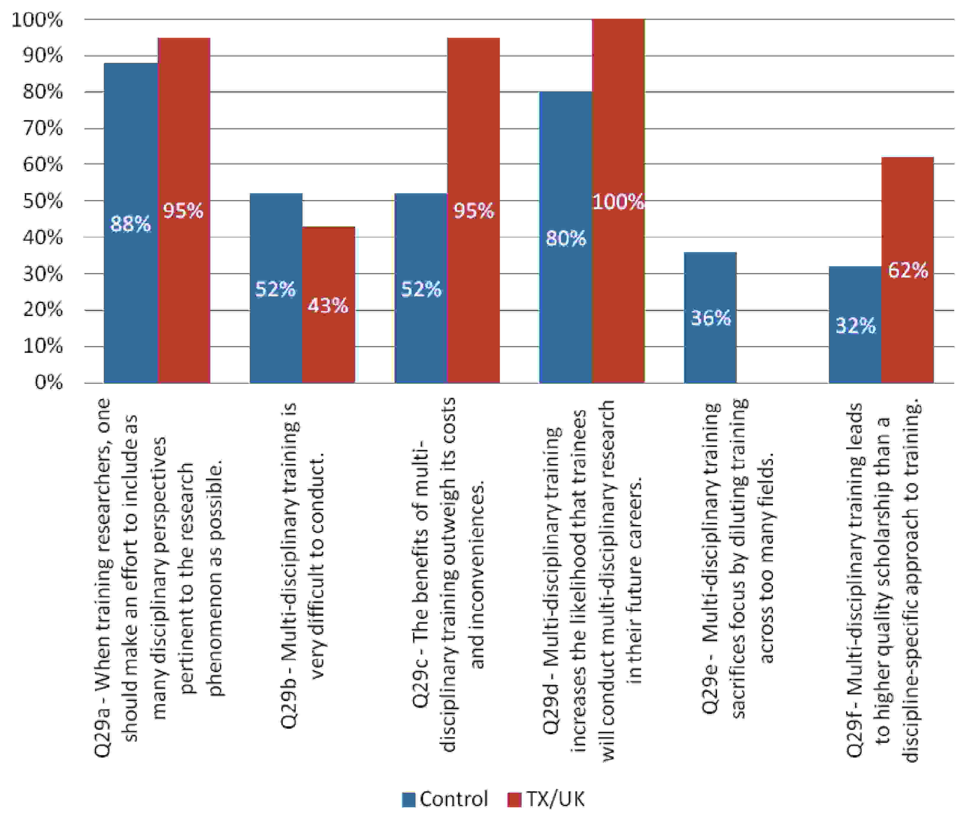


Figure 6.15: Training.

From Figure 6.16 it can be observed that the respondents involved in the TX/UK Collaborative have generally more open attitudes. For example, a significantly greater proportion of TX/UK respondents participate in groupings with the express intention of collaborating. Furthermore, although both cohorts have a propensity to collaborate, those academics from within the TX/UK Collaborative have a higher propensity to value fields outside their areas of expertise.

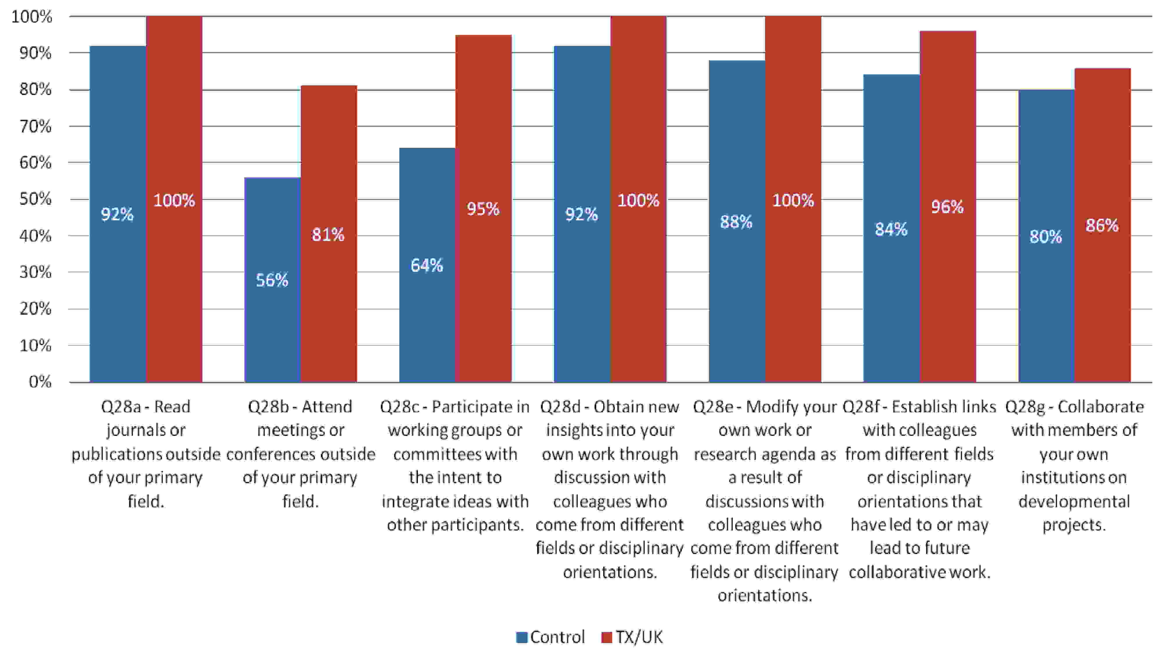


Figure 6.16: Collaborative activities.

6.3.2 Academic Research Collaborations with Industry

Figure 6.17 presents weighted total of companies worked with by each cohort over the past four years, adjusted by size of cohort. The following key observations can be made from these data:

- The above data present an encouraging perspective suggesting that on average each Control cohort Academic has been working with three companies while TX/UK counterparts have been working with ca. 4 companies.
- This positive level of engagement demonstrates definite alignment between the activities of both academics and industrial partners.
- Both the control and TX/UK participants see engagement as reciprocally relevant yet the TX/UK Participants are more engaged however this does not seek to consider any potential factors such as nature of the academics involved “e.g., Seniority”.

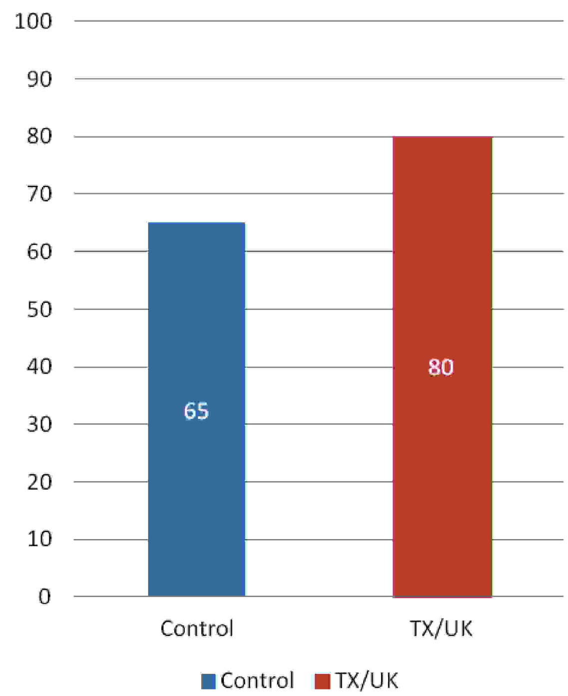


Figure 6.17: Weighted total number of companies worked with in past 4 years.

Figure 6.18 represents the weighted percentage of respondents who have worked with companies over the past four years. The following observations can be made:

- A far greater proportion of the TX/UK cohort engaged with companies over the course of this four-year phase, with a 45% higher propensity to be engaged with industry.
- It can be highlighted that in both cohorts that there is nowhere near a majority, meaning that there is still significant work to be done for academic-industrial collaboration to become fully embedded across the institutions.

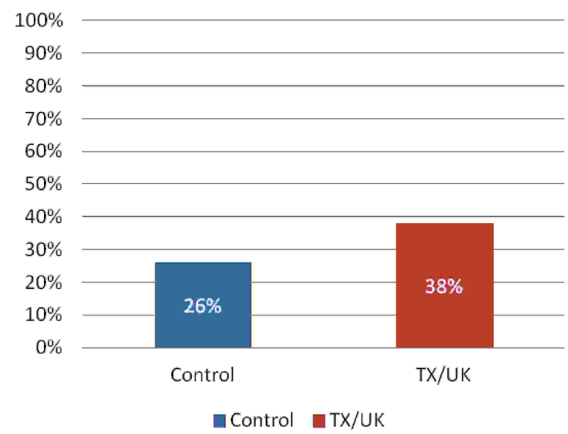


Figure 6.18: Percentage of respondents who worked with companies over the past four years.

Figure 6.19 presents the "the repeat business" phenomenon to investigate whether collaborations lead to further work. The following key observations can be made:

- Collaborations from both cohorts have lead to follow on business. However it can not be drawn from the data as to whether this stems from limited or significant prior work. Those which lead to further work demonstrate that value found by both partners leading to ongoing relationships.
- It can be seen that there is an 80% greater likelihood of repeat engagement with the TX/UK Collaborative participants. This represents a significant advantage for developing strong relationships.

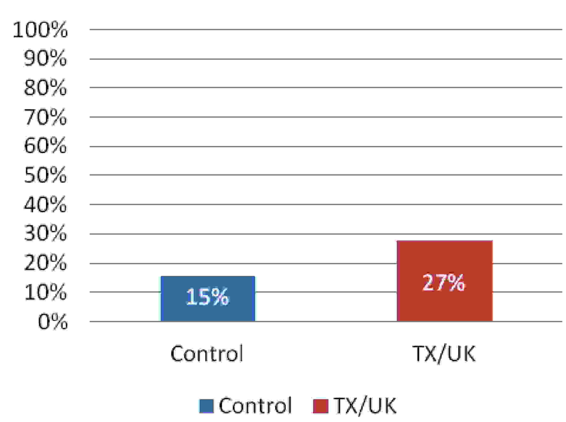


Figure 6.19: How many of these collaborations at completion have led to follow on research collaborations.

Over the course of the past four years there has been significant investment in facilities across the Swansea University campus. Figure 6.20 represents percentage of follow-on collaborations from each cohort based on the facilities, which they work within over the past four years. It can be seen that:

- The role of facilities in enabling collaboration appears greater amongst TX/UK respondents. Within the TX/UK cohort that there is a 93% greater emphasis on the facilities which the cohort work with being a facilitator to further collaborations.
- The importance of facilities to enable collaboration is however remarkably low, suggesting that other factor(s) are of significantly greater importance
- However, with this is in mind, it can still be seen that within both cohorts that the facilities are recognised by the stakeholders as enabling.
- Inclusive to this it could be said that the facilities are important to both the academics and industry.

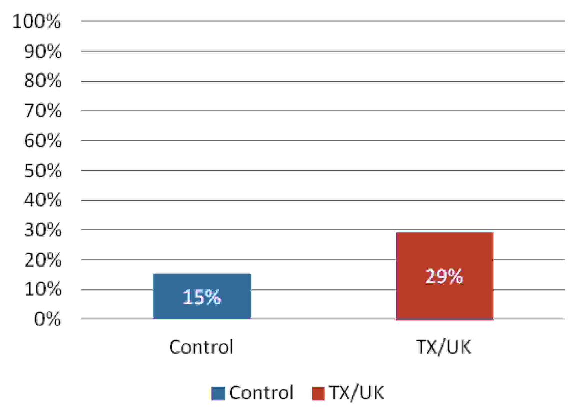


Figure 6.20: Collaborations due to facilities that the respondents work within.

Figure 6.21 represents project feed-in from past collaborative partners. This explores the phenomenon of referral between actors within a cluster (whatever is geographical boundaries may be). From the data, the following key observations can be made:

- It can be seen that there is only a 3% difference between the two cohorts. Although this may not be statistically significant it does though highlight that for each cohort there is an almost equal network effect in that previous collaborators were satisfied with their performance that they recommended them to others. This also highlights that the work that had been done previously was seen and valued by others.
- While it might not be expected for enterprises to refer collaborators to a valuable source of ideas and support, the proportion of projects coming from referrals is relatively low for both cohorts.

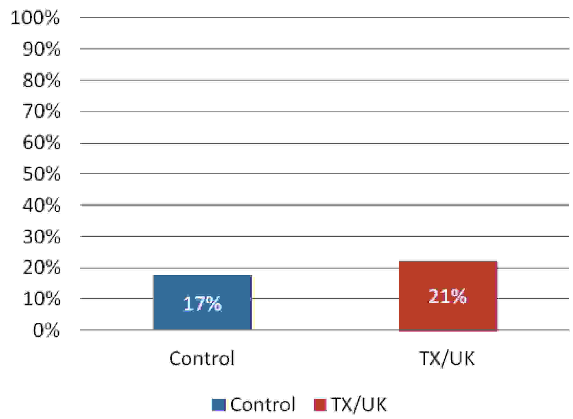


Figure 6.21: Number of project over past four years have come indirectly via partners with whom collaboration occurred in the past.

6.3.3 Collaborations Academia-Academia

Focussing solely on respondents from both cohorts based at Swansea University: the questions in Figure 6.22 have explored whether there exists, or is perceived to exist relevant and effective support and commitment for collaborations at Swansea University.

The following can be observed:

- From responses to the first question it can be seen that within the TX/UK cohort that there is stronger institutional support, emphasis and awareness.
- From responses to the second question it can be seen that both groups feel that they have institutional support.
- Responses to the third question demonstrate that both the Control and the TX/UK cohorts think positively of the support of their senior management. Highlighting that both cohorts feel the same views of senior management and their facilitation of collaboration within their respective schools).

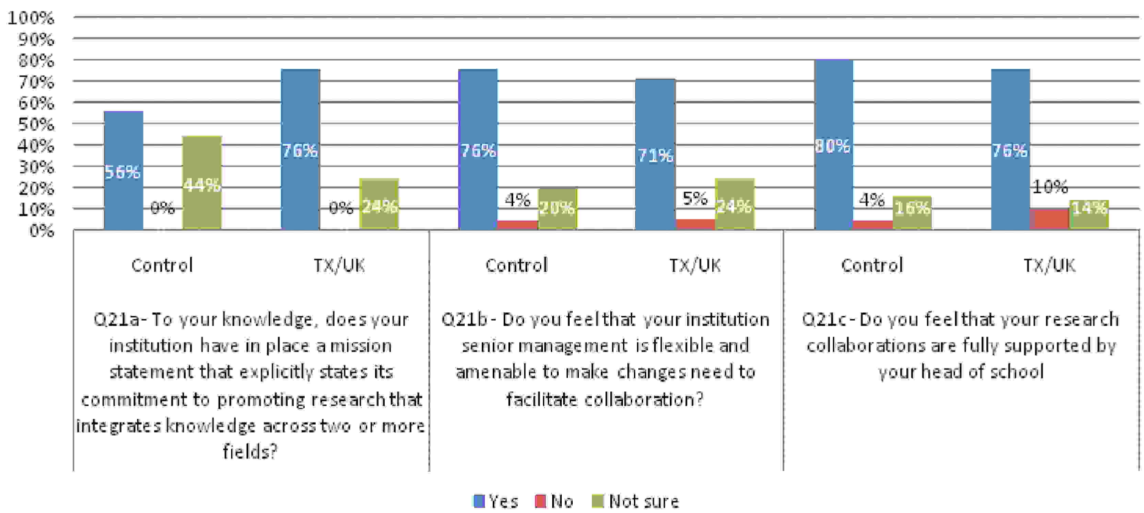


Figure 6.22: Collaborative resources.

Figure 6.23 above presents an overview of inter-institutional activities that are occurring within the institution and whether the two cohorts were or are aware of the inter-institutional activities. It can be seen that there is:

- Significantly more activity and awareness on the TX/UK cohort's side than on the Control side. This may imply the TX/UK cohort is more embedded than the Control within institutional and inter-institutional activities.

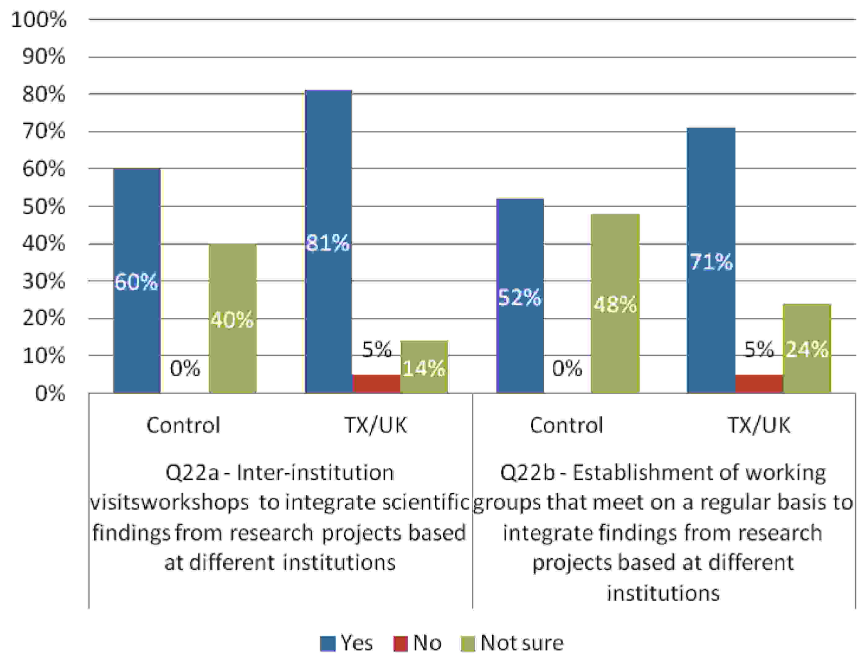


Figure 6.23: Internal inter-institutional activities.

We have described how research culture is important in facilitating the identification and realisation of collaboration opportunities not only within one's own field(s) but also the field(s) of others. This allows researchers to be able to identify synergies and enhance the collaboration with one's own expertise and knowledge. Figure 6.24 demonstrates this phenomenon as follows:

- Question Q20a, highlights that collaboration is more ingrained in the TX/UK cohort than within the Control.
- Both Questions Q20c and m, both the TX/UK and Control cohorts recognise the interdisciplinary challenges and its value, yet it is more so within the TX/UK cohort.
- Question Q20d highlights that there is a high level of openness in both the TX/UK and the Control cohorts.
- Both Questions Q20f and h, suggest greater integration amongst the TX/UK cohort.
- Question Q20j suggests that the TX/UK respondents are trained in more disciplines that the Control cohort.

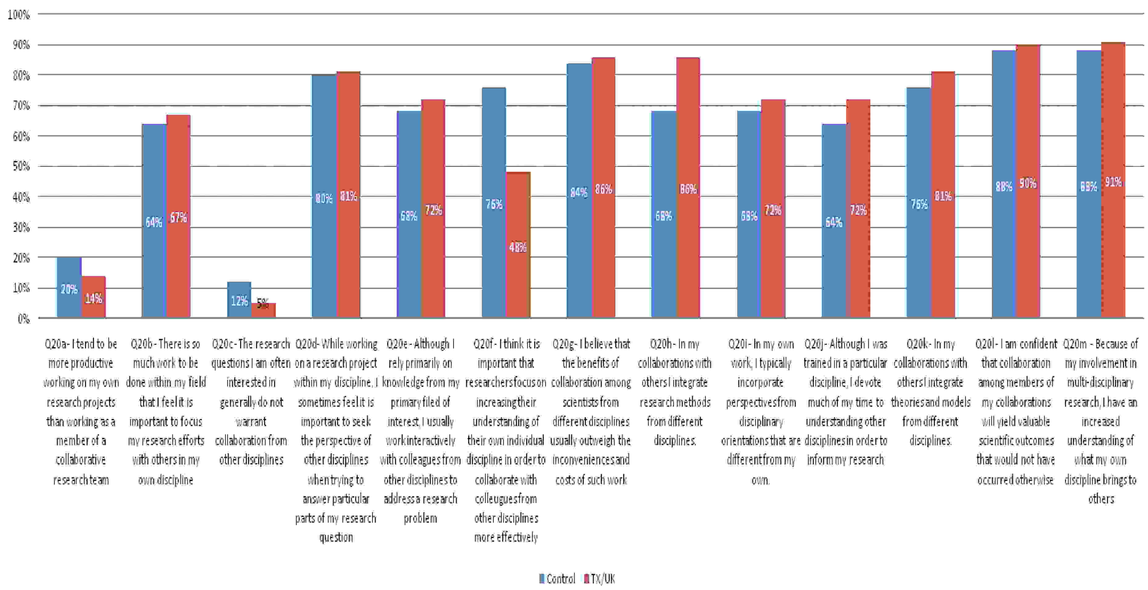


Figure 6.24: Research ethos/culture.

Figure 6.25 presents an overview of the cohesiveness of the Control and the TX/UK cohorts, internally, institutionally, and regionally. This is observed within the following:

- A clear trend of trust.
- From Q23d, it can be seen that TX/UK participants are significantly more positive about regional cohesion than Control group respondents, who are more positive about institutional alignment (Q23c).
- Within both Questions Q23a and b, it can be seen that there is strong internal and institutional network in the TX/UK Collaborative participants.
- In Q23e, both the Control and the TX/UK cohorts see relevance of collaboration and international networking abilities.

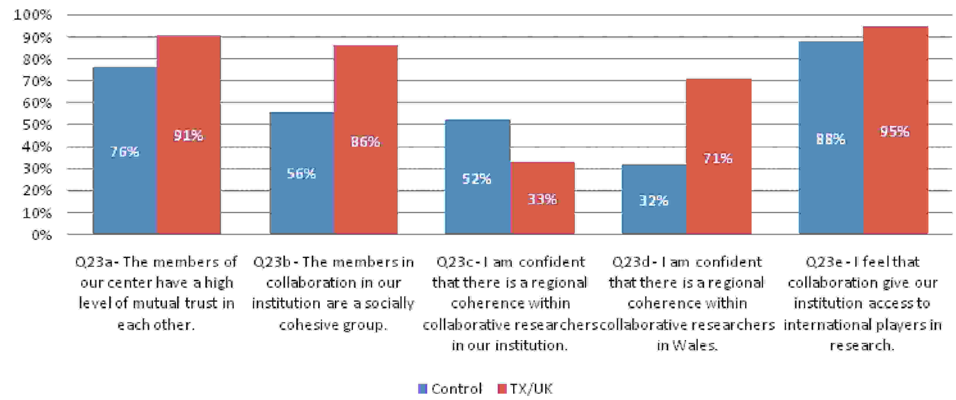


Figure 6.25: Cohesiveness.

As can be seen in Figure 6.26, both group of respondents view their own institutions favourably, yet interestingly there are a slightly higher proportion of the feelings of warmth, satisfaction and successfulness in the Control group, whereas the TX/UK Collaborative respondents found collaboration to be fuller, more exciting, stimulating, productive, facilitating, cooperative and enjoyable than the control group.

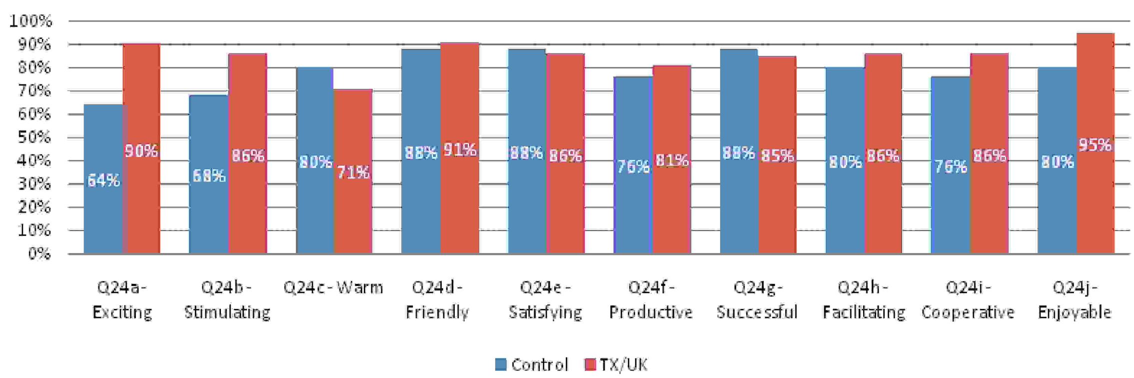


Figure 6.26: Overall impression about the institution.

Interestingly within the TX/UK Collaborative respondents they felt better about themselves as a part of the academic community within Swansea University than their counterparts do, and dramatically not intellectually isolated as the control does (Figure 6.27). This observation introduces an interesting perspective of the individuals themselves, i.e., did their optimism and integration bring them to the Collaborative, or is it an effect of the process.

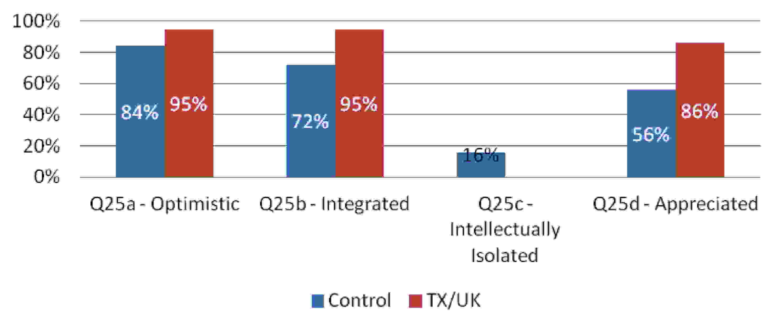


Figure 6.27: Both cohorts feeling as a member of Swansea University the institution.

From the above (Figure 6.28) it can be observed that:

- Both cohorts recognise the relevance and impact of collaboration.
- Within the TX/UK Collaborative respondents there is a greater satisfaction of collaboration than within the Control group and
- A significantly higher level of trust and openness within those members of Swansea University that are involved with in the TX/UK Collaborative.

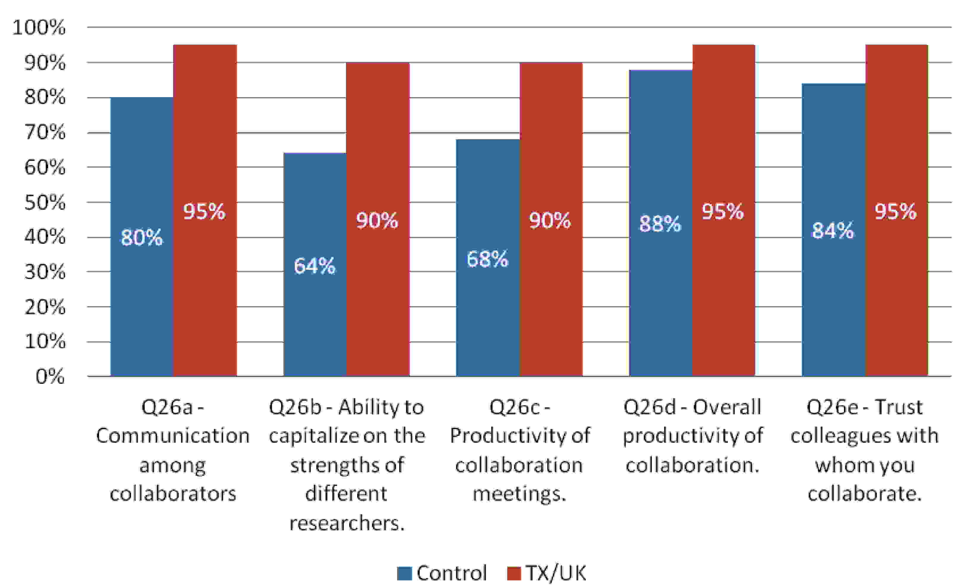


Figure 6.28: Magnitude of satisfaction of opinion of collaboration within Swansea University.

6.4 Supplemental Questionnaire

A supplemental questionnaire was conducted amongst the TX/UK and Control cohorts to further explore the issues investigated through the first questionnaire.

6.4.1 Nature of Collaboration

The first question asked was to identify the overall number of collaborations undertaken by the Control and "Collaborative" cohort researchers during the three years of the Collaborative. Both groups were given the range of 0 to 10 collaborations to identify, and asked to list their main and most recent collaborations over during Phase II of the Texas United Kingdom Collaboration 2007-2010. The result of this first question shows that during this period the "Collaborative" researchers were involved in 37% more collaborations than the control researchers (Figure 6.29). Digging further into the data shown below it was identified that one professor and one researcher involved in the "Collaborative" had undertaken 10 collaborations over the past three years.

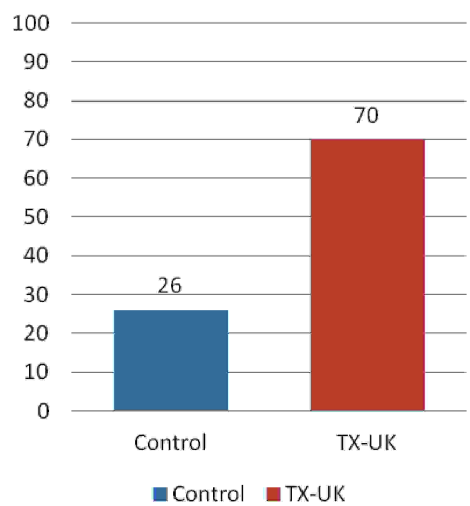


Figure 6.29: Number of collaborations.

The second question explored the nature of the academics' involvement in the identified collaborations. This tested whether they saw their involvement as being:

- Basic Research, where by pure basic research is research carried out for the advancement of knowledge, without working for long-term economic or social benefits and with no positive efforts being made to apply the results to practical problems or to transfer the results to sectors responsible for its application. (OECD, 1993).
- Applied Research, whereby applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective, (OECD, 1993).
- Commercial, where their work is related to developing a product or process.

The results shown in Figure 6.30, show that while a greater proportion of Commercial Research is undertaken by the Control cohort, when combined with Applied Research the proportion is greater for the TX/UK cohort.

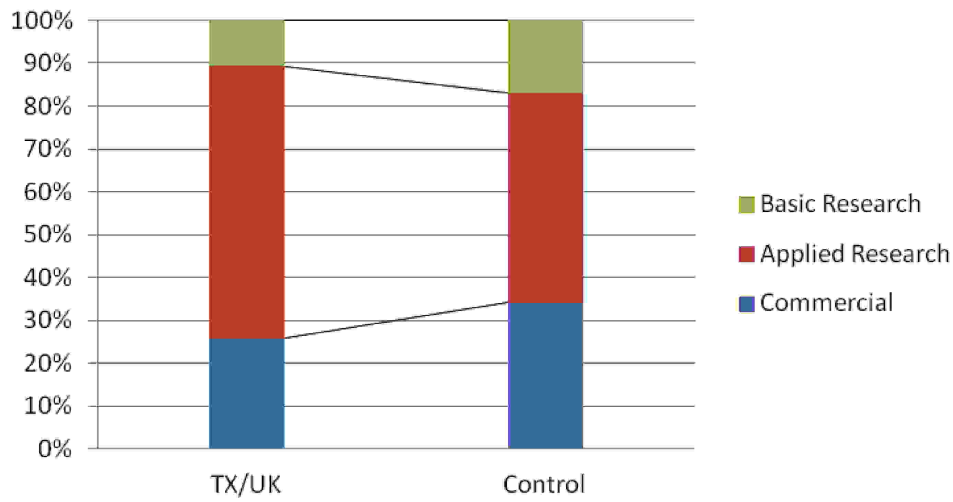


Figure 6.30: Nature of involvement of the cohort.

6.4.1.1 Nature of Interest

Both groups were asked about the nature of their interest in the collaboration (Figure 6.31): this being to explore the specific aspiration in terms of outcome of the collaborations. The general trend across both cohorts is a slight decrease in Commercial and Applied Research outcomes. Compared with Figure 6.30 it can be seen while there is increased interest in Basic Research outcomes within the TX/UK cohort, this is accompanied by a decrease in interest amongst the Control cohort for commercial outcomes.

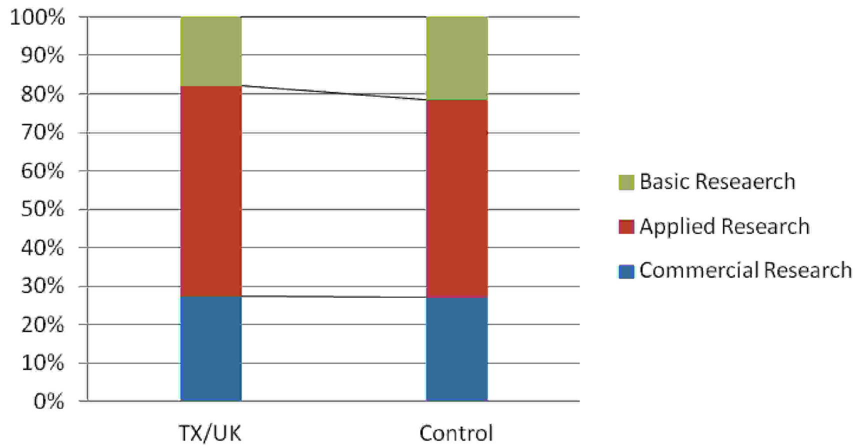


Figure 6.31: Nature of interest by cohort.

6.4.1.2 What has this led to?

The outputs of academic research were also explored. The most startling of the findings was when the two groups were asked what has their collaborations led to in terms of output. Considering equal numbers of participants in both cohorts, the TX/UK cohort delivered 48% more outputs from their collaborations than the Control group (see Figure 6.32). This rather crude measure gives equal value to both academic and commercial outputs. However, within the overall findings this trend remains for almost every individual type of output.

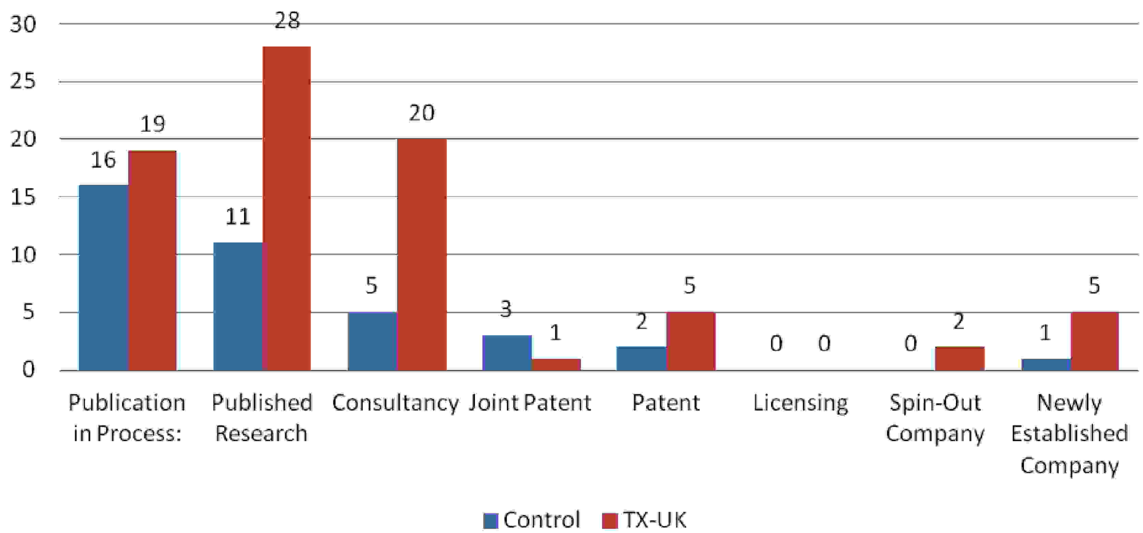


Figure 6.32: What has this lead to: key performance indicators (KPIs).

6.4.2 Measurement of Impact

It can also be seen (Figure 6.32) that there is a high proportion of publications that are in process by both groups yet there was 44% more amongst the TX/UK Collaborative cohort than amongst the Control cohort.

While the outputs of publications is important to the RAE standing of the university and plays an important role in the amount of research funding the university would obtain after the exercise it is the more relevant economic key performance indicators (KPI's) of the two research groups which are of interest within this study.

Within this study consultancy was able to be captured and although both groups engage in consultancy activities the TX/UK researchers are 60% more engaged in consultancy activities than the control research group, this could infer that those researchers within research collaborations networks have a greater opportunity to gain consultancy through the network.

Both cohorts also reported a number of spinout and newly formed companies. Within the TX/UK cohort there were 2 spin-out companies formed over the past three years compared with none amongst the control group. Compared with a broader definition of newly established companies (i.e., including spin-in and other routes) the TX/UK researchers founded five newly formed companies to the Control group's one.

6.4.2.1 Location, Location, Location

The focus of this study was to see in its most basic form, whether a region is able to leverage an international research network for economic development. In this case the two research groups were asked what kind of collaboration were they involved in; a 1-1 collaboration; where one entity was involved with the single respondent was in operation in a single local, and Multi Partnership collaboration where by a single respondent was involved with an entity that involved multi locations within an identified geographical location. Interesting enough was the fact that within both groups all researchers worked in an equal proportion of 1-1 collaborations within Wales, thusly inferring that there is proportional academic economic spill-over within the region, with the TX/UK researchers having a higher proportional engagement outside of the region than the control.

6.4.2.2 One-to-One Partnerships

Figure 6.33 on the following page presents the geographical spread of 1-1 partnerships across the TX/UK and Control cohorts.

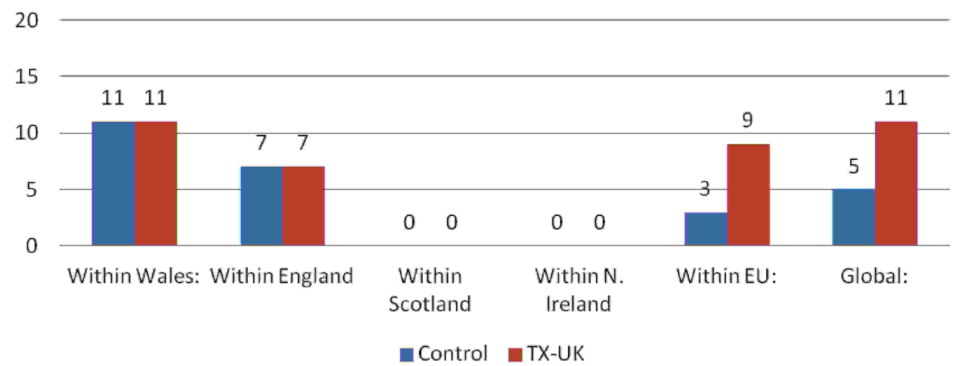


Figure 6.33: Geographical of location 1-1 partnership.

From Figure 6.33, the following can be observed:

- TX/UK and Control cohorts present the equal numbers of 1-1 collaborations across the UK.
- TX/UK cohort is involved in significantly more 1-1 collaborations with partners in the EU and elsewhere around the world.

6.4.2.3 Multipartite Partnerships

Figure 6.34 below presents the geographical spread of multipartite partnerships across the TX/UK and Control cohorts.

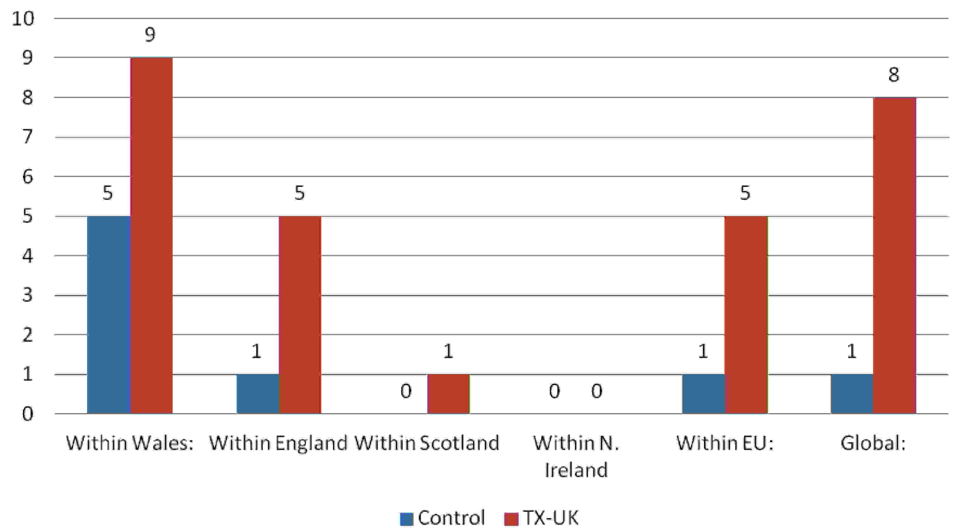


Figure 6.34: Geographical of location multi-partite partnerships.

In contrast with the 1-1 partnerships presented in Figure 6.33, a definite difference in number of partnerships with UK involvement can be seen between TX/UK and Control cohorts. This and other key observations can be summarized as:

- As for 1-1 partnerships, TX/UK cohort is involved in significantly more activity involving EU and Global partners.
- TX/UK cohort is involved in significantly more partnerships involving the UK.

6.5 Interviews

Over the course of this study semi-structured interviews were conducted with twelve key individuals involved the Texas/United Kingdom Collaborative six on the Texas side and six on the United Kingdom. These comprised of the Political Supporters, Academic Facilitators, and Coalface Researchers

6.5.1 6.5.1 Interview Participants

6.5.1.1 Texas Political Supporters

Name	Role(s)	Texas/UK Involvement
		continued on next page

Dr. Malcolm Gillis	Former President Rice University, Chairman of the TX/UK Collaborative	Overall Chair of the TX/UK Collaborative on both sides; Instigator of the Collaborative
Hon. Ian Murray	Former Consul General Houston	Former co-instigator of the TX/UK collaborative

Table 6.1: Texas political supporters.

6.5.1.2 Texas Academic Facilitators

Name	**Role(s)**	**Texas/UK Involvement**
Dr. Denis Headon	Director of the TX/UK Collaborative	Overall Director and Administrator of the TX/UK Collaborative
George Abbey Sr.	Rice University, Baker Botts Fellow for Space Policy	Co-Instigator and Partner Facilitator of the TX/UK Collaborative

Table 6.2: Texas academic facilitators.

6.5.1.3 Texas Coalface Researchers

Name	**Role(s)**	**Texas/UK Involvement**
Prof. Mauro Ferrari	Professor and Chairman of Department of Nanomedicine and Biomedical Engineering and Experimental Therapeutics, the University of Texas M.D. Anderson Cancer CenterPresident, Alliance for NanoHealth	Partner in Cancer Research Project with Dr. Steve Conlan
Dr. Terry Fossum	Professor of Veterinary Surgery, Texas A&M UniversityDirector Texas A&M Institute for Preclinical Studies and the Michael E. DeBakey Institute for Comparative Cardiovascular Science and Biomedical Devices	Partner in Bioengineering BSc with Swansea University Engineering and Medical Schools

Table 6.3: Texas coalface researchers.

6.5.1.4 Wales Political Supporters

Name	Role(s)	Texas/UK Involvement
Edwina Hart AM, MBE	Minister of Health and Social Services	Sponsor of Strategic Initiatives aligned with the Collaborative
Paul Williams OBE	Director of NHS Wales	Former Director of ABM NHS Trust, Clinical Trials Partner, Involved in Pan Wales Development of the Collaborative

Table 6.4: Wales political supporters.

6.5.1.5 Wales Academic Facilitators

Name	Role(s)	Texas/UK Involvement
Prof. Julian Hopkin	Rector of Swansea University Medical School	Intuitional and Political Champion of the TX/UK Collaborative
Prof. Ian Cluckie	Pro-Vice Chancellor Research, Swansea University	Intuitional

Table 6.5: Wales academic facilitators.

6.5.1.6 Wales Coalface Researchers

Name	Role(s)	Texas/UK Involvement
Prof. John White	Chair of Research Swansea University Medical School Head of Cancer Research ILS	Involved in the Collaborative since 2007, Collaborative Champion in the School of Medicine, Collaborating in Reproductive Cancer Research with Baylor College of Medicine
Dr. Steve Conlan	Co-Director of CNH Researcher interest: Cancer	Involved in the Collaborative since 2007, Collaborative Champion in CNH, Collaborating with MD Anderson Cancer Research Center

Table 6.6: Wales coalface researchers.

6.5.2 Interview Observations

The semi-structured interviews investigated a range of sub-hypotheses through questioning amongst the stakeholder groups. The following sections outline the key findings of these interviews, highlighting areas of alignment and non-alignment amongst stakeholders regarding these issues, together with other observations.

6.5.2.1 Political Supporter

Question	Alignment	Non-Alignment	Other Observations
Is there Regional Coherence and what can be done to improve or strengthen?	Recognition of critical role of collaboration; Coherence exists yet room for improvement remains; Commitment to supporting further developments	Stronger coherence in Wales with the Public Sector; Stronger Coherence in Texas with Private Sector	Welsh Assembly Government Supports Regional Coherence; At the institutional levels it is seen that there is a hindrance from senior management
Are institutions across the region responsive to the collaboration agenda?	In the main all are responsive; Institutional responsiveness is led by individuals	Greater cajoling needed on the Welsh side	Within Wales, funding mechanisms have not yet driven collaboration
Do you see collaboration as a strategic imperative for institutions?	All agree, Yes	Some institutions see collaboration as a "means", others as an "end"	On both sides it was seen to be away of accessing more research funds and drives ratings
What do you see the role of government as being?	Facilitator & Funder; Providing light touch support	Texas no government involvement at Board level	
Is the regional cluster growing and in the right direction?	All agree, Yes	Within Wales dual agendas of Healthcare delivery and Broader-Education and Economic Development Agenda	Texas am more Mature Cluster, Wales is still in its Infancy; Both recognize the Economic Impact of the Sector

Table 6.7: Political supporter responses.

6.5.2.2 Academic Facilitator

Question	Alignment	Non-Alignment	Other Observations
How does your institution align with Regional Partners?	Strongly where funding opportunities exist, yet also see benefits impact; Work with broad range of stakeholders	Apart from Swansea no other Welsh Institutions are involved; Within Wales WAG Policy makes alignment	
How is your institution changing to facilitate collaboration?	Strategic, multi-disciplinary partnerships	Within Wales there was a mix of alignment to Public Sector Research focus versus multinational enterprise inward investment	Rice's research collaboration Building and Swansea's ILS I&II and CNH
How is collaboration embedded in your strategic plan?	Institutional endorsement of programs that facilitate collaboration		On both sides by institution endorsing and funding of research infrastructure project; In Wales via building on regionally funded projects
What do you see the role of government as being?	Facilitator	Within Wales it was seen that is a thicker layer of bureaucracy	Within Texas, there was a stronger sense of government enabling vs. imposing
Is the regional cluster growing and in the right direction?	Yes, with plenty of scope		Yes, with the funding of Infrastructure for R&D

Table 6.8: Academic facilitator responses.

6.5.2.3 Coalface Researcher

Question	Alignment	Non-Alignment	Other Observations
How do you work with other regional stakeholders?	Via International, National and Regional Research Funders, Companies and Academic Research Initiatives		Within Texas, it was highlighted that they are better at translating both research and commercial potential to stakeholders
			continued on next page

Is your institution responsive to the collaboration agenda?	Yes	Within Wales, it was seen that in some cases prodding had to be done at the Senior Management Level	Slight misalignment on the Welsh side between what Management wants and what Researchers want
Do you see collaboration as a strategic imperative for your institutions?	Absolutely	In Wales it was seen to be a way to develop indirect research funds that otherwise might	Key for both sides in the development of research and funding
What do you see the role of government as being?	Funder	In Wales, Government tries to operate outside its areas of expertise	On both sides government was seen as the funder through Research Councils and other mechanisms both regionally and nationally
Is the regional cluster growing and in the right direction?	YesAll highlighted the respective development stage of the clusters		On the Welsh side it was seen that working with Texas would allow for their cluster to develop faster.

Table 6.9: Coalface researcher responses.

6.5.3 Other Observations

In addition to the specific issues explored through the core questions asked in the semi-structured interviews, a number of participants made comments and observations of interest to the study. These include the following:

6.5.3.1 Dr. Gillis, Rice University (Former President and Chair of the TX/UK Collaborative)

How started: UK government was looking for a high density of R&D in the Medical Sector and were reviewing the Boston Areas, they were convinced to also look at Houston where the Texas Medical Center, the US largest Research and Medical facility.

Why: Also access to facilities and material as the issue was during the period of Phase I of the Collaborative where access to Stem Cell lines were legislatively prohibited in the USA. Inclusive to this they were looking to increase the research outputs of the universities involved within Phase I, knew that putting smart people in the same room that they would identify synergies between themselves and generate outputs in Research and publications.

6.5.3.2 Iain Murray (Former Consul General Houston, Texas)

Why: Looking at Boston, but were looking to gain inward investment into the UK through research building on access to people, research, and facilities. The attitude of openness within Texas was the weight that tipped in Texas's favour versus Boston.

6.5.3.3 Edwina Hart (Welsh Assembly Government, Minister for Health and Social Services)

Looking at this opportunity of being in this prestigious research collaboration is very impactful to not only Swansea but to Wales in general in regards to speeding up innovation in the medical and health sector. Wales being a small country it is easy to meet with the decision makers to be able to facilitate opportunities.

Swansea has been able to increase the research funds of the Medical and Engineering schools due to this collaboration inclusive to this they have brought not only World Class Medical and Engineering Science and Experts to Wales but taken the best in Wales to Texas. Opportunities like this to create a streamlined framework of capturing the benefits while capitalising on the opportunities should not be missed. Flexibility and accessibility is key, opportunities in gaining knowledge and innovation to better the Healthcare offering in Wales.

6.5.3.4 Paul Williams (Director of NHS Wales)

The opportunity of bringing the NHS Clinical Trials Infrastructure to the Collaborative is a key driver for the NHS in building new and novel ways of delivering healthcare in Wales. By tying into the TX/UK Collaborative we gain access to one of the World leading cancer research centers and are able to bring to bear the value of phase II trials for research in Texas. Building throughput of new products and processes will allow the Welsh NHS to maximise on its strategic investments with Universities, especially Swansea University. Inclusive to this is the access to some of the best medical minds in the world; by bringing them together we can drive knowledge development in the NHS with our Clinical Researchers for Translational outputs.

6.5.3.5 Dr. Denis Headon (Director of the TX/UK Collaborative)

A small fraction of the world's research can take place in Wales - international collaborations will increase the influence and reputation of Wales in research and development. Wales can benefit from research carried out elsewhere by forming collaborations with leading researchers in other parts of the world, especially the USA

Building international collaborations provides access to the world's best science, scientists and facilities. Prime Minister Brown's speech, "Enlarging the Anglosphere", delivered in the US on April 16, 2008 contained six proposals, four of which are currently fostered by the Collaborative: enhancing student and faculty exchanges, increasing cooperation on enterprise, strengthening cooperation in health research and fostering collaboration in other areas of research.

6.5.3.6 George W. S. Abbey Sr. (Rice University, Baker Botts Fellow for Space Policy)

There is a need for the emphasis of "Team Science" through alliances, collaborations and consortia availingthe synergy of team approaches and "big" science. An example is the changing face of the biosciences in the post genomic era with converging technologies – nano, bio and info, and new enabling technologies.

Opportunities for interdisciplinary and multidisciplinary collaborations – cross-departmental, cross-institution, academia/public/private, and international can lead to key advances an example would be the International Space Station ISS.

The aim should be in building new areas of research and capacity in these areas and creating the knowledgeable human capital who understands not only the Science but the relationships on which the collaborations are built. Since retiring from NASA, after years of service and brokering the many international countries and agencies into collaborating in the ISS, the one thing I keep on hearing from former international partners is, "*Since you have left George, no one understands the relationship which has been created.*"

> NOTE: This statement was echoed at the 2nd Annual IMSS at Rice University, May 2008, by the Administrators of ESA, ROSCOSMOS, and IBMP.

Young people today are choosing not to go into science and engineering, and the enrolment of US students in these educational fields is going down in our universities. This matters because, as you can read in the recent report, "United States Space Policy: Challenges and Opportunities Gone Astray," published by the American Academy of Arts & Sciences, in today's world, technology is critical to this country's leadership role. We don't manufacture a lot of goods anymore, but we have maintained our leadership role with our technology. Without the input of bright, innovative young people, that leadership role is going to be affected.

Look at all the problems we need to address – the environment, alternative energy sources, health care and our aging infrastructure, not to mention space exploration. The solutions all come down to technology and the availability of bright and innovative young people with questioning minds.

6.5.3.7 Prof. Ian Cluckie (Swansea University, Pro-Vice Chancellor of Research)

Since arriving in Swansea University in 2008, the University has been pursuing ambitious and radical policies to accelerate the development the University as a strong, research-led institution. By being included in one of the most elite of international research groups provides our researchers and students the opportunity to work and understand the wider world.

The University understands that it cannot be world-class university on its own and that research is increasingly a global activity. The University recognises that even the largest universities in the UK cannot provide the critical mass of staff and facilities to develop cutting-edge research in many areas of science and technology. The Universities membership in the Texas-UK Collaborative shows that Swansea is addressing this challenge. Inclusive to this is the recognition of the effort and work that goes into creating the relationships with partner institutions, the University see's its role as a facilitator in assisting the researchers win research awards and conduct world class research.

6.5.3.8 Prof. Julian Hopkin (Swansea University, Rector of the Medical School)

The School of Medicine is delighted by this opportunity to join other world leading British universities in the Collaborative. The facilities of the Medical School and ILS were planned to establish links with research partners from the world's leading institutions. Being included in the Collaborative is an important stage in that process. ILS' innovation powers and the Blue-C supercomputing is the key to this – as is the very exciting emergence of a new Centre for NanoHealth, which represents collaboration between the University's Schools of Engineering and Medicine at its best. Building on the infrastructure investments and the opportunity to leverage them to the benefit of others, is key to developing translational discoveries.

The opportunity of contributing to the Collaborative based on harnessing ground breaking, new technologies in delivering medical and health advance along with training of researchers and clinicians is vital and valuable.

Inclusive to this is the partnership with the local NHS Trust and the ability to conduct human trials; with such a large catchment of patients it too becomes an instrument for leveraging with partners in the development of novel health and medical innovations. This has proven to be quite valuable in that Swansea University is in discussions with a partner institution, Texas A&M University in developing a Trials pathway for such innovations to take advantage, by in partnership conducting Phase I trials at A&M and Phase II in Swansea. This allows the training of researchers in the procedures required for both Phase I & II trials but gives them the understanding of translation to regulatory approvals in both the US and EU.

6.5.4 TX/UK Collaborative "Swansea's Three Year Outcomes"

Swansea University has already exploited this high-profile network, identifying collaborative research opportunities with Rice University, Baylor College of Medicine, Texas A&M University, University of Texas Health Science Center, and MD Anderson Cancer Research Center. The collaboration with Rice University and "The Richard E. Smalley Institute for Nanoscale Science and Technology" in particular, has enabled Swansea to position itself as a lead institution in Nanotechnology and Bioscience Research, generating true value both intellectually and economically.

Over the past three years Swansea University has achieved the following through its partnership in "The Collaborative".

- Successful proposal for the establishment of a Center for NanoHealth, strengthened by the support of the Collaborative.
- Becoming the first international partner in the Alliance for NanoHealth (ANH).

- Participating in the FDA - ANH Nanotechnology Initiative FANTI. Two members of Swansea University sit on a Public Private Partnership (PPP) with the Senior Scientist of the FDA with the goal of developing a Collaboration framework that include stakeholders from industry for faster FDA Approvals (pharmaceutical, biotech and devices).
- £60,000Funding Award from the Houston Foreign Commonwealth Office to promote Research in Wales.
- £6.77 millionfunding from the EPSRC for research on number entry errors with medical devices has been secured by a Collaboration between UCL and Swansea University this will lead to the design and safe use of interactive medical devices – the proposal was greatly enhanced through the support of the Collaborative.
- £1.4 million funding from EPSRC for research supporting Prof. Huw Summers and Dr. Shareen Doak of Swansea University involving collaboration with researchers at Texas A&M University was facilitated by the Collaborative.
- £1.19 million Joint US-UK Research Programme bid, submitted to 2nd Round Review: Environmental Behaviour, Bioavailability and Effects of Manufactured Nanomaterials between Texas A&M and Swansea University School of Medicine: Shareen Doak as UKPI in the area of In vitro (geno) toxicity along with Gareth Jenkins and Paul Lewis.
- Establishment of joint taught student programmes with Texas A&M University in Bioengineering, NanoMedicine and Process Safety Engineering.
- The Award of “Bridging the Gaps” from the EPSRC for Multidisciplinary Research “Hops” across disciplines, ∼£1.5 million for 3 year for
- The development of collaborative research facilities MOU between Texas A&M‘s Texas Institute for Preclinical Studies (TIPS), Texas Institute for Genetic Medicine (TIGM), National Center for Advanced Therapeutics Manufacturing and Swansea University’s Institute of Life Science (ILS).

The vision of this formal framework collaboration is to be the conduit to preclinical animal studies from Wales, UK and possibly Europe for Texas A&M’s facilities with Swansea University providing access to Human Trials facilities and human biologic material. This will provide a throughput from preclinical to human and access to the US market for companies from UK/EU and conversely for US companies to the UK/EU (Figure 6.35). Texas A&M’s National Center for Therapeutics Manufacturing would conduct low level therapeutics development for usage in FDA/EMEA preclinical trials and then scale up for FDA/EMEA Human Trials.

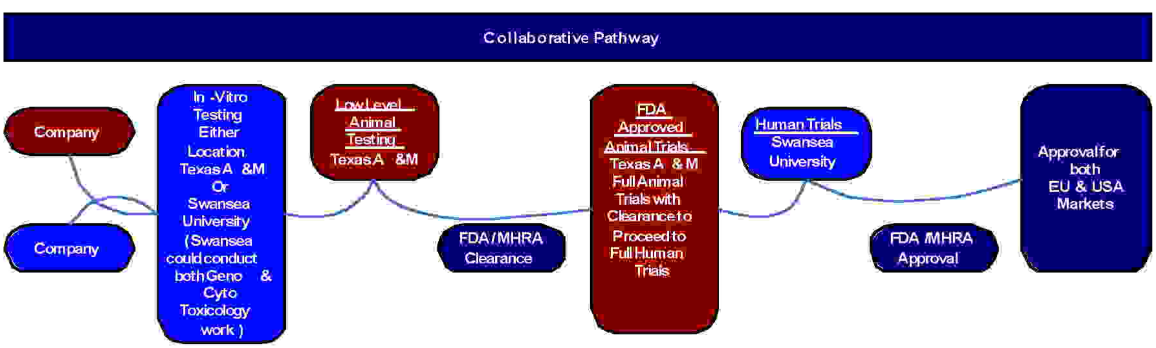


Figure 6.35: Texas A&M University a Swansea University facilities collaboration for preclinical and clinical trials.

Other outcomes include:

- The development of collaborative academic program MOU between UT Health Science Center and MD Anderson Cancer Research Center (Number one Cancer Research Center in the USA) for MSc NanoMedicine and Swansea University's Schools of Engineering and Medicine.
- Joint Research Program with Dr. Bert O'Malley of Baylor College of Medicine and Prof. John White & Dr. Steve Conlan on Endometrial Cancer.
- The development of a collaborative Research Center MOU with the Baylor College of Medicine NIH Center for Diabetes and Endocrinology Research. (One of nine NIH Research Centers in the USA).

A number of high profile visiting speakers were involved in the program:

- Dr. Malcolm Gillis (Former President Rice University and Chair of Cancer Prevention Research Institute of Texas).
- Dr. Wade Adams (Director Richard E. Smalley Institute, Rice University).
- Prof. Andrew Barron (Charles W. Duncan - Welch Chair of Chemistry and Professor of Materials Science, Rice University).
- Prof. Mauro Ferrari (MD Anderson Cancer Research Center and President – Alliance for NanoHealth).

All of the collaborative Research Bids have given an Induced Investment to Swansea University of ~£10 million.

> NOTE: Investment induced is measured in £, this is the *gross*amount of direct tangible or intangible investment from the private sector or: commercial, charitable and not-for-profit organizations and private individuals (WDA, 2004/5, p.41).

Huggins and Johnson present the case that in more heavily relied on in economical deprived regions of the UK such as Wales, universities are more heavily relied upon for value generation, both intellectually and through translational discoveries. This means that initiatives such as the Texas/United Kingdom Collaborative which give regional researchers access not only to world-class expertise and facilities, but also to new markets and opportunities for creating the needed value generation. Their thesis therefore suggests that such activities should not only be merely encouraged, but actively supported to realize their wider regional benefit.

6.5.4.1 Prof. Theresa Fossum

Was not involved directly in Phase I or Phase II but via the Bioengineering at Texas A&M. The importance of access to facilities are a key driver in the fact of the difficulties within the UK in conducting Phase I Clinical Trials where as in Texas is quite easy. It was identified that the access to Phase II Clinical Trials was much easier in the UK; we identified an opportunity for building off one another to gain advantages for both locals, Texas for access to Patients and Human Trials in Swansea and for Swansea the Phase I animal trials. Interestingly, other colleagues of mine that are in more into the Texas/United Kingdom Collaborative have given their endorsement, Dr. Mauro Ferrari, the author of the US National Institute of Health's; National Cancer Institute: Novel Technologies for Non-invasive Detection, Diagnosis, and Treatment of Cancer, Special Emphasis Panel (Chair); Executive Office of the President of the United States of America: Nanotechnology Research Directions: National Science and Technology Council, Committee on Technology, Interagency Working Group on Nanoscience, Engineering and Technology, President of the Alliance for Nano Health informed me that Swansea was the first international member to the Alliance and that he knows first hand that the people and facilities are putting out world class science. For Texas A&M it id the opportunity to build and increase the universities R&D and assist in the universities 3rd mission of engaging in economic development. We see a great opportunity for companies in Wales, UK, and Europe to work with us through Swansea University as it gives us a complete regulatory pathway for approving medical devices and therapeutics in two of the world's largest markets. It also is a benefit to have the capable people in place in Swansea to allow this facilitation and framework to be put in place. For us its about the People, Science, and Economic out puts, while keeping the over arching Governance flexible enough to allow room to breath on both sides of the pond, yet staying within the boundaries. Framework is the word I will choose with capable people like Theresa Fossum and Mike Pishko on our side and Jim Abbey, John White and Steve Bain on the Swansea side.

6.5.4.2 Prof. Mauro Ferrari (President of the Alliance for Nano Health, MD Anderson Cancer Research Center)

The Alliance for NanoHealth (ANH) saw the opportunity to create a mechanism for collaboration through with Swansea University and in so doing created the International Affiliate Center (IAC) program. Upon visiting Swansea University in 2008, he was very excited to take at the research that was being conducted and from that decided to take preliminary steps in establishing a formal relationship with Swansea University. Dr. Ferrari also stated that he has great expectations from this developing international collaboration and hoped that the affiliation with the Alliance for NanoHealth supports the endeavours of the Centre for NanoHealth not only in the European Union but globally. Inclusive to this was stated that by linking in the global centers and training the next generation of researchers and regulatory agents, new novel Nano-therapeutics could make it into mainstream medical and healthcare, by working in partnership between Academia, the Private Sector and Government this is achievable.

6.5.4.3 Prof. John White (Swansea Medical School, Chair of Research)

The "Collaborative" gives the opportunity for not only meeting great minds in Texas but brings Wales' minds to Texas. It also broadens the research by creating synergistic links, building on similar pathways but using different approaches. Capitalising on the knowledge bases both in Texas and Swansea has allowed Swansea University to win pivotal research funding awards and has highlighted the capabilities of the collaboration between the Schools of Medicine and Engineering. Inclusive to this is the similar mindset of creating value, whether it is by the research to better Human Heath, the ability to assist R&D of companies or the training of the next generation of researchers who value "Multidisciplinarity".

It is also important for administration both "Institutional" and "Governmental" to realise their roles in collaboration, as facilitators to enable collaboration to flourish and not be impeded by bureaucracy. There is no room for parochialism in collaboration.

It has been proven that centers of academic excellence can help launch and grow biotech companies. The Institute of Life Science (ILS) is the new research institute for the Medical School at Swansea University. ILS is a £52 million collaboration between the Welsh Assembly Government, IBM, and Swansea University.

A major asset of the ILS is an IBM Blue C supercomputer, the largest computer dedicated to life sciences in the U.K. (2.7 teraflops power now, increasing to 30 teraflops in 2009). Blue C supports the ILS in its interdisciplinary approach to translational medicine, which covers areas like NanoHealth, health technology assessment, and health services research.

ILS has tech transfer, incubator, and business facilities and is part of the National Mass Spectrometry Service Centre. It will be at the heart of the largest NHS trust in Wales with University status and a focus on clinical delivery and commercial partnerships.

6.5.4.4 Dr. Steve Conlan (Swansea University, Co-Director of CNH)

The key to successful growth of a Nanomedicine hub is forging industry and research partnerships. Build on the university's strengths in engineering and physical sciences by searching for researchers and clinicians eager to cross-disciplinary boundaries.

The culture of researchers is very important to feel supported not only in a research group but in the School and in the wider University. Knowing you have support from both the Schools and Universities administration is empowering both personally and academically.

6.6 Bibliography

- Audretsch D., 1998, "Agglomeration and the location of innovative activity", Oxford Review of Economic Policy, Vol. 14, pp. 18–29.
- Audretsch D. and Feldman M., 1994, "R&D spillovers and the geography of innovation and production", The American Economic Review, Vol. 86, pp. 630–640.

- Belussi F., 1999, “Policies for the development of knowledge intensive local production systems”, Cambridge Journal of Economics, Vol. 23, pp. 729–747.
- BIS, 2010, “Small firms given a major boost by Budget growth plans”, www.bis.gov.uk, Accessed 2010.
- Bradsher K., 2010, “China Drawing High-Tech Research From U.S.”, NY Times, Global Business.
- Burgi B, and Pradeep T., 2006, “Societal Implications of Nanoscience and Nanotechnology in Developing Countries” Current Science, Vol. 90, No. 5.
- Burt R., 1987,”Social contagion and innovation: cohesion versus structural equivalence”, American Journal of Sociology, Vol. 92, pp 1287–1335
- Davenport S., 2005, “Exploring the role of proximity in SME knowledge-acquisition”, Research Policy, Vol. 34, Iss. 5, 2005, pp. 683-701.
- Davies D. and Weinstein D., 1999, “Economic geography and regional production structure: an empirical investigation”, *European Economic Review* Vol. 43**,** pp. 379–407.
- DIUS, 2009, “Department for Innovation, Universities and Skills Response to the House of Lords Science and Technology Select Committee Nanotechnologies and food inquiry”, www.parliament.uk, Accessed 2009.
- Feldman M., 1994,”The Geography of Innovation”, Kluwer Academic Publishers, Boston.
- Granovetter M., 1985, “Economic action and social structure: The problem of embeddedness”, American Journal of Sociology, Vol. 91, pp. 481–510.
- Gulati R., 1999, “Network location and learning: The influence of network resources and firm capabilities on alliance formation”, Strategic Management Journal, Vol. 20, pp. 397–420.
- Harrison B., 1991, “Industrial districts: Old wine in new bottles?”, Regional Studies, Vol. 26, pp. 469–483.
- Hanson G., 2005, “Market potential, increasing returns and geographic concentration”, Journal of International Economics, Vol. 67, Iss. 1, pp. 1-24.
- Huang Z., Chen H. and Roco M., 2004, “International nanotechnology development in 2003: Country, institution, and technology field analysis based on USPTO patent database”, Journal of Nanoparticle Research Vol.6, pp. 325–354.
- Kay L. and Shapira P., 2009, “Developing Nanotechnology in Latin America” Journal of Nanoparticle Research, Vol. 11, Iss. 2, pp. 259-278.
- Keeble D. and Wilkinson F., 1999, “Collective learning and knowledge development in the evolution of regional clusters of high technology SMEs”, Regional Studies Vol. 33, pp. 295–303.
- Kostoff R., Koytcheff R. and Lau C., 2007, “Global nanotechnology research metrics”, Scientometrics, Vol. 70, No. 3, pp. 565–601.
- Krugman P., 1991, “Increasing returns and economic geography”, Journal of Political Economy, Vol. 99, pp. 483–499.
- Marshall A., 1986, “Principles of Economics”, 8^{th} Ed., Macmillan, Basingstoke.
- Moore G., 2005, “Dealing with Darwin: How Great Companies Innovate at Every Stage of Evolution”, Portfolio Hardcover, ISBN-10 -1591841070.
- National Materials Advisory Board (NMAB), 2006, “A Matter of Size: Triennial Review of the National Nanotechnology Initiative” EmTech Report.
- OECD, 2005, “OECD SME and Entrepreneurship Outlook – 2005 Edition”, www.oecd.org, Accessed 2008.
- Osegowitsch T. and Sammartino A.,2008, “Reassessing (home-)regionalization”, Journal of International Business Studies, Vol. 39, pp. 184–196.
- Parker R., 2008, “Leapfrogging Development through Nanotechnology Investment: Chinese and Indian Science and Technology Policy Strategies”, China-India-US Workshop on Science, Technology and Innovation Policy.
- Porter M., 1998. “Clusters and the new economics of competition”, Harvard Business Review Vol. 76, pp. 77–90.
- Quinstas P., Lefrere, P. and Jones G., 1997, “Knowledge management: a strategic agenda”, Long Range Planning, Vol. 30, pp. 385–391.

- Rabellotti R. and Schmitz H., 1999, "The internal heterogeneity of industrial districts in Italy, Brazil and Mexico", Regional Studies, Vol. 33, pp. 97–108.
- Rudd E., 2008, "Discussion on investment in a technology based start-up" Swansea University.
- Shapira P., and Wang J., 2009, "From Lab to market: Strategies and issues in the commercialization of nanotechnology in China", *Asian Business & Management,* Vol. 8, pp. 461-489.
- www.nanopaprika.eu, Accessed 2010.
- Yip G., Rugman A. and Kudina A., 2006, "International success of British companies", Long Range Planning, Vol. 39, Iss. 3, pp. 241–264.
- Youtie J. and Shapira P., 2008, "Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development", Research Policy, Vol. 37, pp. 1188–1204.

Chapter 7

Discussion[1]

We have presented the methodology and results of this study. The following section presents the discussion of the findings in the context of the five components: people, science, culture, economics, and governance.

7.1 People

Human capital is fundamental to the development and sustainability of a knowledge economy. Indeed some commentators claim that up to 70% of all global assets can be described as 'human capital' (Milken 2010). For a generation the US, Europe and Japan have largely dominated the global knowledge economy. However the world is changing. China for example has a deliberate strategy to repatriate the students who have studied around the world over the last 20 years. They are offering incentives that include generous salaries and significant investment in research facilities in order to create an infrastructure capable of supporting a sustainable knowledge economy. China is targeting sectors for strategic investment including nanotechnology, bioscience, low-carbon technology and digital media. China is not the only economy emerging from the 2008-2010 financial crises on the front foot, India, Vietnam, Mexico, Russia, Brazil and several others suddenly have the financial capability to invest in human capital in infrastructure to compete in the near and medium term. All of this represents a serious threat to the old order. Much of the innovation capacity of the US has been driven by brilliant young talent immigrating to the US from around the world. This source of talent and human capital may dry up and the US will have to depend on home grown human capital. In Europe the economies have suffered badly in the financial crisis. Significant cuts in government spending are predicted for the years 2012 to 2017. The HE sector in the UK is expecting cuts of up to 25% in University budgets. These cuts could not come at a worse time when one recognises the fierce competition for talent and markets that will come for the range of new economies and regions. For a small principality like Wales, on the periphery of Europe there is little margin for error. The stake holders will have to work together to develop and deliver a strategy for this new global context.

At the recent Global Conference entitled "Shaping the Future" (Los Angeles 2010) Michael Milken quoted the statistics shown in Table 7.1. The comparable statistics for European region are not yet published. However these statistics show that the US at least is not recognising or gearing up for the challenge. If these figures are correct then an average family in the Far East is investing up to seven times more in the education of new generation than the comparable family in the US. Like any statistics there are arguments regarding the detail, however these show a picture that few in the US or in Europe would challenge. Education is no longer prioritised by our society in the way it was.

[1]This content is available online at <http://cnx.org/content/m43445/1.1/>.

Category	% Spend US	% Spend Far East
Household	38	10
Transportation	17	6
Food	10	18
Education	2	15

Table 7.1: Household spend as a percentage of income.

The role of the UK and Welsh Higher Education (HE) sector is critical to the agenda. The research shows that industry needs the support of Universities but in very specific ways. Firstly the critical role of developing human capital with the skills and knowledge needed to become quick useful to business. The human capital does not only need to have STEM skills but also commercial awareness is essential. The talent that is needed to keep Wales and the UK as a meaningful player in these emerging sectors must have a mindset that is open, collaborative and global. Secondly the Universities must be an environment where world class research can flourish. They must be capable of recruiting and retaining the best research talent. Clearly no University can be world class in every subject but there does need to be pockets of truly excellent research work. The research clearly shows that industry needs Universities to focus on the human capital elements of their portfolio of activity. They see other offerings as a much lower priority including access to facilities, advice on manufacturing and regulatory matters and on business strategy. The message is clear 'give us appropriately trained and experienced talent and create a relevant world class research environment, leave the business operations and value generation to us'. Perspectives from the study underpinning this are as described above.

7.1.1 Supply of Talent

- The data demonstrates the high level of expertise and the multidisciplinary nature of the "Human Capital" involved in the activity across the cluster.
- The importance of ongoing training and development is clear from both the Collaborative questionnaire and stakeholder interviews. The continued success and growth of regions being underpinned by development of such skills fits with the observations of numerous commentators such as the ONS (2004) and Work Foundation (2006).

7.1.2 Networks

- The global spread of both 1-1 and multipartite partnerships within the TX/UK cohort demonstrates the reach of the knowledge network. The worldwide perspective of innovation systems poses an interesting question for how this fits with the regional approach of considering a Knowledge Economy as presented by Cooke and De Laurentis (2003).
- The network effect of knowledge dissemination and value creation across the region of Southwest Wales is considered by Abbey et al. (2008) for the Technium/ILS I network. Extending this across the CNH, ILS II network into the TX/UK Collaborative presents a significantly larger network to consider.

7.2 Science

It is clear from the study that industry looks to higher education to establish and maintain pockets of 'world class' research. Local industry often uses the fact that relevant research activity at the highest level exists in its locality as a differentiator when negotiating a new commercial relationship. Most companies in Wales active in the knowledge economy are on the smaller end of the spectrum. This often means that local research has a potentially disproportionate impact. Such small enterprises are unlikely to have a critical mass of research of their own and therefore their offering to a third party can be greatly enhanced by local research excellence as long as it is relevant, accessible and open.

There is recognition that local HE cannot be world class in all areas but that some exceptional activity can serve as hook that can form the basis of discussion with others who may be looking for expertise that may satisfy a deficiency in their tool-kit. Without some unique offering (Unique selling point-USP) it is much more challenging to develop a dialogue and define mutual benefit in an emerging relationship with global partners. Partners who are at the leading edge often seek to form alliances with others who are also at the leading edge.

Having world class research is an essential condition, but on its own insufficient to form an optimal platform for an emerging cluster. The research also has to be relevant to an emerging global sector and market. Research is particularly powerful as a cluster driver if it lends itself to multidisciplinary working. Hardly a product or service in the modern marketplace generates commercial return without containing aspects that flow from many contributory scientific, technical or business disciplines.

There has to be a clear and defined route that translates research, thereby creating real and tangible value. Intellectual property plays a key role but it must not stand in the way of creating relationships. Too often IP issues become a barrier to progress rather than a facilitator of opportunity. Bureaucrats and there associated bureaucracies involved in these discussions often despite not understanding the science are empowered by their organisation to dictate the agenda, often with the result that the underlying business opportunity is driven away. This is clearly an area where science, governance and culture have a direct influence on value creation and on the ability of a world class research activity to catalyse a knowledge cluster.

Perspectives from the study underpinning this are as described below.

7.2.1 World Class Science

- The strong showing of sector-focused publications from Swansea demonstrates World Class research strengths. In addition, secondary data including the RAE outcomes for Swansea University and the activities of partners in Texas (e.g., Author of the US NIH Nanotechnology in Cancer Research Policy), shows a major critical mass of research excellence in fields related to the sector.
- Participants in the Stakeholder interviews represent a range of World Class research groups and facilities. These include MD Anderson Cancer Research Center, The Michael DeBakey Institute and UK National Mass Spectrometry Service.

7.2.2 Relevance

- The KTN questionnaire supported the sub-hypotheses of need for sectoral relevance of facilities, in particular for Bio-Tech companies. This also is a factor in consideration of company revenue relating to nature of facilities required. Initiatives such as CNH, ANH, and ILS II are all examples of the cluster developing provision in line with this sectoral fit.
- The significant proportion of Applied and Commercial research undertaken within collaborations suggests a strong alignment with industrial needs and opportunities. The level of alignment demonstrated supports the ability to use the knowledge generated in meaningful ways leading to economic outputs, as presented by OECD (1996).

7.3 Culture

Most developed and emerging economies are strategically targeting the knowledge economy as a development priority. At the recent Global Conference 'Shaping the Future' (Milken Institute, Los Angeles 2010), senior thought leaders concluded that mankind's challenges distilled down to two issues; Education and Energy.

Education creates Human Capital; the raw material of the knowledge economy, without which any strategy is doomed to failure. Human Capital, their knowledge, skills and ideas, need to be embedded in a culture where they can be nurtured and allowed to flourish. Without the appropriate culture even the best talent will struggle and inevitably decide to relocate to where the culture is appropriate and supportive.

Throughout the study, four themes reoccurred, namely openness, collaboration, global perspective, and multidisciplinarity. A cross-cutting aspect of this is the requirement for an open culture as in the knowledge economy of the 21^{st} Century no single individual, enterprise or region can succeed alone. Further, in order to succeed and sustain success, organisations need to work in relationships which recognise that each partner has to achieve its value goals, including ensuring its own sustainability.

Effective and sustainable collaboration has to be based on honesty and truth; values that are often claimed but not always honoured in spirit or letter. An open collaboration is often one with organisations that offer different but compatible skills, expertise and other resources. The relationship shares the same goals and seeks to achieve the same collective outcomes even though the value achievements of the partners may be different and perhaps not equal, but always fair and equitable. The context of the 21^{st} century inevitably requires partnerships to be global in certain aspects. Rarely can a knowledge driven commercial initiative optimise value for all stakeholders unless the initiative has a global strategy and global aspirations. The International Space Station (ISS) is an extreme example, though even small research commercialisation opportunities rapidly look towards world wide markets. Multidisciplinarity is rapidly becoming a prerequisite for success, with partners willing to bring different but compatible expertise. The regional culture must recognise the aforementioned attributes of being open, collaborative, multidisciplinary and global, while governance processes must ensure that a supportive and enlightened culture is embedded.

Another essential feature of the optimal culture is often referred to as 'a can-do attitude'. Often, particularly in public sector organisations a 'oh we did our best' mindset prevails while opportunities are missed. Many observers of the Welsh comment on the acceptance of the lowest common denominator. As long as we are all the same and no one stands out then it is acceptable. This will not do in the modern world, where success must be celebrated and failure forgiven. Observations are often voiced regarding the willingness of the public sector in Wales to hide behind the 'rule book' rather than find a way of working through the rules to achieve a goal. For example, good and wise European guidance on matters relating to State Aid and Procurement are seen by civil servants as insurmountable barriers and result in avoidance of taking risk or, even to avoid seeking a constructive way to proceed. This approach is not replicated in other competing regions and can in certain scenarios lead to Wales being disadvantaged. Culture change takes time and must be nurtured by a governance infrastructure and process that ensure the development and protection of that culture.

Perspectives from the study underpinning this are described below.

7.3.1 Collaborative Activities

- The high overall levels of satisfaction with collaboration, amongst respondents to the Collaborative questionnaire demonstrates the receptiveness and positive attitude of academics towards engaging in collaborations. This is an encouraging sign of acceptance.
- Participants in the TX/UK Collaborative demonstrate a stronger propensity for collaboration than the wider Academic community in Swansea, both for academic and industrial collaborations. This high level of activity suggests stronger linkages across their cluster, a key factor in establishing competitive advantage Porter (2000).
- The multidisciplinary nature of collaborators involved in the TX/UK Collaborative provides an interesting perspective of a more open culture within the cluster which fits with Porter and Sterns' (1998) observation that not all actors within a cluster are necessarily aligned with a particular industry.
- The greater prevalence of activities to support collaboration amongst the TX/UK cohort suggests a stronger culture and valuation of collaboration.

7.3.2 Values

- The responsiveness of institutions and individuals in realizing collaboration opportunities is recognized as a key success factor amongst respondents to the stakeholder interview. In general there is a positive view of institutional responsiveness, though limitations are observed in the abilities of institutions to provide the levels of support and alignment required.
- From the Collaborative questionnaire, a positive view towards support and facilitation was also seen, however those involved in the TX/UK cohort with a wider perspective were most positive.

7.4 Economics

The heading ‘economics’ in the context of this study reflects the need to develop a sustainable cluster that creates true and measurable value, delivering a meaningful impact upon the region. The process starts with the identification of a sector that is relevant to the region and which has a global impact, offering markets with the commercial potential to contribute to the regional economy. Theoretically (or perhaps at least hypothetically), in a perfect world a region would gather together its key stakeholders, and with the benefit of the latest well-researched evidence arrive at evidence based consensus of which sector to develop, and the optimum approach. A holistic and integrated strategic plan would then be agreed and an implementation plan delivered. However, the world is imperfect and Wales is not a sufficiently coherent and cohesive community to deliver such an ordered solution. Despite this, in fairness to WAG, the regional government has published an economic development strategy “A Winning Wales” which together with further work defines the priority sectors as:

- Pharmaceuticals/Bio-Chemicals
- High technology
- Aerospace
- Agri-Food
- Construction
- Financial Services
- Creative Industries
- Automotive
- Hospitality, Leisure and Tourism
- Social Care

The WAG strategy does not contain the detail required to form the basis of a detailed regional plan. The implementation has therefore had to emerge ‘ground up’. The landscape of research in Wales is dominated by the HE sector as there is little large corporate R&D and the SME sector, active though it is, has not yet reached ignition point as a cluster. The University sector has been encouraged to compete by the funding model through instruments such as the Higher Education Economic Development (HEED) Fund. However, activities remain focused upon other major funding streams and their associated metrics, such as the Research Assessment Exercise, which is essentially a device designed to rank Universities to drive a formula for their financial reward. The RAE historically has not given ‘impact’ an equal weighting to more traditional academic metrics such as peer review articles, though there is currently much speculation as to how this will change under the Research Excellence Framework (REF).

There is therefore little surprise that in the main Universities across the UK, and arguably particularly in Wales, fail to work in strategic alliances in support of government economic strategy. Universities also make much of their independent nature and there at times seems to be near religious belief that they should not necessarily do what government asks them even in the context of economic development. At the time of completion of this study (Q1 2010), the world was beginning to emerge from at least the first phase of financial and economic crisis. The UK and consequently Wales had suffered badly and the public sector was facing significant cuts in budgets which were certain to come into play following the May 6^{th} General election of 2010. The WAG election cycle meant that a new Minister of Education (appointed following the retirement of the previous First Minister Rhodri Morgan in December 2009) had a further 12 months in office prior to WAG elections in May 2011. Signs were therefore emerging in the spring of 2010 of new determination to bring the Universities of Wales to heal using budgetary cuts as both carrot and stick, particularly in the context of collaborative working in support of economic development.

In the context outlined above, identification of target sectors for cluster development had, in the period leading up to Q1 2010 been largely left to individual institutions. Swansea University had responded to this challenge with three initiatives targeted at cluster development The Institute of Life Science (ILS), The Centre for NanoHealth (CNH), and the Institute for Advanced Telecommunications (IAT). These initiatives realised differing levels of success. IAT lacking institutional and regional embeddedness seems to have suffered and could form the subject of further study. ILS and CNH however survived that initial infant mortality period ('Death Valley'), benefitting from a common governance structure, and are starting to flourish. Both ILS and CNH benefited from major funding from the WEFO Convergence programme in 2009 drawn from EU Structural Funds. The application process for funding required detailed market and sector analysis, and were judged to be potential vehicles for cluster platforms. Collaborative working emerged during the bidding process and WEFO. Both projects benefited from the market led and economic driven application process, which should be a model for future similar activity in Wales.

The creation of value, particularly for the regional economy is a central to this thesis. Traditionally, for certain activities, Wales has done well in comparison with other UK regions. For example, in terms of generating spin-out companies, Welsh universities have done comparably well in contrast with their English counterparts. Swansea University have historically produced more than its share of such companies, even though that flow appears to have dried up in recent years possibly due to changes in governance processes (this could also be the subject of further study, particularly since the second most prestigious research institution in Wales seems to have stopped performing on this KPI).

Creating spin-out companies is one matter, growing them is another challenge altogether. It is growing indigenous companies that creates dynamism in the economy and stimulates activity leading to cluster creation. Wales performs badly in this regard, with very few knowledge based companies formed in Wales growing at pace. There appears to be a number of reasons for this.

Firstly, management skills and acumen seems lacking. In fairness these skills are rare and highly valued in the global market place. Successful managers of knowledge business with a proven track record can name their own price in the 'transfer market'. However, which of Wales' or for that matter the UK's business schools developing these skills? There is a big potential role for the Business Schools of Wales to play in developing the business leaders that a sustainable knowledge cluster will need. It could be argued that the Business Schools are overwhelmingly focussed on the traditional, and institutionally profitable, MBA delivery rather than on developing specialist programmes that are of direct local impact.

Appetite for risk is another issue of direct relevance and importance. Public sector organisations, are traditionally risk averse and the default situation of comfort is often one where do nothing option is seen as the safe option. Indeed the HE funding councils could themselves be accused of adopting a prudent 'safety first' approach to initiatives that touch on economic development issues.

Measuring value creation is of great importance and identifying the KPIs that truly reflect the development of value is another aspect that could benefit from review. Too often, traditional metrics are meaningless. The counting of patents generated is a classic example, for patents in their own right have no value until the ideas embedded in them are introduced to the market. Again, Wales has historically boasted an excellent rate of patent generation but no one has followed and reported on the generation of value under the cover of those patents.

Perspectives from the study underpinning this are described below.

7.4.1 Science in Growth Sector

- As shown in the KTN questionnaire enterprises across the sector are growing rapidly. Considered against Moore's Life-Cycle Model (2005), the individual sectors considered all offer significant growth and employment opportunities.

7.4.2 Access to Markets

- Observations from the KTN questionnaire demonstrate a broad coverage of international markets by companies operating in the sector. This links in with the consideration by Davis and Weinstein 1999 highlighting the importance of such market access in being a key contributor to growth.

7.4.3 Strategic Governmental Support

- The role of government in supporting through investments and provision of facilities is highlighted in the KTN questionnaire. However it is also clear that the "facilitator" role should be considered more so when it comes to the management of business and creation of value. This is echoed by the observations of "Political Supporters", "Institutional Facilitators", and "Coalface Researchers" in the stakeholders' interviews.

7.4.4 Value Generation

- The greater "productivity" of *promiscuous* collaborators is a stark example of a cluster providing a "*whole is greater than the sum of its parts*" (Porter 2000).

7.5 Governance

Governance is responsible for facilitating the strategic direction of an organisation. It establishes and maintains corporate values and seeks to ensure that they are embedded in the culture. Governance allows the executive to deliver the agreed vision. This study has identified that there is a culture in Wales that tends to see governance as a necessary evil; an inconvenience and a distraction. This view seems to be endemic and is in need of urgent attention. In addition there seems to be a total disconnect between the governance of different organisations, particularly those in the public sector. HE governance structures seem to have little shared vision and there is limited strategic dialogue both within and across areas of the public sector. Divisions of WAG, the HE sector, the NHS and local authorities seem to compete rather than collaborate. Whilst this view might seem controversial, it is certainly the opinion often held by business in Wales. The advantage of being a small nation that should be 'joined up' seems to be being lost. However, as identified during the study, green shoots of optimism can be seen as the benefits of partnerships such as the Texas/UK Collaborative draw together collaboration amongst the HE, Health, and broader public sectors, together with industry.

Take for example the comparison between Wales and Ireland in terms of alumni and diaspora. The Irish have exploited their diaspora to great economic and social effect. Virtually every city and region of the US has an Irish society and this is used effectively to establish networks and partnerships. The Welsh on the other hand do not even have a developed data base of university alumni a resource that could be very valuable in the context of the knowledge economy. The individual universities refuse to share information with each other or with government regarding their alumni. This means that each separate organisation has an under resourced alumni infrastructure leaving a valuable asset neglected. Diaspora and alumni networks can be of great value to a knowledge economy cluster in terms of partnership development, recruitment and retention of key individuals and in building the reputation of the region globally. If the executive functions of the region fail to collaborate in the common good then it is only a strong and integrated governance process that can force change.

Another identified barrier to the development and implementation of a knowledge economy cluster strategy in the South West Wales region is the ability of key actors to be commercially flexible. IP policies in particular are key to the agenda, it is they that can facilitate or conversely be a barrier to open innovation.

Perspectives from the study underpinning this are described below.

7.5.1 Regional Coherence

- Both the stakeholder interviews and Collaborative questionnaire highlight the importance of regional cohesiveness to establish strong and effective linkages across clusters. While strategies such as the Science Policy for Wales (2006) aim to achieve this, it is clear from stakeholder interviews that much remains to be done.
- The role of government in providing facilitation through good governance and provision of resource was acknowledged by all interview respondents. The role of commercial value creation should be left to the private sector. However, where other value can be delivered, e.g. within the Public/Education sectors, it could be considered that Academics and Civil Servants may also be considered as a variation of Schumpeter's Entrepreneur.
- The institutional perspective of cohesiveness shows that those engaged in collaboration are more positive about alignments with external partners. This suggests a virtuous circle of collaboration spawning collaboration. Further data underpins this, demonstrating a greater scale of collaborative activity amongst those already engages in the TX/UK Collaborative.

7.5.2 Strategic Imperatives

- Embedding a collaborative culture, developing collaborative human capital, and realizing World Class multidisciplinary research collaborations are seen by all interview respondents as strategic imperatives. Respondents at all levels were aligned in this observation.
- The recognition of mutual value generation is a key emerging theme from the responses of all stakeholders interviewed in the study. This includes consideration of academic, commercial, and economic development outputs. However some respondents draw attention to some institutions being more focused on collaboration rather than the outcomes of collaboration. This sits interestingly with the observation by Faster Cures (2010) in discussing the need for more outcome focused collaborative research activities.

7.6 Bibliography

- Abbey JV, Mainwaring L. and Davies G.H. 2008, "Vorsprung durch Technium: building a System of Innovation in South West Wales', Regional Studies, Vol. 42, Iss.2, pp. 281 – 293.
- Davis D. and Weinstein D., 1999, "Economic geography and regional production structure: an empirical investigation", *European Economic Review* Vol. 43, pp. 379–407.
- De Laurentis C., Cooke P. and Williams, G., 2003, "Barriers to the Knowledge Economy- New Media Cluster in the Periphery", Paper presented at the Regional Studies Association International Conference, Scuola Superiore Sant' Anna Pisa 12th -15th April 2003.
- Faster Cures, 2010, "Entrepeneurs for Cures: The Critical Need for Innovative Approaches to Disease Research", The Center for Accelerating Medical Solutions.
- Milken Global Conference, Los Angeles April 2010.
- Moore G., 2005, "Dealling with Darwin: How Great Companies Innovate at Every Stage of Evolution", Portfolio Hardcover, ISBN-10 -1591841070.
- NAW, 2006, "Enterprise, Innovation and Networks Committee, Review of Science Policy in Wales", National Assembly of Wales.
- OECD, 1996, "The Knowledge-based Economy", Organisation for Economic Co-operation and Development.
- ONS, 2004, "Social Trends Report 34: Proportional effect on earnings of a degree level qualification: by sex and degree subject", 1993-2001, Dataset ST340510, UK National Statistics.
- Porter M., 2000, "Location, Competition and Economic Development: Local Clusters in a Global Economy", Economic Development Quarterly, Vol. 4, Iss. 15, pp 15-34.

- Porter M. and Stern S., 1999, "The New Challenge to Americas Prosperity: Findings from the Innovation Index", Council of Competitiveness.
- Work Foundation, 2006, "The Knowledge Economy in Europe: A Report prepared for the 2007 EU Spring Council, The Work Foundation.

Chapter 8

Recommendations[1]

This research study involved interaction via questionnaire and semi structured interviews with a range of stakeholders who have a direct interest and significant influence on the development of a sustainable nanotechnology cluster in the South West Wales region. Recommendations have emerged from the study which strategy and policy makers may find useful. They fall broadly into the five components of such a cluster as hypothesised by the work, namely people, science, economy, culture and governance. Some recommendations could clearly be included in more than one of the components; however, the following categorisation is broadly in line with the discussion.

8.1 People

- That the Higher Education (HE) sector ensures that there is an education provision in place at undergraduate and postgraduate level tailored to the needs of regional emerging clusters.
- That those programmes and indeed all HE programmes should include a business theme as part of the ethos of a programme and not simply have a module that may be 'tacked on' in order to make a token gesture.
- That HE provision should seek to develop an open, collaborative, global mindset in the student population, thereby preparing them for the economic landscape of the 21st Century.
- That HE should seek to recruit and retain academics who also reflect the open, collaborative and global philosophy thereby not only contributing to the broader economic life of the region but also serving as mentors in that regard to the students under their influence.

8.2 Science

- That pockets of world class research are essential if a region is to develop a sustainable knowledge cluster.
- The research has to relevant to the world of business and to the targeted sector.
- That the intellectual property (IP) generated must have a clear translational route leading to the creation of value.
- That the science is embedded in culture appropriately governed by a system, which understands the science, the sector and the world of business.

8.3 Economics

- That key stakeholders in Wales establish a protocol for communicating individual value imperatives.

[1]This content is available online at <http://cnx.org/content/m43447/1.1/>.

- That a road map leading to the creation of value be a prerequisite for any application for public sector funding initiatives.
- That the Business Schools of Wales be engaged in a strategy for developing the management talent tailored for knowledge business.
- That a dialogue on the subject of the most appropriate approach to risk amongst stakeholders should lead to a common understanding of organisational perspectives and protocols for dealing with the issues in a pragmatic and timely manner.
- That a dialogue on the subject of the most appropriate KPIs amongst stakeholders should lead to a common understanding of organisational perspectives and protocols for measuring progress along the value road map in a meaningful manner.

8.4 Culture

- That regional stakeholders recognise the need to develop in partnership a culture that recognises the need to be open, collaborative and global.
- That an integrated regional communications strategy be put in place that ensures that success is celebrated.
- That partners, particularly in the public sector, recognise the need to be outcome rather than process driven.
- That openness to realising activities delivering combined public and private sector outcomes become embedded with a “can do” mindset.

8.5 Governance

- That a strategy is put in place to enable a dialogue between the governance infrastructure of key stakeholders driving collaborative work to a common vision
- That key regional stakeholders adopt open, global, multidisciplinary working as their *modus operandi*.
- That regions steward their knowledge economies by effectively combining the five core components of: people, culture, economics, science and governance.
- That institutions embed collaborative working within their strategic plans reflecting their role within the regional innovation system.
- That processes are established and operated to facilitate and support activity, removing barriers and obstacles rather than creating them.

Chapter 9

Conclusions[1]

The research question set at the commencement of this study was:

"How a Region Can Lever Participation in a Global Network to Accelerate the Development of a Sustainable Technology Cluster"

In brief, the answer to this research question is an emphatic yes. However, the research has shown that there are five key components to a knowledge economy, namely: People, Culture and Economics, bound together by good governance and scientific excellence. Having established the core components for a knowledge economy, the question of sustaining that knowledge economy and bringing its benefits to bear upon a region through the creation of clusters was also studied. In order to achieve this, an open, collaborative, global and multidisciplinary culture and environment must be created and nurtured.

People or Human Capital is the fuel that drives a knowledge economy. They must be developed by the local education system but also the best talent must be recruited from around the world, and above all else nurtured and retained. Pockets of world-class research are an essential pre-requisite. It is not possible to be expert in everything; therefore playing a meaningful role in global networks is vital. This has to be support by and embedded in an open, collaborative, multidisciplinary and global culture. Skills in the development of value, particularly economic value, must be nurtured to enable regions clusters harness the opportunities of technological and economic trends. For example, management expertise in guiding knowledge business through phases of development is a key enable, which is currently deficient within Wales. All of the above must be well governed through an enabling, facilitating, integrated framework, which Wales as a small nation should be able to deliver.

During the period of this study, the global context has changed dramatically. Emerging economies such as China and India are now investing hugely in creating knowledge economies of their own, which are already competing effectively with the established countries of the developed nations. The situation has been further compounded by the 2008-10 global economic crisis. For the first time in recent history, the world has been led out of recession by the emerging nations. This means that those emerging economies are able to invest heavily in their strategies, giving further impetus to their campaigns of becoming global knowledge economies on the world stage. Never before has it been more important for a small region such as Wales on the periphery of the European Union to develop and implement an integrated knowledge economy strategy. This research shows that participating in global networks, such as the Texas/UK Collaborative should be central the strategic approach of developing regional knowledge economies and technology clusters.

[1] This content is available online at <http://cnx.org/content/m43444/1.1/>.

Chapter 10

Abbreviations[1]

ANH - Alliance for Nano Health
AUTM - Association of University Technology Managers
BERR - The Department for Business, Enterprise and Regulatory Reform
BIS - The Department for Business, Innovation and Skills
CNH - Centre for NanoHealth
CU - Cardiff University
DTI - Department of Trade and Industry
ELWa - Education and Learning Wales
EMA - European Medicines Association
EPSRC - Engineering and Physical Sciences Research Council
ERDF - European Regional Development Fund
ESF - European Social Fund
ETP - European Technology Platform
EU - European Union
FANTI - Food and Drug Administration – Alliance for Nano Health Nanotechnology Initiative
FDA - Food and Drug Administration
FDI - Foreign Direct Investment
GDP - Gross Domestic Product
GP - General Practioner
GVA - Gross Value Added
HEFCE - Higher Education Funding Council for England
HEFCW - Higher Education Funding Council for Wales
HE - Higher Education
HEI - Higher Education Institutes
HRH - His Royal Highness
IBM - International Business Machines Corporation
ICT - Information Communication Technology
ILS - Institute of Life Science
IMNOS - Institute for Micro and Nano - Science
IP - Intellectual Property
IPED - Institute for Policy and Economic Development
IPR - Intellectual Property Rights
IT - Information Technology
KESS - Knowledge Economy Skills Scholarships
KPI - Key Performance Indicators

[1]This content is available online at <http://cnx.org/content/m43442/1.1/>.

KTN - Knowledge Transfer Network
KTP - Knowledge Transfer Partnership
MIT - Massachusetts Institute of Technology
MNC - Multidisciplinary Nanotechnology Centre
MRC - Medical Research Council
NAoMITEC - NAno and MIcro - TEC SMEs in Integrate Projects and Networks of Excellence
NAW - National Assembly of Wales
NHS - National Health Service (UK)
NIH - National Institute for Health (US)
OECD - Organization for Economic Cooperation and Development
OSTP - Office of Science and Technology Policy
PECTIC - Positron Emission Tomography Imaging Centre
POWIS - Prince of Wales Innovation Scholarships
Q1 - Quater One
QR - Quality Related
RAE - Research Assessment Exercise
R&D - Research and Development
SCOT EXEC - Scottish Executive
SET - Science, Engineering and Technology
STEM - Science, Technology, Engineering and Maths
STEmM - Science, Technology, Engineering, Maths and Medicine
TEP - Technology Exploitation Programme
TX - Texas
UK - United Kingdom
UNICO - University Companies Association
US or USA - United States of America
USP - Unique Selling Point
UW - University of Wales
UWA - University of Wales Aberystwyth
UWCM - University of Wales College of Medicine
UWS - University of Wales Swansea
WAC - Welsh Affairs Committee
WAG - Welsh Assembly Government
WEFO - Welsh European Funding Office

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

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A Study of How a Region Can Lever Participation in a Global Network to Accelerate the Development of a Sustainable Technology Cluster

The growing importance of the knowledge economy and technology-focused regional clusters upon economic development has seen a new perspective brought in light of the recent global economic turmoil. The events of the past two years have demonstrated the truly global and inter connected dimension of technology and enterprise, while highlighting the benefits of collaboration and the risks of not working together. Previous studies have examined technology and business cycles, as well as regional economic development and the role of collaboration in innovation. The roles of academia, industry, and the private sector within innovation systems at the national and regional levels have also received significant consideration. Through detailed study of the needs and opportunities of the Life-Science Nanotechnology Sector, it has been shown that the determining factors for success centre around the people involved and how they work together. In parallel, the study has made use of the Swansea University involvement in the Texas/United Kingdom Collaborative to explore five core components of effective and impactful collaboration, namely: People, Culture, Economics, Science and Governance. In conclusion a number of recommendations are made to assist a region in successfully harnessing the potential to lever participation in a global network as part of a strategic approach for development of a sustainable regional technology cluster.