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Spaces of Knowledge: University – Industry Interaction in Wales

Tamsin Elizabeth Cathan Davies

Submitted to the University Wales in fulfilment of the requirements for the Degree of Doctor of Philosophy

Swansea University

2007

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Summary

This thesis focuses on interaction between universities and industry in Wales and how it is affected by different spaces of knowledge. The subject of university – industry collaboration is topical in both recent research and policy. Previous research into university – industry interaction has suggested that reintegrating the scientific research performed in industrial R&D and academia can lead to increased innovative activity and thence to economic growth, a goal for economically peripheral regions such as Wales. It has also drawn attention to the importance of social processes in the establishment and success of links between the two types of organisation. However, this research has not addressed in detail the functioning of these social processes through which knowledge is transferred, transformed and translated from academic science to industry (or vice versa). Focussing on five industries identified as having past, present or future importance to the Welsh economy – aerospace, life sciences, opto-electronics, steel and sustainable energy – the processes through which knowledge passes from academic science to industry are explored using a mixed methods approach. This approach consisted of semi-structured interviews with the academic and industrial participants in individual instances of university – industry interaction plus a number of policy makers and implementers and a questionnaire survey of the selected sectors. Significant levels of interaction between industry and academia were found in all sectors, particularly the steel industry. However, a number of impediments to interaction were also revealed concerning differences between academic and industrial practice. Processes of converting bonding to bridging social capital and vice versa are shown to be important in forging and maintaining links. Embodied conceptions of knowledge are revealed to be important for understanding knowledge flows and their success or failure. In the light of these findings, Welsh policy aimed at promoting interaction is evaluated and a number of recommendations made.

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Chapter 1

Introduction

With the notion of the knowledge-based economy has come an increased expectation that universities contribute to the development of their regional economy. Schemes promoting university – industry links, academic spin-out firms and the development of university-based business incubators, both in European regions and further afield attest to this new role for universities. Whilst it has been recognised that universities can have a beneficial effect on a region's economy by providing employment for local people and a market for local businesses (Armstrong et al, 1997; Bleaney et al, 1992; Huggins and Cooke, 1997; Palomäki, 1997; Ricci, 1997; van Geenhuizen et al, 1997), schemes promoting university – industry links often have a more ambitious rationale.

Universities, as local producers of knowledge and innovative ideas, are thought to have a potentially important place in the development of an effective regional innovation system (RIS). A regional innovation system is 'a set of interacting private and public interests, formal institutions and other organisations, that function according to organisational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge' (Doloreux, 2003, page 70). In other words, within a given region there are a number of interacting public and private actors. These actors include financial institutions, such as banks and venture capitalists, public bodies such as regional government, higher education institutions (HEIs) and government funded research laboratories, and commercial organisations, such as manufacturing firms, distributors and so forth. When these actors exist in a cooperative, change oriented culture, there is greater sharing of knowledge which in turn leads to learning and further knowledge production by the actors, thereby contributing to the development of new products and processes, i.e. innovation (Cooke et al, 1997). Improved capacity to innovate is believed to increase competitiveness (Callejon and García-Quevedo, 2005; Hayter, 1996) and the development of a knowledge-based economy (Broström and Lööf, 2006) all of which is purported to enhance regional economic development.

As producers and disseminators of new knowledge through their research activities and publications, and to educators of the future workforce who will apply such knowledge in the workplace, universities are obviously key actors in the regional innovation system. Indeed Chatterton and Goddard (2003, page 19) suggest that 'regionally engaged universities can become a key locational asset and powerhouse for economic development'. Universities are seen as contributing to innovation by being a source of formal technology transfer and spin-outs, by becoming the focal point for high-technology clusters, by providing a locally available source of knowledge that spills over to nearby firms, as well as the development of cultural and leisure facilities such as arts and sports centres which help to attract a young educated workforce (Florida, 2002). There is an emphasis on technological innovation in the literature and hence the contributions of academic science are seen as particularly important.

Following a decline in heavy industry many regions, such as Wales, the Basque country and parts of Finland, have sought to develop knowledge economies through the creation of new, innovative, high-tech industries (Kaufman and Todtling, 2000). Such regions can suffer from problems of 'lock-in' to old technological trajectories because of their industrial economic past. Such a situation arises because of the path-dependent nature of economic development (Hayter, 2003). Path dependency occurs 'when the fortunes of certain places under conditions of technological change [are] partly determined by pre-existing conditions (Coe et al, 2007, page 125)[1]. Asheim and Cooke (1999) see strong regional innovative capacity as vital to breaking path dependency and changing technological trajectory. Therefore claims that universities can encourage the growth of innovative clusters of industry and thus help to regenerate deindustrialised regions are very attractive to policymakers wishing to boost economic growth in an area since most regions in the Global North, even the poorest and most deindustrialised, have a university (Cooke, 2002).

However, the prolonged separation of industrial R&D and academia has led to the formation of distinct practices and cultures within the spaces in which they are performed meaning that in practice reintegration of industrial and academic research is not straightforward. Scientific research relevant to industry has been performed in both universities and industrial research laboratories since the last quarter of the nineteenth century, when firms first began to establish R&D facilities. Such facilities were originally established in Germany by chemical firms, in which educated chemists were employed to develop and improve processes used by the firms (Donnelly, 1986; Hayter, 1996; Massey, 1992 et al). However, employees of industrial R&D facilities have historically been required to carry out research that is in the main directly applicable to developing the products and processes of the firm to which they are attached, while those employed by universities have been required to make novel contributions to the accumulated base of academic scientific knowledge (Donnelly, 1986; Hayter, 1996; Massey et al, 1992). The differing functions of research in industry and academia have led to a spatial division of labour

[1] A classic example of lock-in due to path dependence is the Swiss watch industry which struggled to adopt new technologies following the invention of the digital watch. Swiss mechanical watch makers found it hard to abandon centuries of tradition while new watch makers in countries such as Japan had

and the formation of two separate spaces of knowledge. Basic research for the sake of knowledge tends to take place in universities or government laboratories, and applied research for commercial exploitation tends to take place in industrial research facilities or government sponsored institutions (Lommnitz Adler and Chazaro, 1999).

Thus a contradiction arises. Universities, as producers of knowledge, should be part of the regional innovation system and their proximity with other regional economic actors ought to aid the development of a knowledge-based regional economy. For peripheral regions with little traditional of innovation or industrial R&D in particular, they ought to be important sources of knowledge and ideas. However, the different cultures, practices and norms of academia and industry may work against successful engagement and reduce the potential for interaction. Moreover, peripheral regions may be least able to make use of their universities' knowledge and expertise (Chapple et al, 2005). This thesis, therefore, is concerned with the movement of knowledge between these two spaces of knowledge, academic science and industry in the context of peripheral regions. Specifically, it addresses this topic in the context of Wales, concentrating on several themes. These are the presence of interaction between Welsh universities and firms in Wales which enable the movement of knowledge, barriers and incentives to interaction, relationships that facilitate the movement of knowledge, the changes that knowledge undergoes when it moves and the outcomes of the various programmes aimed at promoting university – industry interaction in Wales.

Wales is an appropriate setting for such a study because it is quite typical of peripheral regions in the Global North. Having had an economy reliant on heavy industry which suffered following deindustrialisation from the mid-twentieth century

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no such historical ties and therefore found it much easier to adopt the new technology (see Glasmeier, 1991).

onwards, policies are now in place to regenerate the region by developing a knowledge economy. Wales also has an established tradition of higher education and the history of its HEIs serves to illustrate the ongoing conflict between the university as an elitist institution and the university as a socially engaged local actor.

Historical context: the university in Wales

All of Wales' thirteen higher education institutions, except for the University of Glamorgan, a former polytechnic, are or have been members of the University of Wales. From its foundation the University of Wales attracted a greater mix of students from different social classes than other British universities, and, unusually for the time, allowed women to graduate. It also attempted to pursue study relevant to the Welsh economy. However, it was not entirely successful in its efforts to integrate itself with industry because tension had arisen within the University of Wales over the interaction of academia and industry even before the institution had opened. It was not clear whether the university was to be associated with a higher status liberal education or a lower status practical education useful to industry, nor whether the students were to be from the aspiring middle classes or from the lower classes. According to Gwynn Williams (1993) the establishment of a Welsh university, like the establishment of the civic universities in England, was initially driven by the demand for an education for the middle classes (Tilling, 2002). However, the founders of the University of Wales, who were middle to upper class educated Welshmen, had views on the education to be provided by their proposed institution reflecting both the pre-industrial ideal of a liberal education and the modern relevance of science to industry. While some figures felt that study should be for its own sake, others believed that a university education would allow the

Welsh people to improve their lot by embracing the industrial revolution through learning chemistry and the English language. Somewhere between the two extremes, the first Principal of Cardiff, John Viriamu Jones, felt that the motivating factor for a university in Wales was to educate teachers for schools in Wales.

The first colleges of higher education in Wales were the non-conformist theological colleges, which began to be established in the eighteenth century for the education of Welsh ministers. According to the Aberdare Report on education in Wales published in 1880, these colleges drew their students from the lower classes (Gwynn Williams, 1993). A Church of England theological college in Lampeter, which usually took students from higher social classes, was established in 1822 for the education of Welsh priests, in the vain hope that it would stay the tide of non-conformism. However, during the nineteenth century there was also a concerted movement to establish a university by the educated Welsh middle-classes who wished to educate their sons in Wales. They eventually drew people from the lower classes into the campaign for the establishment of a Welsh university and collections were held at the local chapels. The first step to establishing the University of Wales was made in 1872 when the University College of Wales opened in Aberystwyth. The Aberdare Report resulted in two further colleges being established in Cardiff and Bangor in the early 1880s. The report suggested that a practical education was particularly important for the Welsh people and emphasised subjects that were felt to be important for professional and commercial life. However, some of these subjects were in fact more suitable to a pre-industrial liberal education than to the needs of industry. Although applied science was included, so were English literature and classical studies. It was the middle classes that were most emphasised as the beneficiaries of a university education in the Aberdare Report. However, the report also provided anecdotal evidence of the efforts of colliers and quarrymen to acquire an education through night classes. Indeed, it was believed that many people of lower class origins in Wales were unusually concerned about education, perhaps because from the eighteenth century the non-conformist tradition had combined religion and education in the form of Biblical study (see Williams, 1884/1998).

From the outset the college at Cardiff tried to link itself to the industries of coalmining and steel making, then prevalent in South Wales, and Bangor tried to link itself to quarrying, then prevalent in North Wales. Both colleges hoped to attract funding from industry. However, despite appealing to the self-interest of industrialists, with one or two exceptions there were few responses and the colleges remained fairly disengaged from industry. By the early 1890s there were chairs of engineering and mining in Cardiff, but neither post was very successful initially and the Department of Mining faired particularly badly. Similarly, the study of geology failed in Bangor, so no School of Quarrying could be established. It was in fact the coalminers, rather than their more wealthy employers, who responded to a call for industrial scholarships and the employees of various collieries collected to fund several of these. However, the Cardiff Technical School was more successful and in Aberystwyth and Bangor the application of chemistry proved useful to the initially sceptical local agriculturalists.

The colleges in Bangor, Aberystwyth and Cardiff gained their charter in the early 1890s, and became colleges of one body, the University of Wales, which had degree awarding powers. This body continued to expand, absorbing HEIs across Wales, until the recent break away of the University of Wales Cardiff to become Cardiff University. The award of the charter was in part due to the increasing recognition that the colleges were seeking to solve problems that had immediate relevance to the economy of Wales. Furthermore advocates of a Welsh university had sought to prove that those attending the institution would be drawn from all social classes: traditionally the colleges had been thought to attract more members of the lower classes than universities in other parts of the UK. Indeed Gwynn Williams (1993) shows that from their foundation to their federation as a university the colleges in Aberystwyth, Cardiff and Bangor drew about twenty percent of their students from a working class background, and a large proportion from a farming, small tradesman or shop keeping background. However, the tensions between the vision of the university as a place for the pursuit of knowledge for its own sake and the vision of the university as an institution open to the needs of the Welsh economy and all levels of Welsh society which were present at the foundation of the University of Wales, were already entrenched and remain to the present day.

A note on terminology

Before moving on to the main body of the thesis it is necessary to define some of the terms used in the work. Some terms, such as 'social capital' and 'regional innovation system', refer to concepts that have been subject to much theoretical debate. These concepts are discussed in chapter 2 and their terminology is not discussed here. Rather this section covers terms which have more than one meaning but are used in one particular way in this work.

Firstly, given that this work purports to have relevance to the development of peripheral regions, it is important to define what is meant by a peripheral region. As Doloreux and Parto (2004, page 14) note, the term region has been used within academic literature to refer to areas on a variety of different scales and cohesiveness, including entire countries, provinces, NUTS II administrative areas, cities and ‘small-scale industrial districts below the urban level of aggregation’. However, in the context of this study Cooke et al’s (1997, page 480) definition of regions as ‘territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions’ will be used, since this definition seems closest to the customary, non-academic use of the word. Hurcombe et al (2005) debate whether Wales should be considered a region of the UK or a nation in itself, as this issue impacts on whether Wales-wide networks and organisations should be considered national or regional. This debate could be extended to entities such as the innovation system. The answer according to Cooke et al’s (1997) definition is that Wales is both a region and a nation. They specifically include stateless nations as well administrative areas such as states, provinces, *Länder* and so forth. Thus it makes sense to speak of Wales having a National Assembly, a National Eisteddfod and so forth but of also having a regional innovation system, since this is also part of the UK national innovation system (Cooke et al, 1997). Moving on to the notion of the peripheral region, it is necessary to note that it is inextricably linked to the notion of the core region, and one cannot be defined without the other. Whilst relations between the industrialised countries of the Global North and the less industrially developed countries of the Global South are often described in terms of core and peripheral regions (e.g. Murphy, 2006; Potter, 2002) in this study these terms refer to regions within a particular country. Core regions are economically successful regions, generally exhibiting high levels of urbanisation and industrial agglomeration and providing significant amounts of highly skilled, highly waged employment (Gatrell, 1999). Other regions may be considered peripheral to core regions if they are difficult to access physically or if they are culturally inaccessible, that is, they have poor IT, local business and institutional networks, lack people with IT skills, poor civic society and poor local – global links. This latter form of peripherality is known as aspatial peripherality (Copus, 2001). As such, peripherality tends to lead to disparities in regional economic activity and income, with peripheral regions tending to have a sparse population in comparison to the core region, a dependence on the production of staples and a predominance of low-skilled, low-paid employment. The preponderance of branch plant industry with its headquarters and R&D facilities sited in the core region helps to sustain the peripheral region's dependence on the core (Humphrys, 1980). In the UK the southeast of England are considered a core region, while Wales and Scotland are considered peripheral regions (O'Farrell and Oakey, 1993).

Additionally, it is necessary to define several terms referring to the institutions discussed in the thesis. First of all, the terms 'higher education institution (HEI)' and 'university' are used interchangeably in the study. This is because all the HEIs in Wales are either universities in their own right or members of the University of Wales. Second, the study differentiates between interaction between universities and industry and collaboration between universities and industry. The former includes any types of links between firms and universities, such as informal conversations between staff or attendance of firm employees at public lectures given at the university by academics. Collaboration refers to a more formal relationship between the firm and the university. Normally a contract or agreement of some sort will be in place and the two organisations will be working together on a specified project. Thirdly, the thesis makes frequent reference to technology transfer employees. These are individuals who are engaged in activities the aim of which is to encourage universities and firms to work together in the hope that knowledge will pass between the two. Such individuals may be employed by a university or an intermediary body, such as the Welsh Assembly Government (WAG). Their activities are diverse – they include running university commercialisation centres or business incubators, liaising between academics and firms, assisting with the start-up of academic spinouts and finding academic partners for firms that are looking for academic expertise – and may not include technology transfer in the strictest sense. However, this term has been selected for individuals engaged in this type of work since it is aimed at technology transfer in the wider sense of moving scientific knowledge from academia for the purposes of technological development. Finally, the term 'small to medium enterprise' (SME) is used to describe firms employing up to 250 people. This is the standard use of the term by Welsh organisations such as the Welsh Assembly Government and higher educations institutions.

Wales: industrial, economic and policy context

Today much of Wales is either rural or deindustrialised. Whilst the more populous south and north-east were previously reliant on heavy industry, such as coal mining and steel making, the last deep-cast mine recently closed and the steel industry has steadily diminished. In rural areas employment in agriculture is in long term decline (WAG, 2002a). In the wake of the declining employment in the resource-based economy of Wales, employment in the services sector grew, with 67% of workers employed in services in 1994 compared to 49% in 1975. The growth of secondary manufacturing was encouraged, with the Welsh Development Agency marketing Wales as a low wage economy during the 1980s in order to secure foreign direct investment (Cameron et al, 2002). Between 1984 and 1995 21,700 new jobs were created in foreign-owned manufacturing plants (Lovering, 1998) and by 2001 17.3% of the working population of Wales were employed in manufacturing, compared with a UK average of 14.2% (Source: National Statistics website: www.statistics.gov.uk). However, the secondary manufacturing sector remains small in absolute terms, with Welsh GVA in manufacturing being smaller than all of the other twelve UK regions except Northern Ireland and the northeast of England (Source: National Statistics website: www.statistics.gov.uk). It has also tended to provide low-skilled, low-paid and increasing unstable jobs (House of Commons Welsh Affairs Committee, 2005; Lovering, 1998). The instability of employment in the secondary manufacturing sector was particularly graphically illustrated when an investment by LG secured in 1996, which promised 6100 jobs, failed to materialise despite a £247m assistance package and development of a customised greenfield site, due to the downturn in the Asian economy (Phelps and Tewdwr Jones, 2001). Other, more recent, large-scale redundancies have included Panasonic reducing the workforce in its Cardiff plant by 480 in 2004 and the loss of 650 jobs from Sony plants in Bridgend and Pencoed in 2005.

Deindustrialisation and a decline in agricultural employment have lead to Wales becoming one of the more disadvantaged regions of the UK (see table 1.1), and indeed the European Union (EU). With only 73% of the average EU GDP per capita in 1997, West Wales and the Valleys were awarded European Structural Funds in the form of Objective 1 funding for the period 2000-2006 (Midmore, 2002). Even including the more prosperous parts of Wales, in 2004 GVA per head was only 78% of the UK average (Stokes, 2007), primarily due to a higher rate of economic inactivity and a lack of highly paid jobs compared to the rest of the UK (WAG, 2002a). The economic inactivity rate in Wales was 24% of working age people[2] in the first quarter of 2007, compared with a UK economic inactivity rate of 21.2%

[2] Women aged 16 to 59 and men aged 16 to 64.

during the same period, despite the Welsh unemployment rate being only just below the UK average of 5.5% at 5.4%. Many of the economically inactive have long-term health problems: in some constituencies of West Wales and the Valleys up to 12% of people aged 16 to 64 were claiming Long-term Incapacity Benefit during August 2006 (Stokes, 2007). Cameron et al (2002) found that earnings in Wales had declined relative to those in Great Britain since the 1970s and that this is partly accounted for by the fact that 'jobs have tended to disappear in well-paid industries to be replaced by jobs in lower-paid industries' (Cameron et al, 2002, page 8). Mean gross weekly earnings for full-time employees on adult rates were 87.4% of the UK mean in 2006 (Stokes, 2007). The lack of highly paid jobs is partly due to the predominance of low-skilled work: highly qualified people able to attract larger salaries tend to migrate to suitable job opportunities outside Wales (WAG, 2002a). Thus, in 2003 17.5% of the working population in Wales had no qualifications, compared to a UK average of 15% (Source: National Statistics website: www.statistics.gov.uk). An example of the lack of skilled work available in Wales is the low numbers employed to perform R&D. In 2003, the estimated number of personnel engaged on R&D in business was 0.27% of the regional workforce, compared to a UK average of 0.57%, while 0.03% of the regional workforce were engaged on R&D in government establishments compared to a UK average of 0.07% (Owens, 2005). R&D expenditure by businesses in Wales stood at £264 million in 2003, making up 1.9% of expenditure on R&D by UK businesses: the smallest percentage of all UK regions except Northern Ireland (ONS, 2005). Additionally, even relatively well paid jobs are paid less than they are in other parts of the UK. For instance, Cameron et al (2002, page 5) note that 'although banking and financial services is the second highest paid sector for full-time men in Wales, it is the worst paid region relative to banking and financial services in other regions of the UK'. Wales has become increasingly dependent on jobs the public sector, such as health and education, for well paid employment, with a greater proportion of the workforce employed in this sector than in the rest of the UK (Cameron et al, 2002).

Table 1.1: Key indicators for Wales compared to selected other regions of the UK

Region	GVA per head as percentage of UK average, 2006	Regional labour force engaged on R&D in business/ government, 2003 (%)	Gross weekly earnings of full-time employees, first quarter of 2007 (£*)	Unemployment rate for all persons aged 16+, first quarter of 2007 (%**)	Economic activity rates for all persons aged 16+, first quarter of 2007(%***)	Population of working age with no qualifications, spring 2003 (%)
UK	100	0.57/ 0.07	494	5.5	63.2	15.0
England	102	0.62/ 0.07	504	5.7	63.4	14.6
Northeast England	81	0.31/ 0.00	417	6.7	60.0	18.8
Southeast England	115	0.98/ 0.15	573	4.8	65.8	10.6
Northern Ireland	81	0.41/ 0.03	400	4.1	60.5	23.7
Scotland	95	0.30/ 0.12	465	4.9	64.2	14.7
Wales	77	0.27/ 0.03	442	5.4	59.5	17.1

*Not seasonally adjusted
** Total unemployed as a percentage of all economically active persons
***Total economically active as a percentage of all persons aged 16 – 59/64

(Source: National Statistics website: www.statistics.gov.uk; Owens, 2005)

Wales performs poorly in terms of the number of businesses per head of population and the number of people starting businesses (WAG, 2003b). In 2005 the stock of Welsh VAT registered businesses per 10,000 people of working age was 92% of the UK average (Stokes, 2007). Hurcombe et al (2005, page 5) note that 'attitudes to entrepreneurship are not favourable and few people believe that there are good opportunities to start a business in Wales'. Martin et al (2005) suggest that part of the problem is an equity gap which exists between core and non-core regions of the UK. The UK venture capital industry is highly concentrated in the Greater London area, while Wales has the lowest concentration of venture capital firms in the

UK except for Northern Ireland. Furthermore, the venture capital firms located in Wales are mostly in the south (Martin et al, 2005) as are the majority of business angels (Hurcombe et al, 2005). Both venture capital firms and business angels tend to invest in firms in their own regions (Martin, 2005; NBAN, no date), with business angels favouring firms within three hours travelling time (Hurcombe, 2005). Thus the relative lack of venture capital firms in Wales combined the fact that the venture capital firms and business angels that are present tend to be in south Wales which has poor transport links to mid and north Wales, suggests that Welsh firms seeking investment, especially those outside south Wales, are likely to struggle to find it. Of course, it could be that the reason there are few venture capital firms in Wales is that there is no market for private equity, but this seems unlikely given that Hurcombe et al (2005, page 8) note that:

> In 1999 – 2000 the British Venture Capital Association described Wales as a business angel "hotspot" – a region which had significantly higher proportions of business angel activity (measured in terms of the number of investments) than their regional share of UK VAT registered businesses.

As Martin et al (2005, page 1226) explain, the lack of market for venture capital can itself be a symptom of a lack of supply:

> The growth of venture capital in local economies involves a learning process in which investees learn about the uses of venture capital and the best ways to secure this finance, intermediaries learn how to encourage demand and connect investors and investees, and venture capital firms learn about the risks and trends in their potential markets. A lack of venture capital firms in a region may mean that these knowledge chains are weak and incomplete, and this may depress local demand for risk capital which, in turn, may deter additional venture capital firms from setting up in that region, and lead venture capital firms located elsewhere to see the problem as one of lack of local demand rather than a lack of local supply.

Additionally, a venture capital market, as well as requiring innovative new firms to invest in, needs a significant financial centre and 'supporting specialist business, legal, advisory and related services' (Martin et al, 2005, page 1227) to function. These too are lacking in much of Wales.

Following its establishment in 1999, the Welsh Assembly Government put in place a number of policy objectives for transforming the Welsh economy. These seek to encourage innovation and entrepreneurship, improving the population's level of education, improve transport and communications infrastructure, support businesses and rural economies, establish Wales in global export and tourism markets, and promote environmentally sustainable economic activities (WAG, 2001; WAG 2002a). These objectives were tied in with the west Wales and valleys Objective 1 programme (Bachtler, 2003). Policy emphasis has shifted from encouraging foreign direct investment to encouraging the endogenous growth of SMEs and increasing 'the knowledge, research and development, and innovation capacity in all parts of the Welsh economy' (WAG, 2002a, preface).

As part of its objective of encouraging innovation, the Welsh Assembly Government set a target in its strategic framework for economic development, *A Winning Wales* (WAG, 2002a), of increasing business enterprise R&D expenditure from 0.4% of Welsh GDP in 2001 to over 1% by 2010 (Stokes, 2007)[3]. It suggests that 'better application of technologies and research and development by industry and academia in support of businesses is vital to competitiveness and long term survival' (WAG, 2003b, page 9), thus also targeting the thirteen higher education institutions in Wales as underperformers in the economy, claiming that:

> Welsh HEIs do not have strong records for levering money from corporate sponsorship...and research contracts with funders outside the Research Councils. The result is that corporate and other sectors have a weaker relationship with Welsh HEIs which in turn diminishes their [the HEIs] contribution to the economy
>
> (WAG, 2002b, page 3)

Welsh Assembly Government funding and European Union Structural Funds have been channelled into a variety of schemes encouraging the exploitation of knowledge from Welsh HEIs for the benefit of the Welsh economy. These schemes have provided not only physical infrastructure, capital and business services aimed at developing knowledge-based industry in Wales, but have also aimed to build social infrastructure between universities and firms by developing networks between academics and firms, forming academic spinout companies that retain links with their parent institutions and encouraging firms to approach universities. The largest of these schemes is the Technium project, begun in 2001. This project has involved a £150 million investment into a network of high-technology business incubators across Wales. These incubators promise state of the art facilities, business support and university expertise under one roof. The Knowledge Exploitation Fund (KEF) has a smaller budget of £40.5 million. Established in 2000, it provides funding for patent and proof of concept, collaborative industrial research projects, technology transfer networks and technology transfer centres. To encourage the formation of academic spinout companies the Wales Spinout Programme was started in 2000 with a three-year budget of £1,397,873. This programme was extended for another five years following an independent review in 2002 (HEW and HEFCW, 2003). The Centres of Expertise for Technology and Industrial Collaboration (CETICs) were originally established in 2001 by the WDA, with funding of £3.5million to allow companies in Wales to access the best expertise and facilities in Welsh universities. A further £3.3 million of European Union funding was secured in 2004 to support the CETICs until 2007. Other programmes are in place to facilitate companies in finding appropriate academic expertise in Welsh universities, provide student work

[3] Business enterprise R&D expenditure had increased to 0.7% of Welsh GDP by 2003, the most recent figure available (Stokes, 2007).

placements and fund joint product development. The Higher Education Funding Council for Wales (HEFCW) also established the Higher Education Economic Development Fund (HEED) in 2001, which had a budget of £3.1 million for the academic year 2004-05, with the aim of providing a single funding stream for third mission activities to encourage a strategic approach to economic development activities from universities (HEFCW, 2004; WAG, 2002b and 2003b). The ultimate aim of these programmes is to strengthen the regional innovation system and to facilitate the development of a sustainable knowledge-based economy providing a greater number of highly skilled and well paid jobs (Higher Education and Economic Development Task and Finish Group, 2004).

These programmes and the policy aims at which they are directed are similar to those of industrialised and industrialising countries across the world. Academic incubators and technology transfer centres are common across Europe (see, for example, Carayannis et al, 2000; Grimaldi and Grandi, 2005; Lovrek et al, 2003). Further afield, Beesley (2003) notes similar policy aims to those in Wales in recent Australian, Canadian and US government statements, and that these countries have all established research centres for collaborative work between universities and industry, with encouraging results. To overcome low business R&D, the Hong Kong government has funded programmes promoting university – industry interaction in four areas: start-up business incubation, technology transfer, R&D support and life-long learning. Universities' internal governance structures have been found to be key to the success of these programmes (Patchell and Eastham, 2003).

Whether the Welsh programmes have been successful is debatable. For example, in the academic year 2001/2002 Welsh HEIs reported that they had signed 531 research contracts with businesses, an increase of almost 29% from the academic year 2000/2001. 42% of these contracts were with SMEs, the majority of which were in Wales. 22 new academic spinout firms were established (DELNI et al, 2004). However, in the academic year 2002/2003 the same HEIs reported 443 research contracts with businesses, of which 19% were with SMEs, and the establishment of 14 new academic spinout firms (DELNI et al, 2005). Furthermore, WAG's Higher Education and Economic Development Task and Finish Group (2004) suggest that the sheer number of programmes available 'indicates a fragmentation of effort and illustrates the need to find ways of drawing the support together to provide it on a more strategic and holistic basis' (page 28). It also suggests that Welsh universities need to market their research strengths in a more strategic and integrated manner and that more attention needs to be paid to licensing opportunities for their research.

Structure of the thesis

The subsequent chapters of the thesis are set out following manner. Chapter 2 reviews the existent literature on university – industry interaction and related areas, namely innovation and innovation systems, knowledge flows and social capital. There is a large body of work concentrating specifically on university – industry interaction, but much of it lies outside the economic geography canon in fields such as business and management science, economics, economic sociology, education, engineering, and the history and sociology of science. Similarly, disciplines such as philosophy, political science, science communication and sociology have contributed to the literature on related areas. The chapter therefore brings together work from a number of disciplines to highlight gaps in our knowledge and to draw out themes for further study. In the light of the discussion in Chapter 2, Chapter 3 develops the research problem in detail and sets out the specific research questions for the project. It defines the project's scope of study – interaction between Welsh universities and firms in the Welsh aerospace, life sciences, opto-electronics, sustainable energy and steel industries – and then goes on set out the methodology of the project, explaining the reasons for selecting the particular combination of methods used. Chapters 4, 5, 6 and 7 are results chapters and address different aspects of the project's findings.

Chapter 4 aims to accomplish four objectives. Firstly, it provides background important for understanding the in-depth studies of individual interactions presented in Chapters 5, 6 and 7 by presenting quantitative and qualitative data which describe the structure of the industries selected for study in the project, the number of interactions between firms in these industries and Welsh universities and the nature of these interactions, sources of funding utilised for interactions and the motivations and impediments to interaction presented by both firms and academics. Secondly, it tests a model of university – industry interaction drawn from previous empirical studies of interaction with the results obtained for the selected industries in Wales. This provides an overview of how typical or otherwise patterns of university – industry interaction are in Wales. Thirdly, the chapter explores the reasons why the majority of firms in the industries under study do not choose to interact with Welsh universities. Reasons for non-engagement between universities and individual firms are little explored in previous literature and make an interesting comparison with the impediments to interaction cited by firms that do engage with universities. Finally, the chapter considers the spatial division of scientific labour between industry and academia in light of the quantitative and qualitative data presented. Specifically it examines whether policy aimed at promoting university – industry interaction and more general economic changes have altered this division of labour.

Chapter 5 deals with the formation and maintenance of links between Welsh universities and firms in Wales. As social relations appear to be one of the essential factors that allow actors within a region to work together successfully and, more specifically, bridging social capital appears to be particularly important for knowledge sharing, an understanding of the role of social capital in building relationships between universities and firms is important for the development of collaborative links and an effective regional innovation system. The development of bridging social capital between culturally diverse groups is thought to enable them to work together (O'Brien et al, 2005), but the role of social capital in spanning university–industry boundaries has not been widely explored (Murray, 2004). Therefore, this chapter concentrates on the role of social capital, and the related notions of trust and communication in university – industry interaction.

Chapter 6 explores the flow of knowledge between academia and industry. In the past such flows have tended to be narrowly conceived in the notion of knowledge spillovers (Breschi et al, 2005). This chapter seeks a more nuanced understanding of the movement of knowledge between academia and industry. It starts by examining the presence of incompatible underlying principles governing academia and industry and the processes that work to overcome these incompatibilities, enabling knowledge flows. The chapter then considers the forms that these knowledge flows take. In particular, it examines the construction of knowledge during interaction between academia and industry, the translation of knowledge as it passes from one space to another and its eventual transformation by different perceptions and usages in the different spaces.

Chapter 7 evaluates the implementation of policy promoting university – industry interaction. While the preceding chapters all have implications for policy formation, this chapter examines how regional development policy aimed at developing a knowledge economy functions in practice where it involves universities and firms interacting and how it appears to the people involved in its implementation. Specifically, it considers the execution of programmes used to fund university – industry interaction in Wales, and highlights how some of the principles underlying these programmes lead to unintended consequences.

Finally, Chapter 8 presents the ultimate conclusions of the study. It draws together the findings to presents and presents some areas for further research.

Chapter 2

Understanding relations between academia and industry: a review of the literature

This chapter provides the theoretical context for the rest of the thesis, drawing together themes from relevant literature. It is divided into five sections. The first three sections take an evolutionary approach to understanding why, as the Lambert Review (2003, page 14) puts it, 'companies and universities are not natural partners: their cultures and their missions are different', with specific reference to academic science. The first section begins by considering the nature of science and scientific activity. Specifically it argues that while science is a socially constructed activity, various rationalist assumptions, such as the idea that science advances towards a true understanding of the universe, remain important in practitioners' beliefs about how their activities should be conducted. The commercial priorities of industry are sometimes felt to be incompatible with these beliefs. The second section goes on to consider why it is that science is constructed in this way, explaining the current relationship between academic science and industry through the historical analysis of scientific practice and organisation. This section is particularly concerned with the origins of the spatial division of labour between academia and industry in class structure, and the conflicting arguments posited by Gibbons et al (1994) and Whitley (2000) over whether this division is being broken down or not. The third section considers a particularly important manifestation of the spatial division of labour between academia and industry, the linear model of innovation. This is the model of innovation on which most policies for encouraging reintegration have been based.

Thus this section argues that there is an inherent contradiction in much policy aimed at promoting university – industry interaction which limits its success.

Sections four and five move on to current understandings of university – industry interaction and how it contributes to regional development. Specifically, section four argues that previous research has been too focused on the idea of the knowledge spillover and that there is a need for a more nuanced understanding of knowledge flows between academic science and industry. This includes understanding the many different types of market mediated knowledge flows, pure knowledge spillovers and how the two interact, understanding how knowledge flows between different spaces and the conditions that allow its flow. Lastly, because social conditions are revealed as particularly important in enabling knowledge flow between universities and industry, section five examines the idea of social capital and discusses its use of as a tool for understanding the reintegration of different spheres of research.

The Construction of Different Scientific Spaces

Early sociologists of science such as Hagstrom (1965) and Merton (1973) proposed that a set of institutional norms govern the activities of scientists. The Mertonian norms of universalism, disinterestedness, organised scepticism and communalism (Merton, 1973) have often been regarded as 'the secret of science's epistemic success' (Demeritt, 2000, page 323). These norms characterise science according to the tenets of rationalism. Science is conceived of as a rational, objective activity producing an internally consistent body of knowledge, progressing towards truth under the steam of its own internal logic (Barnes, 1996). Later philosophers and sociologists of science, such as Kuhn (1970) and Feyerabend (1975), question the notion of scientific rationality[1]. In the work of the Edinburgh School of the sociology of science, as Barnes (1996, page 115) puts it, '[r]ationality...is not something that exists outside of us to explain the social, but it is something that is made within the social to explain the outside'. In a similar vein, Latour and Woolgar (1986) reject the existence of norms as an explanation of scientists' behaviour. This study finds that researchers rarely invoke norms when explaining their activities. Nevertheless the notion of that science advances towards truth through the application of a rational method remains popular among those performing science (Hamlin, 1992). Accordingly, Latour and Woolgar (1986, page 70) find that scientists 'insist that their activity is in no way to be associated with beliefs, a culture, or a mythology. Instead, they claim to be concerned with "hard facts"'. Thus several researchers have suggested that the values of academic science remain largely rooted in a rationalist perspective and that for some academics the commercial priorities of industry pose a threat to the values that ensure scientific progress. This section explores their ideas in more depth.

Demeritt (2000) describes the Mertonian norms of scientific research as opposed to policies that are intended to reorient universities towards becoming commercial enterprises by providing knowledge as a product for industry and education as a service for students. The Mertonian norms are associated with universities as places for pursuit of knowledge as a good in itself and with this knowledge being for the improvement of society. Under the Mertonian norms knowledge is universal and its production is not affected by vested interests of the producer. Thus, some researchers involved in the physical and natural sciences resist the commercialisation of their work on the grounds that a loss of academic autonomy

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[1] Some philosophers of science have retained elements of rationalism in their work. See, for example, Chalmers (1982), Losee (1993) and Newton-Smith (1981).

and a tendency to sharing findings only with paying firms, rather than publicising them, may impede science's advance towards truth (Feller, 1990; Fuller, 2003; Harvey, 1973). This is not to say that scientists will produce false knowledge claims, though this may be the case, but that research into fruitful areas may be neglected in favour of more lucrative fields. Further commercial secrecy will also hinder the flow of knowledge between scientists, hence obstructing scientific progress.

Hamlin (1992) describes how the motives driving the progress of technology in the marketplace and science are perceived to differ. Firstly, he believes that technological knowledge is tacit and diffused throughout organisational structures, while a piece of scientific knowledge can belong to one person, but when codified is divulged for others to use. He also argues, after Kuhn (1970), that most science is problem driven, but like Mackay and Gillespie (1992), that innovative activity is driven by a very different problem, the need to make money. Thus new technologies need not be developed to meet the demand for a new product or process. Rather a product or process may be invented first and demand for it created through marketing. Technological activity is characterised, generally, though not universally, as a pattern 'in which one solves problems that do not exist *a priori*, and then persuades a public that a problem has been solved' (Hamlin, 1992, page 527). This means that technology involves continuous activity, as new products must constantly be developed in order to keep up sales, since even without competition, the market for a particular product will eventually become saturated. This is rather different from science in which the general belief is that if a problem is solved correctly it remains solved. Scientists working under the tenets of rationalism, can imagine a time when their work will be complete but it is hard to see a similar end point for technology, when we have the best possible television or car. Further, while science may undergo a paradigm shift because of a build up of anomalies that render the old paradigm incompatible with what is known about the world, a technology paradigm shift occurs for different reasons. Working technologies must be compatible with the world otherwise they physically would not work. Also technologies from one paradigm work just as well in the old one as they do in the new. For example, narrow gauge steam engines and the BASIC operating system for the Commodore 64 behave in the same way today as they did upon their invention. It may be difficult to use them because modern rail tracks are the wrong size for narrow gauge engines and modern PCs do not run BASIC, but nothing has changed about the world that we could not use them were we to have the right equipment. They have simply been superseded by technology that is more efficient, faster and more versatile. Newton's laws, on the other hand, do not behave in the same way today as they did upon their invention: once they described the whole universe, now they only describe a specific part of it under certain conditions. Hence, technological paradigms change because 'we recognise future conditions of application in which the paradigm will not work (or when we see an alternative paradigm that will work in those future conditions)' (Hamlin, 1992, page 529). In effect, we choose the conditions in which to apply a technology, which would be equivalent in science of choosing the external world that best fits with emerging ideas, an idea completely at odds with the conventional view of science.

Massey (1997) argues that these different constructions go back to the emergence of the university out of the clerical culture of the Roman Catholic Church. Like priests, academics had monopoly over certain formalised knowledge and formed a separate all male elite. This similarity is evidenced by the fact that Oxbridge fellows were not allowed to marry until 1882, and women could not be awarded Oxbridge degrees until the early twentieth century. Moreover, academics indulged in reason, which was associated with the mind, the spiritual, the masculine and the objective, and directly opposed to emotion, nature, the body, the physical, the feminine and the subjective (see also Gibson-Graham, 2004). Industry, involving physical activity of the body was therefore opposed to the pursuit of knowledge. These associations linger today, affecting the way in which universities and industry interact. For example, in their eagerness to characterise themselves as ersatz universities, R&D facilities of high tech industries set themselves apart from production facilities (Massey et al 1992). The limiting effect of this separation of R&D and production on innovation is discussed below.

The above accounts show that science and industry are socially constructed in conflicting ways that impede their integration. Firstly, the tenets of rationalism and the Mertonian norms, which are seen to be essential for the progress of science towards truth, are felt by some researchers to be undermined by demands for commercial gain. Secondly, the motives that drive the progress of science and the progress of technology are different and even conflicting. Finally, historically academia and industry are divided along the lines of the mind / body dichotomy.

The spatial division of labour and its implications for university – industry interaction

Massey's (1997) account suggests that historically contingent factors play an important part in the construction of scientific spaces. The importance of historically contingent factors in their construction can be seen particularly clearly in the notion of a spatial division of labour between science and industry. Research from countries as diverse as Japan (Amano and Poole, 2005), the UK (Massey et al, 1992) and Hong Kong (Patchell and Eastham, 2003) have suggested that there is a spatial division of labour between academia and industry which acts to restrict innovation by acting as a barrier to the reintegration of academia and industry. Massey et al (1992) suggest that in the UK this division of labour has its roots in the British class system. Social hierarchies are arranged differently in other countries. Hence if Massey et al (1992) are correct we would expect to see a difference in the way in which labour is divided socially and spatially in different countries. This section therefore examines evidence for a social division of labour along the lines of the class system in the UK, before going on to consider whether this idea explains similar divisions of labour in other countries.

Historically, British scientists tended to be 'gentlemen' and were isolated from industrial activity, as were the upper classes in general. Even in the 1850s there were not usually paid careers for scientists (Latour, 1987); it was an occupation for men with a private income. Engineering, on the other hand, was seen as a lowly occupation, since it was associated with dirty factories. According to Massey et al (1992) this spatial division of labour between basic research, industrial R&D and production remains today, dividing high status mental work from low status manual work, with industrial R&D still associated with the latter because of its link to production.

Though associations between industry, academia, the British class structure and social and spatial division of labour may be sketched in the rather simplistic terms of a division between upper class, high status mental labour in academia and lower class, lower status manual labour in industry, a more detailed look at the history of academia and industry reveals a more complex picture. Tilling (2002) notes that well into the British industrial revolution middle-class managers and gentlemen did not study science except as a hobby. Science at universities was limited to abstract work. It was recognised having useful industrial applications and thus as being important for the improvement of the economy, but its study was felt to be most appropriate for the working classes. In fact, Tilling (2003) and Sharp (1998) claim that the industrial revolution occurred *in spite of* the universities rather than *because* of them, and innovation usually occurred through the modification of existing technologies by those who worked with them. In this sense, there was a definite social and spatial divide between the practical science associated with industry and the lower classes and the pure science associated with academia and the higher classes.

According to Tilling (2002) this social and spatial divide arose in the following manner. Until the nineteenth century Oxford and Cambridge were the only higher education institutions in England with university status (Withers and Mayhew, 2001). Although in the Middle Ages Oxford and Cambridge were open to all, by the eighteenth century they tended to provide education to the upper classes and acted to maintain the existing social structure. Only members of the Church of England could attend and students were required to board at institutions charging high fees, which excluded those of a lower socio-economic status. Further, it was felt that allowing the middle classes into these establishments would devalue the education provided there, while educating the working classes would give them ideas inappropriate to the type of work they were destined to carry out. The education provided was a non-vocational 'liberal' one in which science played little part. Scientific research was not felt to be a major function of the universities; their role was to transmit a received body of knowledge. Thus for Tilling (2002) the ideal of the pursuit of knowledge for its own sake harks back to the pre-industrial university, where education was a mark of social status and the knowledge it imparted was not a requirement for its recipient's future occupation. This ideal, with its associations of high status, is incompatible with the idea developed during the industrial revolution that knowledge is a commodity, since exploitation of knowledge for commercial gain is associated with lower social status.

However, despite the presence of these instituted ideals within the university, Tilling (2002) argues that the commercialisation of the English university during the industrial revolution rescued it from falling into social insignificance and allowed it to regain prestige and influence. He notes that it was the growing importance of science to the industrial revolution that allowed scientific research and education to become established in the university system. The industrial revolution provided the impetus for the university to move away from non-scientific, non-vocational scholarship associated with the upper classes, towards scientific enquiry, original research and practical education more suited to those involved in industry. By the middle of the nineteenth century new universities were established for the education of the newly wealthy middle classes, and these had more of an emphasis on a practical education. Driven by industry's importance to the economy and the reliance it had on science, the function of the university changed. Original research and the generation of new knowledge became important, and experimental science became an accepted part of education, even in Oxford and Cambridge.

Because of the fundamental change in the nature of the work done by the university described above, a tension arose between the entrenched ideal of the university as a provider of knowledge as an end in itself, associated with high social status, and the new role of the university as a producer of practical knowledge, previously associated with low social status. Hence, 'there is a long tradition in

British universities of preferring more aesthetic cultural and discursive studies to commercial and monetary subjects like economics' (Martin and Sunley, 2001, page 153) and academic resistance to policy designed to exploit universities for economic improvement can be attributed to historically instituted ideals rooted in class structure.

The spatial division of labour outside Britain

Heyman (2000) suggests a process of change in the function of universities occurred in Germany, but with a rather different outcome than in the UK. In Germany, the development of the research university was not only the outcome of growing industrialisation but also more closely integrated with it. He argues that the first modern research university, the University of Berlin, which was established in the early the nineteenth century, was influenced by the thought of Wilhelm von Humboldt who advocated study balanced between the pursuit of the truth and use, the former being having become associated with speculative philosophical thought and the latter with empirical science. However, gradually this notion was replaced due to the pressure from the state, which wanted knowledge useful for its imperialist activities on one hand and knowledge useful for industry on the other, with the view of science as a producer of instrumental knowledge. As in Britain, abstract knowledge was afforded higher-status than practical skill so '[t]echnical professions, such as bridge building, chemistry, and architecture, became 'scientific'' (Szöllösi-Janze, 2005, page 346). However, the German universities were integrated with administrative and economic structures and produced specialised research useful to both of these, rather than for its own sake, receiving funding both from the state and from industry, and becoming important actors in Germany's industrial and imperial might (Szöllösi-Janze, 2005).

According to Pritchard (1998) the differing class systems in the UK and Germany do partly explain the differences between university – industry relations in the two countries. She suggests that because the UK achieved national unity and a homogenous political culture early by European standards, within the ruling classes '[t]here existed a consensus about a university-based, communal life-style which became the framework for the gentlemanly idea of education.... From this consensus derived the British emphasis on character formation as an objective of university education' (Pritchard, 1998, page 121). On the other hand Germany established itself as a nation-state much later than the UK and prior to unity it had no shared national identity, political culture or class system. Thus Pritchard (1998, page 122) suggests that '[i]n the absence of consensus, it was understandable that instrumentalism should predominate in higher learning. The result was an emphasis on professional training rather than on character formation'. This emphasis on university education as professional training in Germany may explain why Massey at el (1992) find that while in the UK engineering was perceived as a low status job during the industrial revolution, since it was closer to the lower class technical work performed on the shop floor, in Germany it had relatively high status. Even today, the British notion of management is of 'a function or status in its own right' (Massey et al, 1992, page 67), which means it is divorced from the manufacturing process it oversees (Sayer, 2004; Warner, 1994). In contrast, German managing is not thought of activity applicable to a variety of situations or processes. Instead managers manage particular substantive processes, and historically it is scientists, technologists and engineers who have supervised manual labour. Massey et al (1992) suggest that antipathy of academic science towards industry remains in the UK today, reflected in the reluctance of basic scientists to go into more commercial sectors despite cuts in basic science funding and the significant growth in status and numbers of engineers in electronics and IT in recent years, perhaps because these are seen as 'clean' industries, removed from the old-fashioned shop floor. Thus Britain shows a marked division of labour along the lines of status and prestige, which are not so obvious in Germany. Gamage and Mininberg (2003) and Patchell and Eastham (2003) suggest that former British colonies, such as Australia and Hong Kong, have inherited the British division of labour between academia and industry. That this division of labour has served to reinforce the gap between industry and academia is apparent in the lack of technological development and R&D investment by British industry during the 1960s and 1970s and low levels of business R&D in Hong Kong (Massey et al, 1992; Patchell and Eastham, 2003).

However, although differing social hierarchies may go some way to explaining the separation of academia and industry, the situations found in other countries that share an instrumental view of higher education show that other contingent historical factors clearly have a role to play. American universities established before independence followed the British model (Gamage and Mininberg, 2003) but it was the German model of the university that was copied by the US research universities when they were established in the late nineteenth and early twentieth centuries and they similarly contributed to the USA's growing economic and imperial power[2]. Because the USA adopted the German model, engineering had relatively high status there as well (Heyman, 2000). Japanese universities were likewise integrated with state structures and their aims of industrialisation, nation and empire building during the same period (Hayhoe, 2002, Kim and Lee, 2006; Sharp, 1998). However, university-industry links remained stronger in Germany until the beginning of the Cold War because the USA did not engage in state co-ordinated collaboration until the Cold War era (Heyman, 2000), while in Japan collaboration between universities and the private sector was restricted by the state until policy changes in the 1990s (Yokoyama, 2006). Furthermore, the majority of Japanese academic staff of the post-war period took an anti-establishment stance, which made them antagonistic to close relationships with industry (Amano and Poole, 2005)[3]. The American university model was in turn adopted by newly industrialised countries such as South Korea and Taiwan as part of their strategy for industrialisation (Kim and Lee, 2006; Law, 1995) but with different outcomes for each country. Government policy did not encourage academic collaboration with industry in Taiwan until the 1980s (Jan and Chen, 2006), whereas in South Korea large companies have actually founded private universities[4] (Ryu, 1998). State intervention and political climate clearly have roles in overcoming or reinforcing a division of labour between academia and industry.

Factors of social status also influence levels of academic entrepreneurship in different countries. Storper (1997) compares academic spin-out activities in the USA, where they have been particularly successful, and France, where they have not. He describes how, in France, scientists and engineers who graduate from the top technical universities can usually enter the top echelons of French industry, gaining

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[2] However, compare Feldman and Desroches (2004) who argue that it is because it was based upon the German Humboldt tradition that Johns Hopkins University has traditionally pursued knowledge for its own sake and even today commercialises relatively little of its research.

[3] A similar situation has existed in Latin American universities following radical student-led campaigns in the early twentieth century. The public universities have confronted the status-quo, forming strong links with trade unions and left wing political parties, opposing right wing political powers and remaining distant from industry (Arocena and Sutz, 2005).

[4] For example, Daewoo founded Ajou University in 1997 and Pohang Iron Steel Company founded Pohang University of Science and Technology in 1987.

positions that give them a high social standing. French science professors are more likely to come from a lower or middle class background because the Roman Catholic bourgeoisie have been traditionally hostile to science and 'the worrying, critical or heretical questions and interrogations which so often orientate organic scientists' (Bourdieu, 1988, page 52). Owing their entry to the upper classes to their academic success, science professors are thus likely to reinvest in the institution that has rewarded them, and to have little inclination to seek power outside the university. However, in the USA scientists and engineers achieve greatest social approval by applying their formal knowledge to entrepreneurial activity.

Contemporary changes in the division of scientific labour

In contrast to the above authors, who emphasise the effects of history on the way in which science is performed, Gibbons et al (1994) claim that the traditional division of labour between universities, industry and other organisations is being broken down and replaced by a radically different way of performing science. Their argument is that in recent years the traditional mode of knowledge production (Mode 1) has altered and is being replaced by a new mode of knowledge production (Mode 2). The features of Mode 1 and Mode 2 are given in table 2.1. In their model of Mode 2 knowledge production, the previously distinct boundaries between production of basic research in universities and applied research outside universities are blurred. Rather than being either aimed at producing either basic or applied knowledge, Mode 2 knowledge production occurs in the contest of application, i.e. it 'is focused on the application of knowledge, whether in industry, government, or society in general' (Gibbons, 2003, page 232). It is also carried out by many different organisations, including universities, firms, consultancies and government agencies, meaning 'knowledge production has become a socially distributed process' (Gibbons, 2003, page 238). Moreover, actors from diverse organisational and disciplinary backgrounds are coming together on individual research projects.

Table 2.1: Gibbons et al's (1994) modes of knowledge production

	Mode of knowledge production	
	Mode 1	Mode 2
Features of mode of knowledge production	Problems set and solved within context governed largely by the interests of academia	Problems set by requirements
	Disciplinary boundaries	Absence of disciplinary boundaries
	Distinction between basic and applied research	Knowledge sought for application
	Homogenous set of practitioners (academics)	Heterogeneous set of practitioners (academics, industrialists, consultants, government researchers)
	Permanent, hierarchical structure	Transient, heterarchical structure
	Internal method of quality control (peer-recognition)	Socially accountable and reflexive method of quality control

Source: Gibbons et al (1994)

Gibbons et al's (1994) argument is partly supported by the findings of Dietz and Bozeman (2005) who study the careers of 1200 scientists and engineers based in the USA. They find that in university research centres 'there is now a revolving door between industry and university research jobs' (Dietz and Bozeman, 2005, page 362). Approximately half of the respondents to the study had had at least one job in industry, nearly one in six of their total jobs were in industry and one in eight of their career years were spent in industry jobs. Furthermore, nearly a third had taken their first job in industry and 24% of grants awarded to university research centre researchers were from industry.

On the other hand, Whitley (2000) argues that regarding changes in the way scientific labour is divided in the manner of Gibbons et al (1994) is a severe oversimplification. He argues that there are considerable differences in the 'institutional arrangements governing research and education' (page xvii) across the minority world, which have also varied over time. Contending that academic interest in use-oriented research and human-made objects is not a new phenomenon, Whitley (2000) suggests that disciplinary boundaries within academia have never been completely rigid and a variety of practitioners have been involved in science throughout its history and identifies four modes of performing research that have been in existence since the beginning of science. These four modes are summarised in table 2.2.

Table 2.2: Whitley's (2000) four research modes

Features of research	Mode of performing research			
	Theory-directed explanatory research	Instrumental research	Explanatory instrumental research	Classificatory research
Consideration of use of the phenomena researched	x	✓	✓	x
Explanation of phenomena researched	✓	x	✓	x
Systematic exploration of data	x	x	x	✓

Source: Whitley (2000)

Recently, he suggests, for political and economic reasons there has been an increase in the amount of explanatory instrumental research being carried out within the academic science community in parts of the minority world. However, this is not tantamount to a completely new mode of doing research coming into effect.

Scheutze (2001) is broadly in agreement with Whitley's (2000) thesis on the contemporary division of scientific labour. He presents five types of institutional structure that promote or manage university cooperation with industry, which divide scientific labour within the university. These are shown in table 2.3.

Table 2.3: Institutional structures that promote or manage university cooperation with industry

	Institutional structures				
	Integrated organisations	Peripheral organisations	Subsidiary organisations	Inter-dependent organisations	Independent organisations
Relation-ship to the university	Run by university sub-units, e.g. research groups	Report to central university administration	Legally separate but university is an equity holder	Legally separate but dependent on university despite the university having no formal control or equity	Related to the university through informal / contractual arrangements
Example	Research consortia	Technology licensing offices	Research parks	Alumni associations, university foundations	Government bodies

Source: Scheutze (2001)

He notes that many university – industry cooperative activities are tending, especially in the USA, to move to the periphery of the university. This avoids clashes with 'academic tradition and value systems' (Scheutze, 2001, page 11) and provides 'a buffering effect that shields the university against some possible negative consequences of commercialisation, e.g. litigation or public relations disasters' (Scheutze, 2001, page 11). However, it also leads to fragmentation and hollowing out of the university core which 'could lead to a loss of the core functions and values and, eventually, of the university's identity' (Scheutze, 2001, page 12).

Conclusion

What the above accounts show is that universities and industry have been closely bound together since the industrial revolution and that industry has had a profound effect upon shaping the university as the teaching and research institution that of today. Indeed, to a certain extent the interaction between industry and universities served to legitimise some fields of knowledge as academic subjects. However, equally powerful social forces and historical factors have served to keep them at arms at length. The commercialisation of the university is nothing new, and neither are struggles between the influence of industry and the pursuit of non-applied knowledge, with its higher status connotations. Such struggles serve to explain, to some extent, why policymakers have not always found it easy to promote university-industry collaboration.

The linear model of innovation

A particularly damaging criticism that has been levelled against policies to encourage links between academia and industry, such as establishing science parks and co-operative partnerships between universities and firms, is that they are based on an inaccurate model of innovation, known as the linear model of innovation. The linear model conceptualises the innovation process in the following way. An idea originates at the beginning stage of basic research, and is expanded at the stage of applied research and experimental development. The latter two stages lead to the manufacture of a product and its establishment on the marketplace. According to the model, the stage of basic research takes place in universities or public research laboratories and the stage of applied research in universities, government sponsored institutes or private R&D laboratories. Experimental development occurs in private R&D laboratories and manufacture of the developed product takes place in separately sited plants, often in overseas facilities. The process flows one way from the upstream stage of basic research to the downstream stage of production (Hayter, 1996; Malecki, 1991; Massey et al, 1992; Steinmueller, 1994). If the linear of innovation is a correct model of reality then investment 'upstream' should produce innovative technologies 'downstream'. However, investment in basic research does not necessarily produce a greater number of innovative new products (Sharp, 1998).

Reconceptualising the innovation process

The linear model of innovation was rejected as inaccurate by many academics after research showed that there is not a unidirectional process beginning with basic research and ending with the successful development of a new product. Researchers have reconceptualised the innovation process as a much messier, multidirectional process requiring linkages and feedback between scientific, technological and production stages of development. There may also potentially be impediments between stages (Malecki, 1991; Hayter, 1996; Schuetze, 1996; Sharp, 1998; Antonelli, 2000; Beesley, 2003). For instance, a failed prototype might require a return to the design stage (Padmore et al, 1998).

Since the linear model fails to explain how the innovation process works it cannot direct company or government policy towards increasing innovative activity. For example, firms that treat the path from R&D to production as one-way may incur high costs and extend development times if they do not take into account the need to return to earlier R&D stages for reassessments and corrections (Hayter, 1996). Similarly, science parks often do not allow production on site, meaning companies located in science parks often separate R&D from production, making exchange of ideas and feedback between to the two more difficult and expensive (Antonelli, 2000; Hayter and Gunton, 1984; Kaufman and Todtling, 2000; Sharp, 1998). As policies promoting academic–industry interaction specifically aim at increasing innovative activity, basing them on the linear model is inherently problematic. However, when Beesley (2003) examined policy statements from Australia, Canada and the USA published between 1997 and 1999, she found that, while promoting university-industry collaboration, the statements all assumed the linear model. Similarly, in Britain, Massey et al (1992) found the policy of establishing science parks to be based on this model.

In reconceptualising the innovation process, researchers have given particular emphasis to the Japanese model of industrial R&D, which often involves the location of production and R&D facilities on the same site and the involvement of skilled production workers in a continual process of feedback to R&D (Florida and Kenney, 1994). The treatment of process from research to production in an integrated manner involving discussion and feedback has been described as 'a loopy model of technological change' (Hayter, 1996, page 179). A loopy R&D process is accepted as being more successful at generating innovations and increasing the quality of products and production processes, than a linear R&D process. Loops involving exchange of ideas and feedback also extend beyond firms, and involve other firms, central research laboratories, government sponsored institutes and business services. The employment of loopy R&D is believed to be one reason for the success of Japanese industry (Hayter, 1996; Rothwell, 1994).

Looking at the loopy model of innovation at work in Japan, it would appear that this model is a more appropriate base for policies encouraging academic-industry linkages as it allows for flows of knowledge, ideas and feedback between all stages of the innovation process. The loopy model of innovation resonates with the findings of Feldman and Florida (1994), who suggest that proximity and interaction between similar firms, industrial R&D, university research and business services enhance corporate innovative capacity.

University – industry links and regional development: knowledge spillovers and beyond

As we saw in chapter 1, universities, as local producers of knowledge and innovative ideas, are thought to have a potentially important place in the development of an effective regional innovation system (RIS). Universities are seen as contributing to innovation by being a source of formal technology transfer and spin-outs, and by providing a locally available source of knowledge that spills over to nearby firms. This notion of the knowledge spillover has become widespread throughout the literature of university – industry links, and is often assumed to be a particularly important driver of innovation, since it is seen as a low cost or free source of knowledge. However, the concept is not unproblematic, given that it is often poorly defined and suggests an overly simple process though which knowledge flows between institutions.

This section aims to examine the concept of knowledge spillover from universities to firms, before going on to explore other ways of thinking about knowledge flows from universities and their role in regional development. It is divided into five sections. The first section considers the concept of knowledge spillovers and the mechanisms through which academic knowledge spillovers are thought to occur. The second examines how knowledge spillovers have been addressed in previous studies and reveals a bias towards examining the extent of spillovers as opposed to how they occur. Section three examines the problems that have been identified measuring knowledge spillovers, while section four identifies the source of these problems as weaknesses in conceptualising knowledge spillovers, and argues that there is a need to think beyond the knowledge spillover. The fifth section then shows that by looking beyond the knowledge spillover and addressing the conceptual weaknesses in the knowledge spillover literature a greater understanding of academic knowledge flows and their contribution to regional development can be achieved.

Knowledge spillovers and the university's role in regional development

The notion of knowledge spillovers initially appears quite simple. Griliches (1992, page 36) defines them as 'ideas borrowed by research teams of industry *i* from the research results of industry *j*'. These industries 'may not buy much from each other but may be, in a sense, working on similar things and hence benefiting much from each other's research' (Griliches, 1992, pages 36-37). Breschi et al (2005, page 343) provide a similar definition for what they describe as pure knowledge spillovers; these are said to occur when 'firms profit from the R&D activities undertaken by others without compensating them for the benefits received' (Breschi et al, 2005, page 344). Alternatively, it is possible to think about knowledge spillovers as original and valuable knowledge produced through research that has become publicly accessible (Fischer and Varga, 2003). Knowledge is able to spill over because it has the properties of a public good (Calderini and Scellato, 2005;

Fischer and Varga, 2003). In other words, it is 'freely available to all those wishing to invest in searching for it (non-excludable) and exploitable by different users at the same time (non-rivalrous)' (Breschi et al, 2005, page 346). Knowledge may spill over between any actors in the regional innovation system – firms, universities, governmental bodies, non-governmental bodies and so forth – but much literature focuses on spillovers between firms, or, because of universities' role as producers of knowledge and innovative ideas, between universities and firms (see, for example, Adams, 2005; Audretsch et al, 2005; Beise and Stahl, 1999; Calderini and Scellato, 2005; Feldman, 2000; Salter and Martin, 2001).

According to Breschi et al (2005) there are principally two mechanisms through which knowledge spillovers can take place. These are the movement of employees from one place of employment to another and social networks between actors. Where spillovers between universities and firms are concerned, they are thought to occur when employees move between academia and industry or develop informal links. Employees that move may be graduates seeking jobs in the local area, industrial employees who participate in life long learning schemes run by the local university, academics moving into industry, and industrialists who move into academia (Chatterton and Goddard, 2003; Vermeulen, 2003; Chapple et al, 2005). The informal links that form social networks may exist as the result of personal and professional contacts, such as people who have worked or studied together, or through forums established to encourage interaction between academia and industry.

Academic knowledge spillovers (or indeed spillovers between firms) are thought to benefit the regional innovation system and hence the regional economy in which the university is located, rather than having a more general beneficial effect, because that they are believed to be geographically localised (Feldman and Florida

1994; Audretsch and Feldman 1996). Indeed, Beise and Stahl (1999), Izsushi (2002) and van der Meer (1997) find that geographical proximity between universities and firms is advantageous for the formation of links between the two. This is because much of the knowledge that spills over is tacit rather than explicit. Tacit knowledge is, according to Nonaka and Takeuchi (1995), knowledge that cannot be written down or formulated into a set of procedures. It is also both highly personal and context-specific. This is because it is experiential and cognitive – involving 'know-how' acquired through experience and defying conscious articulation – and can only be understood by people who share the 'norms, conventions, values, expectations and routines arising from *commonly experienced frameworks of institutions*' (Gertler, 2003, page 91, emphasis original). Explicit or codified knowledge, on the other hand, can be codified in written documents, sets of procedures and so forth. It is important to note here that tacit and explicit knowledge are not two different types of knowledge, but two interdependent dimensions: the explicit dimension always relies on the tacit (implicit) dimension (Brown and Duguid, 2001). Thus '[t]hough knowledge undoubtedly can be usefully articulated and explicated, in use the explicit nonetheless always possesses this other, implicit dimension' (Brown and Duguid, 2001, page 204). So, for instance, reading about how to drive a car and learning the correct procedures for driving is not the same as knowing how to drive. Tacit knowledge, embodied as it is in people, does not travel so well as explicit knowledge. This dimension of knowledge is much more easily passed on through face-to-face contact and personal relationships (Johnson et al, 2002; Lawson and Lorenz, 1999), hence the need for driving instructors.

Of course, face-to-face contact and personal relationships are more likely to arise where people are located close to each other, so knowledge spillovers are more likely to occur when the organisation doing the spilling is close to the organisation receiving the knowledge that is spilt (Audretsch et al, 2005; Beise and Stahl, 1999; Breschi et al, 2005; Coronado and Acosta, 2005). Where knowledge spillovers occur through employee mobility, they are still likely to be geographically localised because people often remain in the same area when moving jobs (Huijs, 2003; Nieuwenhuis et al, 2003).

According to Beise and Stahl (1999, page 409) case studies of the successful clusters of innovative industry such as Silicon Valley, Route 128 and Cambridge, England present examples that 'always have universities as a core which generate spillovers received predominantly by companies located in the same area'. In the paradigmatic cases of Silicon Valley, Route 128 and Cambridge, Stanford University, Massachusetts Institute of Technology (MIT) and the University of Cambridge are thought to contribute to the innovation process in their respective regions in three ways. Firstly, all three universities provide working conditions conducive to academic collaboration with industry and to academic entrepreneurship. This allows ideas to pass between the universities and industry as academic and industry staff work together, either on collaborative projects or through academic spin-out companies (Garney and Hefferman, 2005; Jong, 2006; Keeble et al, 1999; Leslie, 1993). During the Cold War, Stanford University and MIT were also very successful in attracting military funding. This in turn attracted some high-technology defence companies to locate near them in the Silicon Valley and Route 128 regions respectively, and also resulted in a number of high-technology academic defence spin-outs into these regions (Lawton Smith, 2007; Leslie, 1993). If such an innovation enhancing effect can be replicated then this suggests an important role for universities when it comes to regional development. In fact, Cooke (2002) claims that most successful clusters of innovative industry have university involvement[5]. He points towards clusters of high-technology firms that have been successfully designed around universities in order to regenerate declining industrial regions, especially in Finland and Sweden.

Claims that knowledge spillovers can encourage the growth of innovative clusters of industry and help to regenerate deindustrialised regions are very attractive to policymakers wishing to boost economic growth in an area (Woodward et al, 2006). This attractiveness is enhanced by the fact that spillovers are seen as a low cost source of innovation because, it is reasoned, borrowed ideas are free. Furthermore, most regions in the Western world, even the poorest and most deindustrialised, have a university (Cooke, 2002). Because of the perceived benefits of knowledge spillovers from universities they have become the subject of a growing literature seeking to quantify academic spillover effects in terms of their significance to the local economy (see, for example, Adams (2005); Audretsch et al (2005); Fischer and Varga (2003); Monjon and Waelbroeck (2003); Woodward et al (2006)). However, many of the studies comprising this literature reach only a limited understanding of knowledge spillovers because of their narrow focus.

Quantifying knowledge spillovers

Typical studies that attempt to assess the economic significance of academic knowledge spillovers, such as Adams' (2005) study comparing localisation of knowledge spillovers from industry to industry with those from academia to industry across the USA or Monjon and Waelbroeck's (2003) survey of the innovation sources of French firms, are focussed on the extent of knowledge spillovers as

[5] For a different view, compare Hall (1997).

opposed to how these spillovers take place. Thus they address issues such as where and how far academic knowledge spills over (e.g. Adams (2005); Fischer and Varga, (2003); Monjon and Waelbroeck (2002); Woodward et al (2006)) and the effects of using knowledge spillovers on new firm location (e.g. Audretsch et al (2005); Woodward et al (2006)).

Audretsch et al's (2005) study of the impact of academic knowledge spillover availability on new firm location does recognise the limits of this approach. The results of their study suggest that the connection between university research output and new firm location is dependent both on the type of knowledge firms require and the mechanism by which it spills over and therefore they note that '[f]uture research may be expected to focus less on uncovering the existence of knowledge spillovers and more on identifying the heterogeneity inherent in both the types of knowledge generated by universities, as well as the various mechanisms that firms use to access knowledge spillovers' (Audretsch et al, 2005, page 1121). Particularly important for the purposes of discussion is the recognition of a need to investigate mechanisms used to access knowledge spillovers, because it highlights a further deficiency of studies focusing on the extent of knowledge spillovers. That is, once the mechanism a firm has used to acquire a piece of knowledge has been revealed, it is quite possible that what originally appeared to be a knowledge spillover is in fact some other form of knowledge flow. Because these mechanisms of knowledge spillover are not identified, many studies purporting to measure the extent of knowledge spillovers may be doing no such thing; rather they are measuring a variety of knowledge flows, some pure knowledge spillovers and some the result of commercial transactions. In fact, as Breschi et al (2005, page 343) argue, 'the term spillover has now become a synonym for any kind of knowledge flow or transfer'. In other words, the notion of the knowledge spillover manages to iron out the complexities of knowledge flow between universities and industry, producing a depleted picture. Such a situation is of more than theoretical interest because a depleted picture of knowledge spillovers is likely to lessen the chances that regions will be able harness these flows for the purposes of enhancing the RIS.

Academic knowledge spillovers – a depleted picture?

Of course, there could be good grounds for assuming that most knowledge flows occur in the form of knowledge spillovers. However, Breschi et al (2005) produce a strong argument that the notion of the knowledge spillover homogenises knowledge flows, thereby producing a depleted picture, because of central flaws in the way it is studied. Essentially, pure knowledge spillovers are often conflated with rent spillovers. Rent knowledge spillovers occur when the maker of a new or improved product, in order to compete, has to sell it for a lower price than its quality, relative to the old or unimproved product, would indicate. The user of the new or improved product will therefore appropriate some of its benefits, rather than the producer taking all of them. On the other hand, as we have seen, pure knowledge spillovers occur when a firm benefits from a piece of R&D that was undertaken outside the company, and this firm does not pay the person or organisation that undertook the R&D for using it. This process occurs not because of a mismatch between the price at which it is competitive to sell a product and the price that would better reflect its quality, but because it is not possible to appropriate all the benefits from a piece of knowledge. Even if patented or otherwise protected, knowledge can be applied in a different context leading to a different innovation. Furthermore there are always tacit elements to an innovation that can leak out of an innovating firm if a member of staff leaves.

Breschi et al (2005) and Griliches (1992) argue that the distinction between these two types of spillover is often blurred in the literature[6]. This is because while authors such as Audretsch and Feldman (1996) aim to study the role of pure knowledge spillovers, they use methodologies that cannot distinguish between pure knowledge spillovers and rent spillovers. These methodologies usually use variations of Jaffe's (1989) knowledge production function approach, which involves estimating a linear statistical model of university R&D spillovers to firms fitted to time-series data such as patent citations or innovation counts. Because this approach does not model the mechanism of knowledge spillovers (Jaffe, 1989), there is a tendency to overestimate the effects of pure knowledge spillovers and to underestimate the role of rent spillovers (Breschi et al, 2005). In other words, data such as innovation counts and patent citations cannot separate pure knowledge spillovers from cases of buying and selling university knowledge (Calderini and Scellato, 2005). For example, there may be commercial links, such as previous licenses or consultancy, between the organisation that has applied for a patent and some of the organisations that have produced patents or journal articles that the applying organisation cites in their patent application. In this case, such citations are not evidence of pure knowledge spillovers. Organisations that have entered into commercial agreements of some sort to obtain university knowledge might well receive spillovers, but these will be rent spillovers and not knowledge spillovers.

This methodological confusion of rent and pure knowledge spillovers, does not explain, of course, why pure knowledge spillovers are overestimated rather

[6] Feldman (2000, page 382) appears to explicitly equate the two, claiming that 'knowledge spillovers may be embodied in goods in which the innovator is unable to appropriate all the surplus from trade'.

than rent spillovers. To understand this issue it is necessary to look at the way that the knowledge in knowledge spillovers in conceptualised.

Conceptualising knowledge that spills over

According to Breschi et al (2005), the overestimation of pure knowledge spillovers occurs because studies assume that knowledge that spills over between firms or universities and firms is tacit knowledge (see, for example, Audretsch and Feldman, 1996). These studies fail to recognise that such knowledge could be codified but is but is deliberately not made explicit in order to make it excludable. Furthermore, codified knowledge available from universities in the form of publications is often excludable because accessing such publications means subscribing to expensive academic journals or making relatively large one-off payments for books or single papers which can be prohibitive for small organisations. Because of these factors, university knowledge seems to bear more resemblance to a club good, such as a television channel, than a public good, i.e. it is a good that more than one person can use at the same time (non-rivalrous) but not freely available to all (non-excludable). Rather than being free, it is a commodity (Rothaermel and Thursby, 2005).

An additional source of the overemphasis of knowledge spillovers and the under-emphasis of rent spillovers in the literature is the epistemological assumptions at work in the notion of the knowledge spillover. Knowledge that spills over is conceived of as disembodied (Asheim and Cooke, 1999; Breschi et al, 2005), meaning that it is not embodied in particular products or processes. It is free-standing knowledge that is perceived as context-free: an example would be the type of knowledge conveyed in blue-prints or designs. It is necessary for spilt knowledge to be disembodied because, as we have seen, if a person comes to know a fact through market regulated activities, such as purchasing products or services, then this cannot be a knowledge spillover. However, the idea that the knowledge in spillovers is disembodied suggests that even tacit knowledge is not context-dependent, in the sense that some ideas, even if they are difficult to make explicit, can be transferred directly from one organisation to another.

This notion of disembodied knowledge arises from traditional epistemology, in which knowledge is conceived as 'absolute, static, and nonhuman' in nature (Nonaka and Takeuchi, 1995, page 58). It is a conception of knowledge that starts to look problematic when we consider that knowledge is what is known and therefore it is necessary for someone to do the knowing. Thus, knowledge is always embodied and, furthermore, is always embodied in people who acquire knowledge through their interactions with other people and the material world. Nonaka and Takeuchi (1995) express this notion of embodied knowledge in their adaptation of the traditional definition of knowledge as justified true belief[7]. They define knowledge as '*a dynamic human process of justifying personal belief toward the "truth"*' (Nonaka and Takeuchi, 1995, page 58, emphasis original), '*essentially related to human action*' (Nonaka and Takeuchi, 1995, page 59, emphasis original) which is context-specific and relational[8]. For Nonaka and Takeuchi (1995, page 61), knowledge is created and expanded 'through social interaction between tacit knowledge and explicit knowledge'. Thus, ideas are not transferred directly from one organisation to another but change according to the context they are in. However, while the notion of knowledge spillover through labour mobility and social networks entails the essentially embodied and human nature of knowledge, the dynamic nature of knowledge often seems to be ignored in the discussion of the

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[7] This definition was called into question by Gettier (1963).

absorptive capacity of firms, that is, their ability to acquire knowledge and to exploit it (Cohen and Levinthal, 1990; Feldman, 2000). Often the absorptive capacity of firms is measured by looking at the amount of knowledge imparted without considering the mechanisms of absorption, that is, how it alters as it flows (Rosaermel and Thursby, 2005).

Reiffenstein (2006), on the other hand, points out that for knowledge to flow between universities and firms (or even between firms) it is likely that it will need some form of translation or transformation. This need, in turn, is likely to entail other mechanisms for knowledge flow, often market mediated, such as sponsored research projects, which allow for extended joint work. For example, Reiffenstein (2006, page 314) notes that the discovery of FM synthesis by a faculty member of Stanford University's music department, John Chowning, passed tacitly to a US electric music instrument firm, a pure knowledge spillover, but 'what ultimately put this knowledge in play was the moment of externalisation when Chowning and Stanford fixed this knowledge in a proprietary manner by patenting and licensing it to Yamaha' – a market mediated knowledge flow. The licensing of the patent allowed the growth of a relationship between Stanford and Yamaha, including a period in which Chowning acted as a consultant to Yamaha and the licensing of further patents. This relationship has allowed knowledge transfer in the form of knowledge spillovers (e.g. through labour mobility (Nelson, 2005)), and in the form of commercial transactions (consulting, licensing). Thus, we see in this example that when we consider more deeply the relational, context dependent and human nature of knowledge, the idea of the pure knowledge spillover becomes more unlikely.

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[8] Wenger (1998) presents a practice-based theory of knowledge that shares some similarities with this conception of knowledge.

The recognition that pure knowledge spillovers are less common than originally thought has three important implications for studies of knowledge flows between universities and firms. Firstly, it suggests that rather than concentrating on knowledge spillovers as a principal contribution that universities can make to their regional economy, they should be considered one among many forms of knowledge flow. In other words, studies should look beyond to other forms of knowledge flow that are equally, if not more, important. Secondly, the dynamic nature of knowledge should be considered when thinking about knowledge flows, that is, its passage between different organisations should not be thought of simply in terms of transferring a static object. Thirdly, when knowledge flows are considered, including knowledge spillovers, the conditions that can give rise to them need to be examined more closely: ideas regarding tacit knowledge, social networks and labour mobility are important here. These implications are considered in more depth in the next section.

Beyond spillovers

i) Spillovers and other knowledge flows

An approach that pays greater attention to knowledge spillovers as one type of knowledge flow between academia and industry among many may go beyond knowledge spillovers but this does not mean, however, that knowledge spillovers are ignored. Such an approach recognises that knowledge spillovers often go hand in hand with market mediated knowledge flows: a licensing agreement between a firm and university may lead an employee of one organisation to move to the other (Nelson, 2005) or may allow the firm to access academic social networks (Murray,

2004) thus facilitating pure knowledge spillovers and further benefiting one or both organisations.

Understanding the interaction of market mediated knowledge flows, which also include flows arising from activities such as services provided to firms by universities in university-based business incubators or science parks (Grimaldi and Grandi, 2005; Lee and Win, 2004), training provided to firms by universities (Holifield et al, 1999), joint ventures between universities and firms (Link and Scott, 2005), consulting (Reiffenstein, 2006) and pure knowledge spillovers (Monjon and Waelbroeck, 2003) gives a clearer picture of how university – industry relations operate, making it more likely that they can be harnessed for regional development. For example, Vaessen and van der Velde (2003) provide a study that demonstrates the interaction of tacit knowledge, explicit knowledge, pure knowledge spillovers, market relations and social networks. They survey the number of linkages formed between employees at the University of Nijmegen in the Netherlands and the wider community. These linkages fall into two categories – socio-cultural participation in clubs or organisations outside of work hours, and professional linkages with external organisations such as businesses, government bodies and not-for-profit civil organisations. Both types of linkages were found to involve commercial and non-commercial relationships. Professional linkages involved formal and informal relations with external organisations, whereas socio-cultural linkages chiefly consisted of social relations which on occasion developed into commercial relations. Pure knowledge spillovers can occur as a result of the informal and social relations in both types of linkages, while commercial relations lead mainly to market mediated knowledge flows. However, the study found that only 10% of employees surveyed had both professional and socio-cultural linkages. This finding has important implications because about half of the organisations that university employees contributed to in their spare time benefited from these employees' academic knowledge and contacts, but this rose to two-thirds for those employees with professional linkages outside the university. Vaessen and van der Velde (2003) suggest that such flows of knowledge strengthen the socio-cultural foundation of the region and this feeds into the regional economy, creating:

> A common regional business culture...in which opportunistic behaviour is abandoned, inter-firm uncertainty is reduced, and actors share a common way of doing business and do not restrict themselves to their own private goals, but are devoted to community goals as well (Vaessen and van der Velde, 2003, page 89).

In such a region informal and formal links reinforce each other.

ii) Understanding how knowledge flows

Considering the dynamic nature of knowledge flows highlights why the mixture of different knowledge flows identified by Vaessen and van der Velde (2003) occurs. Carlile (2004) offers a framework for understanding how both pure knowledge spillovers and market mediated knowledge flows occur, which takes into account the embodied and changeable nature of knowledge present in these spillovers and flows between academia and industry. He identifies three levels of communication complexity for the sharing of knowledge across specialised domains. These are transferring knowledge, translating knowledge and transforming knowledge. As the complexity of communication increases we see an increase in the intensity and depth of relations between the specialised domains suggesting a greater need for formalised relationships.

Thus, knowledge transfer is possible where the individual and/or groups of the specialised domains at either side of the boundary share a common lexicon which can be used to represent the difference and dependencies between the domains. Knowledge flows from publications, conference attendance and, to some extent, informal conversations, would be possible through this mechanism. This would be the mechanism of spillovers and arms length sponsorship of academic research by firms. Knowledge translation is necessary when novel circumstances mean that differences and dependencies between the two domains become unclear with different interpretations existing of the same term or finding, and involves the creation of shared systems of meanings or 'thought worlds' (Dougherty, 1992) and the explication of tacit knowledge. The translation process may involve the creation of shared methodologies, teams consisting of members from both domains and collocation of actors from both domains (Carlile, 2004). Alternatively, certain individuals may act as knowledge brokers, translating knowledge across boundaries (Wenger, 1998; Yanow, 2004). To enable such processes of knowledge translation a formalised partnership is likely to be necessary between the two domains, e.g. a collaborative research project or consultancy. Knowledge transformation occurs when novel circumstances create different conflicting interests between actors which impede knowledge sharing. In addition to the use of teams as outlined in the process of knowledge translation, knowledge transformation may use boundary objects, that is, 'objects that work to establish a shared context' (Carlile, 2002, page 451) between domains, to negotiate changes to how the problem, outcome or object in question is perceived. These may include standardised forms (Wenger, 1998), objects and models, such as prototypes or products (Bechky, 2003) repositories, such as databases (Carlile, 2002). Again, when knowledge flows in such a manner it is likely to need considerable commitment from both organisations in terms of employee time, which generally involve formalised partnerships.

iii) Conditions for knowledge flow

The studies by Vaessen and van der Velde (2003) and Carlile (2004) highlight the importance of the right socio-cultural conditions for the formation of linkages of all kinds between universities, industry and other organisations. These are further emphasised in work by Izsushi (2002), Rappert et al (1999) and Siegel et al (2003) who present studies of university – industry links in the Japan, UK and the USA respectively, which confirm the importance of socialisation effects, such as presence of social networks and shared spaces (e.g. conferences) in their development. Cultural proximity is another important factor: Beise and Stahl (1999) and Sternberg (1999) find firms that co-operate with research institutions have a higher R&D intensity than those that do not, Izsushi (2002) and Sternberg (1999) find that firms with more employees holding university degrees tend have more links than those without, while Millet et al (2002) and Daniel et al (2002) emphasis ease of communication between industrial and academic partners in successful links and Roy (2004) highlights the fit of university technology with regional specialisation. A company management style open to outside knowledge (Corti and Ilenia Torello, 2004; Izsushi, 2002; Millward et al, 2004) is also significant for link formation. Larger firms are more likely to have links with universities than smaller ones (Beise and Stahl, 1999; Shane, 2002). This result may seem counterintuitive given research suggesting that smaller firms are equally or more innovative than large firms (see, for example, Baron 1993; Freel 2000) but is also a matter of cultural proximity because as large organisations, larger firms and universities' practices are more similar than smaller firms and universities' practices in addition to having more money available to fund collaborative projects (Shane, 2002).

Science parks were designed to provide links to local academic institutions for small high technology start-up occupants and to encourage academic spin-out companies. By bringing science and industry together physically, it was hoped that they would become closer together culturally (Hayter and Gunton, 1984). Similar motivations lie behind the establishment of university incubators for high-technology start-up firms, either within or close to university grounds (Grimaldi and Grandi, 2003). However, although the proximity of universities to industry may be important in promoting linkages and technology transfer, it appears that simple proximity of universities and industrial R&D is insufficient to create interaction between the two (Hayter and Gunton, 1984; Malecki, 1991; Audretsch and Feldman, 1996; Garnsey and Lawton Smith, 1998). The level of collaboration between businesses in science parks has been found to be disappointing, both in Britain (Massey et al, 1992) and in other countries, such as Singapore (Koh et al, 2005), Canada and Australia (Malecki, 1991). Links have tended to be ones that existed prior to the establishment of the firm in the science park. Often a science park may be partially occupied by low-tech companies and branches of multinational corporations who like the prestige attached to the location of a science park and can afford the higher rents. Furthermore, large pharmaceutical, chemical and aerospace firms have shown that it is quite possible to bring in research from outside the region in which the firm is located (Anderson, 1995; Hayter and Gunton, 1984; Malecki, 1991; Rees, 2005). There are other factors at work in successful science parks than those of proximity to universities and the willingness of both parties to collaborate. These are the industrial relevance of university research (Ling Ku et al, 2003; Link and Scott, 2003), the availability of business support services and venture capital (Keeble et al, 1999; Ling Ku et al, 2003; Link and Scott, 2003) and pre-existing demand for business accommodation

(Keeble et al, 1999; Massey et al, 1992). Success of academic spin-out activity shows slightly different patterns. A lack of venture capital causes problems (Dodgson, 1991; Smallbone et al, 2002) but so does entering an market with a small number of large, well established competitors (Nerkar and Shane, 2003) and an unsupportive of policy environment (Dodgson, 1991; van Geenhuizen, 2003).

Of course, the extent to which social networks involving universities and industry arise is dependent to some extent on issues of organisational policy, which may be effected by extra-regional factors. A survey of UK universities by Charles (2003) provides a useful starting point when considering this point, as he addresses the willingness of universities to contribute to regional economic development. He finds that nearly 60% of universities claimed that economic development of the local region was a high priority, while only 7% claimed that it was a low priority and all but one of these were specialist institutions. Former polytechnics tend to place more emphasis on regional economic development (see also Beise and Stahl, 1999), with 86% claiming that it is a high priority for them and none claiming that it was a low priority, in comparison to 50% of older universities, and 44% of higher education colleges. Two thirds of universities were found to have a central office that managed regional collaborative funding and a third had some form of special regional development commitment. However, despite the enthusiasm of universities towards regional development suggested by Charles (2003), the evidence presented on their contributions is mixed.

Boucher et al (2003) find that single player universities[9] in peripheral regions of Europe tend to be 'large players in the region in terms of knowledge production and economic impact' (Boucher et al, 2003, page 891), but multiplayer universities

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[9] That is, universities with no other universities in the same region as them.

in such regions have a less clear cut role in terms of knowledge provision and shaping the regional agenda because of competition and hierarchies between institutions. Traditional universities in core regions usually have a less coherent system of regional engagement than universities in peripheral regions and their engagement tends to be on a more informal, personal basis, mainly because of such universities fear greater regional involvement will detract from their national and international reputations for excellence in teaching and research. Newer technologically oriented universities in core regions often participate in sub-regional and local regeneration schemes though competition with traditional universities and a lower ranking in the university hierarchy decreases their regional engagement. Van der Meer (1997) presents similar results in her study of universities in the Netherlands and the UK. She finds that, in particular, universities in subordinate cities experience tension between achieving international excellence and focussing on local problems. Chatterton and Goddard, 2000, page 492) also claim that:

> [i]n terms of research [produced by UK universities that is relevant to regional needs], barriers include the largely national driven agendas of research councils; staff promotion mechanisms, peer hierarchies and academic networks that [...] favour activity of an (inter)national significance; the distribution of funding according to the reputation of academics and higher education institutions rather than to the prioritisation of regional developmental needs.

Several authors have sought to explain why government policies aimed at increasing university-industry knowledge flows are not always successful. A number have found policies aimed at promoting links to be hampered by university policy and funding issues. For example, although Debackere and Veugelers (2005) suggest that those universities that allocate a higher percentage of royalty payments to their academics tend to be more effective at technology transfer, Goldfarb and Henrekson (2003), Jensen et al (2003), and Lavery and Stratford (2003) suggest that policies and programmes to encourage commercialisation of research have disappointing results because there is greater incentive for universities to encourage their academic staff to engage in traditional research activities and so academics receive greater rewards from not commercialising their knowledge (e.g. career progression, prestige, etc.) than they do from commercialising it (e.g. royalty payments).

Conclusion

Starting with the notion of the academic knowledge spillover as a driver of innovation in the regional economy, this section has sought to delve deeper into the idea of the knowledge spillover and to examine whether it provides a concept useful to understanding how universities may contribute to regional development. However, a number of flaws in the conceptualisation and empirical study of the knowledge spillover have been revealed. Specifically, knowledge spillovers are often confused with rent spillovers because university knowledge is assumed to be a public good, whereas it has the characteristics of club good or sometimes even a private good. Furthermore, the conception of knowledge in the knowledge spillover does not sufficiently acknowledge its dynamic and human nature, hiding the ways it is translated and transformed as it flows. Such translation and transformation often requires lengthy collaboration between academia and firms, which generally require some form of formal and market mediated agreement. While it should not be denied that pure knowledge spillovers can occur, they are perhaps less likely than many studies assume.

However, looking beyond spillovers, the associated notions of tacit knowledge, labour mobility and social networks are still at work in the commercial links formed between universities and firms. Indeed there is often a blurring between commercial links and informal links because informal links, usually considered sources of pure knowledge spillovers, may develop into commercial links. Both types of links may lead to increased innovation and contribute to regional development.

Looking at outside factors influencing whether such links develop, we find that most universities in the UK, especially former polytechnics, express considerable enthusiasm for contributing to regional development. However, this enthusiasm is not always translated into practical action. Where links develop a number of factors come into play, including an entrepreneurial spirit in the university and surrounding area and a favourable physical environment. While a university in a peripheral region with no other universities present often contributes significantly to its region, in core regions and peripheral regions with more than one university contribution is often held back by competition with other institutions and concerns about academic hierarchy. Furthermore, policies aimed at promoting commercialisation and interaction are often hampered by short term funding and the tension between a university's drive to international excellence and regional relevance.

Social capital

Strong relationships between institutions within a region, it is believed, create greater innovative capacity (Kaufman and Todtling, 2000) which in turn enhance corporate and regional competitiveness (Hayter, 1996). For this reason the social relations present in economically successful regions have taken a prominent place in the literature (e.g Asheim and Cooke, 1999; Cooke, 2002; Keeble et al, 1999; Maillat et al 1994; Oinas and Malecki, 1999; Saxenian, 1991; Storper, 1997). Particularly important are relations between institutions characterised by trust, shared norms, values and expectations, and, more generally, a collective sense of belonging and mutual investment, which favour future cooperation and dialogue while reducing the benefits of exploitative opportunism. Such relations are more likely to develop in the region due to the proximity of actors with a shared history, education system and policies (Cooke et al, 1997), and can contribute significantly to the economic development of the region by allowing the organisations in a region, such as firms, business support services, universities and other public bodies, to share knowledge and ideas through cooperation (Cooke, 2002). These relations have been conceptualised as a type of non-economic capital possessed by regional actors, known as social capital, and have been identified as an important factor facilitating knowledge sharing between both individuals and organisations (Inkpen and Tsang, 2005; Levin and Cross, 2004). The development of social capital between culturally diverse groups is thought to enable them to work together (O'Brien, 2005) which makes the concept particularly relevant to the subject of university – industry relations. However, the role of social capital in bridging university–industry boundaries has not been widely explored (Murray, 2004). In this section, therefore, the concept of social capital is defined and applied it to the issue of university – industry interaction.

Defining Social Capital

The definition of social capital has been hotly debated in the literature. It has been described as a fuzzy concept due to the great number of competing and ambiguous definitions of the term abounding in the literature (Markusen, 1999). Given the conceptual vagueness surrounding the use of this term, it is helpful to unpick the origins and evolution of the term, in order to find the most precise and useful definition in order to apply this concept to university – industry relations. Originally used in the early twentieth century by Hanifan (1916), the concept of social capital lay dormant for many years in academic libraries, only surfacing every now and then for a low key appearance in the social science literature (see Seely et al (1956), Homans (1961) and Loury (1977)). This remained the case until the 1990s, when, according to Sabatini (2006), it became extremely popular (e.g. Putnam, 1993; Portes, 1998). Since this reawakening, the concept has diffused throughout many social science disciplines including business and management studies (e.g. Murray, 2004; Inkpen and Tsang, 2005), economics (both mainstream and heterodox: see, for example, van Staveren, 2002; Durlauf and Fafchamps, 2004), development studies (e.g. Sabatini, 2006), education (e.g. McClenaghan, 2000; Bailey, 2005), political science (e.g. Putnam, 1993) and geography (e.g. Amin, 2004; Mohan and Mohan, 2002). It has also been embraced enthusiastically by international regulatory institutions such as the World Bank and the International Monetary Fund (Paldam, 2000). During the course of its travels social capital has undergone a series of curious metamorphoses and has been put to work in several different ways. This section looks at how the concept has changed as it has moved through different intellectual spaces and the different jobs it has done for those who have used it. Finally, it considers how useful the concept is as a tool for understanding the ways in which economies work, with particular reference to the sphere of economic geography.

Social Capital and Metaphysics

Early proponents of the term social capital, such as Hanifan (1916), Seely et al, (1956), Homans (1961) and Loury (1977) use it to 'encapsulate the vitality and significance of community ties' (Sabatini, 2006, page 4). However, the first author to have made a significant impact with his use of the concept is the French sociologist Pierre Bourdieu (1980 / 1986). For Bourdieu (1986) social capital is one of four forms of capital, the others being economic capital, cultural capital and symbolic capital. Economic capital refers to money and property, cultural capital is understood as different types of legitimate knowledge (for example, of music or food) and symbolic capital is understood as social honour and prestige (Jenkins, 1992). Social capital, on the other hand, is understood as:

> the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalised relationships of mutual acquaintance and recognition – or in other words, to membership of a group – which provides each of its members with the backing of the collectively owned capital, a "credential" which entitles them to credit, in the various senses of the word.
>
> (Bourdieu, 1986, pages 248-249)

Social capital therefore consists of two elements: social relationships that allow individuals access to the resources possessed by their associates, and the quantity and quality of these resources (Portes, 1998). Economic capital is at the root of the other forms of capital, but they are not entirely reducible to economic capital, in that social, cultural and symbolic capital, like economic capital, allow their possessors access to goods and services that they would not otherwise have but with secondary costs, such as, in the case of social capital, time invested in building relationships (Bourdieu, 1986). Transactions involving non-economic capital, such as appointment of an individual with high social capital to a prestigious role, tend to be characterised by greater uncertainty than those involving economic capital, so transactions using social capital often involve unstipulated obligations between related individuals and lengthy periods of investment that may never show any returns. The uncertainty and lack of transparency seen in these transactions disguise their essentially economic nature, that is, that the outcomes of the possession of social or cultural capital are reducible to economic capital (Portes, 1998).

Social capital is one of the many concepts that Bourdieu draws on to understand society in a way that attempts to overcome the metaphysical opposition between objectivism and subjectivism, and the related oppositions of freewill versus determinism and structure versus agency (Bourdieu, 1988; Siisiainen, 2000). The networks that in part compose social capital are generally based on 'an affinity of habitus' (Bourdieu, 1988, page 150), habitus being 'an acquired system of generative schemes objectively adjusted to the particular conditions in which it is constituted' (Bourdieu, 1977, page 95). It is this concept of habitus that does the job of bridging the gap between structure and agency. Arising from practice, it cannot be reduced to structure, but neither does it allow the individual's actions to be purely governed by rational, calculative choice (Siisianen, 2000). The habitus means that the actions of individuals are neither wholly conscious nor wholly unconscious but the product of lifelong learning processes that mean individuals know the appropriate thing to do in given circumstances without detailed analysis and reflection. A habitus can act in different social fields and the practices it produces are dependent on the context in which it operates. The concept of the social field is also linked to the idea of capital given that it can be understood as:

> a structured system of social positions – occupied either by individuals or institutions – the nature of which defines the situation for their occupants. It is also a system of forces which exist between these positions; a field is structured internally in terms of power relations. Positions stand in relationships of domination, subordination or equivalence (homology) to each other by virtue of

> the access they afford to the goods or resources (capital) which are at stake in the field.
>
> (Jenkins, 1992, page 85)

For Bourdieu the concept of social capital was important in explaining inequality of opportunity. Groups of people with similar positions in a social field make up social classes, so clearly social capital is implicated as one of the elements at work in the construction and maintenance of social inequalities, keeping the poor and dominated classes in subordinate positions and preserving the advantages of the rich and dominant classes. This recognition that social capital has negative effects for some members of society, though it has positive effects for others, is in contrast to some later conceptions where social capital becomes as universal panacea for all social ills. However, although Bourdieu's account of social capital is conceptually sophisticated, the theoretical framework in which it is embedded has been questioned. Specifically, Jenkins (1992) suggests that despite his best efforts, Bourdieu fails to avoid determinism as his theory cannot account for social change without some sort of external influence to alter the habitus. He accuses Bourdieu of possessing an over-socialised conception of human action; that is, one where human action is determined by social structure in the form of norms, customs and habits leaving no room for rational choice.

Parallels with Bourdieu's ongoing metaphysical project can be seen in the work of the American sociologists, Mark Granovetter and James Coleman. Despite the fact that Granovetter (1973) does not use the term 'social capital', his concept of 'the strength of weak ties' has been interpreted as a theory of social capital by later authors (for example, see Burt, 2001; Iyer et al, 2005; Sabatini, 2006; Tura and Harmaakorpi, 2005) and, insomuch as the strength of weak ties is the ability they give to an individual to access resources due to their membership of a network, it does appear to be a form of capital similar to Bourdieu's social capital. Granovetter (1973) argues that a weak tie between two individuals in two separate groups of people with strong ties to other members of their group can act as a bridge between the two groups, allowing information to diffuse from one group to another. For example, in a study of middle-class people who had found a new job through a personal contact, Grannovetter (1973) found that the majority of these contacts were only seen occasionally by the jobseeker and were described as acquaintances rather than as friends. Nevertheless, the majority of these acquaintances were part of a wider network consisting of the jobseeker, his or her contacts and their contacts. He proposes that people are more likely to find jobs through weak ties rather than strong ties because contacts that usually move in different circles from the jobseeker are more likely to have access to different information than contacts that move in the same circles as the jobseeker. That the contact and the jobseeker are members of the same network is important, however, because the contact is able to exert influence on behalf of the jobseeker. Thus, for Granovetter (1973, page 1373) 'weak ties are an important resource in making possible mobility opportunity'. In Granovetter's (1973) discussion of the strength of weak ties it is possible to see the seeds of his later development of the concept of 'embeddedness' (Granovetter, 1985), which he uses in an attempt to the overcome structure versus agency / determinism versus freewill opposition in economic theory, or as he terms it, the opposition between over-socialised and under-socialised conceptions of human actions. Granovetter (1985) argues that classical and neo-classical economics traditionally assume under-socialised conceptions of human behaviour in which actors pursue only their self-interest, unaffected by social structure – perfect competition is only possible where there are no social relations between actors – but when they do take social relations into account they generally do so with an over-socialised conception of human action. In both under-socialised and over-socialised conceptions, social relations actually end up having minimal impact on human action; in the under-socialised case, because actors only pursue what is good for them, and in the over-socialised case, because behaviour is governed by internalised rules. Granovetter (1973) notes that if a jobseeker finds out about a job through a lengthy chain of intermediaries, he or she is one of many people who finds out about the job, and no influence on behalf of the jobseeker is exerted, so no particular tie is crucial to getting the job. This model of job-information flow corresponds to 'the economists' model of a "perfect" labour market' (Granovetter, 1973, page 1372) which ignores any effects of social relations. The more common scenario identified by Granovetter (1973), in which the effects of social relations are clear, refutes this under-socialised view. In his conclusion that 'the personal experience of individuals is closely bound up with larger-scale aspects of social structure, well beyond the purview or control of particular individuals' (Granovetter, 1973, page 1377) the origins of the concept of embeddednes are clear. His later development of the concept seeks to overcome the problems associated with taking an under-socialised or over-socialised view of human action by suggesting that actors' 'attempts at purposive action are instead embedded in concrete, ongoing systems of social relations' (Granovetter, 1985, page 487).

With his emphasis on conceptions of human action in classical and neo-classical economics, Granovetter (1985) is essentially attempting to introduce the idea that social structure can have an independent effect on how economic systems function (Coleman, 1988) while maintaining the notion of rational agency. In contrast to this project, Coleman (1988) attempts to insert a principle of rational agency into the analysis of social structure. His concept of social capital is used to advance this aim. Coleman (1988, page S98) starts with a theory of rational action, assuming that 'each actor has control over certain resources and events'. Social capital thus becomes 'particular kind of resource available to an actor' (Coleman 1988, page S98). He goes on to define social capital as a concept which:

> identifies certain aspects of social structure by their functions, just as the concept "chair" identifies certain physical objects by their function, despite differences in form, appearance, and construction. The function identified by the concept "social capital" is the value of these aspects of social structure to actors as resources that they can use to achieve their interests.
>
> (Coleman, 1988, page S101)

Coleman (1988, page S119) proposes three forms of social capital. First there are obligations and expectations that are dependent on the trustworthiness of the social environment, whilst the second and third forms are 'information-flow capability of the social structure, and norms accompanied by sanctions'. Notable here is the introduction of the idea of trust as related to social capital; trust has no place in Bourdieu's (1986) theory. For the first and last forms of social capital to emerge, Coleman (1988) suggests, in complete opposition to Granovetter's (1973) emphasis of weak ties, that closed social networks must be present, i.e. actors in the network must all know each other. In a closed network an actor who harms others can be collectively sanctioned: something not possible if those harmed do not know each other. This allows the development of trustworthiness and norms. He suggests that social capital is usually a public good, i.e. it benefits other individuals as well as the ones who produce it, and so of the total benefits produced, the producer only accrues a small part. Hence, social capital can be a property of groups as well as individuals. For example, if we take trustworthiness as a type of social capital, then according to Coleman (1988), a person chooses not to betray the trust of others because the benefits he or she receives from behaving in this way outweigh the costs of not taking advantage of them. The other people's actions will be facilitated by their confidence in their associate, but this outcome does not enter into the associate's decision to remain trustworthy or not, unless these actions have some benefit or cost for the associate. If he or she ceases to accrue benefits from being trustworthy and thus ceases to be trustworthy, the fact that this will inhibit the actions of others will not enter into the decision. Thus, Coleman (1988) perceives a disincentive to invest in social capital since the main benefits from investment may go to someone who is not the investor. This situation is a result of his assumptions of purely self-interested, rational action from which a structure is derived that does not allow for possible benefits of uncertainty, and a circularity present in his conception of social capital. This circularity arises because for Coleman (1988) processes that generate social capital (group enforcement of norms and obligations), consequences of possessing social capital (access to information not available without certain social relations) and the social organisation that allows the generation of social capital and the effects of social capital to arise are all types of social capital. Thus, unlike Bourdieu (1986), Coleman (1988) does not distinguish between the results of possessing social capital from social capital itself. So, for example, trustworthiness can be social capital for one actor because it helps him or her attract more customers to his or her business, but are not for another actor because it does not help him or her to attract more customers to his or her business. The problem then arises that the cause of an actor's business success is only identifiable by its effects, effectively meaning that the argument that possession of social capital leads to benefits for the possessor is trivially true (Lin, 1999; Portes, 1998). Despite this flaw, Coleman's

(1988) work has been extremely influential on later work that makes use of the concept, as will be seen below.

Social capital and neo-social Darwinism

In the conceptual frameworks of later work on social capital the attempt to reconcile the metaphysical opposition of objectivism and subjectivism, conceived variously as structure versus agency, freewill versus determinism, and under-socialisation versus over-socialisation, vanishes as an explicit aim. Instead it is replaced by attempts to reconcile a perceived opposition between competing sources of social capital, these being weak ties between groups and network closure within groups. Essentially there is a turn from the creation of meta-theory that explains human action in which social capital is but one concept, to the development of a theory of social capital within an assumed ontological framework. This might partly be the result of the introduction of post-modern and post-structuralist theory, which are characterised by an absence of meta-narrative, into social science disciplines, but also reflects social capital's entry into policy relevant research where social capital is utilised as a tool for generating social change. In this sphere the generation and measurement of social capital are of primary concern. Burt (2001) is a prime example of the former concern. This work has links with Granovetter (1973) and Coleman (1988), attempting to show how both forms of organisation, weak ties and network closure, are sources of social capital, which he sees as a metaphor for social structure that is similar to economic or human capital in that it creates a competitive advantage for individuals and groups. Because Burt (2001) sees social capital as a metaphor his conceptualisation of the term becomes extremely problematic. This is because if we say a tiger is a metaphor for a man, then the man is not actually a tiger, though he has characteristics similar to a tiger; ergo, if we say social capital is a metaphor for social structure with similar characteristics to economic or human capital, then it is not this type of social structure though it has characteristics similar to this type of social structure. Saying social capital is like a form of social structure but is not this form of social structure does not tell us what social capital actually is. If, on the other hand, Burt (2001) means that social structure can have characteristics similar to economic or human capital, and we can name this type of social structure 'social capital', but it is not economic or human capital, then economic and human capital can be a metaphor for this type of social structure, but social capital cannot. Despite a poor conceptualisation of the term, Burt (2001) reconciles the two apparently competing sources of social capital by reviewing a number of empirical studies. He concludes that cohesive teams within firms that also have weaker ties with other groups are likely to be the most successful, a result that leads him to argue that links between fragmented groups of people – which he describes as brokerage across structural holes in a network – are a source of value for the groups, but in order to realise this value, cohesion within the groups is necessary, i.e. network closure must be present, that is, people within the groups must all have ties with each other.

Putnam (2000) terms weak ties 'bridging social capital' and network closure 'bonding social capital' and comes to rather different conclusions about their integration. For Putnam, social capital is essentially a property of groups and he defines social capital as:

> features of social organisations, such as networks, norms and trust, that facilitate and cooperation for mutual benefit. Working together is easier in a community blessed with a substantial stock of social capital.
>
> Putnam (1993, pages 35-36)

He develops the ideas of bonding and bridging social capital in response to criticism that his earlier work on social capital, in which he argues a decline in American civil society has led to a decline in the USA's stock of social capital, does not allow for the possibility of its negative effects (Leonard, 2004). Thus bonding social capital is a property of homogenous groups and generally only benefits those within the group; those outside the group are excluded. The tights bonds of trust, obligation and reciprocity within homogenous groups can restrict the adoption and sharing of new knowledge, preventing innovation and beneficial change in the group. Bridging social capital is a more inclusive in its benefits as it allows information to flow between groups of people. Putnam (2000) equates the presence of bridging social capital in a community with the presence of civil society, conceived of as membership of voluntary organisations such as sports clubs, rotary clubs, parent–teacher associations and so forth. He suggests that it has great potential for generating economic prosperity by paving the way for the acquisition of economic and human capital. For him, social capital is particularly important in deprived communities where it can mitigate a lack of economic and human capital, for instance by providing informal employment opportunities. However, it is these communities that most lack social capital (Leonard, 2004). There is a rather alarming outcome of this argument which has been developed by a number of authors; it points to a form of neo-social Darwinism. As Adam and Roncevic (2003, page 147) put it:

> [e]conomic prosperity is considered to be an expression of the dynamism and creativity as well as the moral consistency of a democratic civil society. There exist numerous sources of social capital; however, the bearers of social capital are first and foremost active citizens. In other words, social capital is the capital of active (and altruistic) citizens.

Thus, the rich become rich because of their superior qualities; the poor are poor because they lack these qualities. In essence the rich deserve to be rich and the poor deserve to be poor. The responsibility for accumulating social capital, from which economic and human capital can be gained, is delegated to the masses as an activity to be performed in their leisure time, as opposed to resting with the government or the corporate world, though governmental and corporate polices might well be to blame for any alleged decline in civil society in the first place (Portes, 1998).

Furthermore, social capital is also used as a tool in order to justify women's unequal position in society. The alleged decline in social capital is blamed on women's increasing participation in the paid labour market: since they also still perform the majority of unpaid labour in the home this leaves them with less time to take part in civil society (van Staveren, 2003). Fukuyama (1997) goes as far as to suggest that men and women have competing reproductive strategies, which were traditionally reconciled through an exchange of fertility (controlled by women) for economic resources (controlled by men). This reconciliation has been broken down by women's ability to control their fertility and their subsequent increased participation in paid work, leading to a more tenuous link between men and their children, and thus to family breakdown, which also causes a decline in social capital. Implicit in such ideas is that society would benefit if women remain economically subordinate to men (van Staveren, 2003).

The conceptual framework behind the notion of social capital at work in such theories is not without its problems. Like Coleman's (1988) definition, Putnam et al's (1993) definition of social capital has been accused of circularity. As Portes (1998, page 19) puts it:

> As a property of communities and nations rather than individuals, social capital is simultaneously a cause and an effect. It leads to

> positive outcomes, such as economic development and less crime, and its existence is inferred from the same outcomes. Cities that are well governed and moving ahead economically do so because they have high social capital; poorer cities lack this civic virtue.

Putnam's (2000) new and improved interpretation of social capital that takes into account the differences between bonding (generally equated with negative effects) and bridging social capital (generally equated with positive effects) has also come under attack. Leonard (2004) argues that Putnam (2000) fails to recognise the inequalities present within communities possessing bonding capital, looking at such communities as homogeneous entities. Her research, on the other hand, shows that individuals, particularly men, only perform favours for people they felt would be able to repay with a similar favour at an unspecified later date. Those unable to reciprocate favours are excluded from such networks. For Putnam (2000), the problem with communities possessing strong bonding social capital is their relative inability to form relationships with other communities or networks. Leonard (2004) suggests instead that inequalities within communities that posses bonding social capital are reproduced if there is any transition to bridging social capital, so both types of social capital tend to benefit individuals rather than communities. This is because individuals who managed to develop bridging social capital from bonding social capital end up excluding their local community from their networks. For instance, she finds that individuals from deprived areas of Belfast who start successful formal businesses based on the informal transactions they had carried out within their local community had to charge high prices that excluded their local community in order to pay for the overheads of running a formal business and this meant expanding into wealthier communities. Furthermore:

> In general, Putnam neglects the role of the state in creating the conditions that facilitate the development of social capital. He tends to see the bridging links between communities exhibiting social

> capital and the state as occurring in a linear fashion, inward to outward. Hence, his analysis makes much of the relationship between strong community networks and subsequent political behaviour. Despite his emphasis on reciprocity, he does not envisage these links as emanating in both directions.
>
> (Leonard, 2004, page 941)

Despite these criticisms, Putnam's idea of social capital has been influential, promising as it does prosperous and happy communities. Because social capital, particularly bridging social capital, has been associated with societal benefits there has been much work on measuring the amount of social capital in communities, relating the amount of social capital to economic growth and comparing amounts of social capital in different places.

Measuring social capital and missing the point

Measuring social capital is not easy, especially as the many definitions of social capital make it unclear what is being measured. Fukuyama (1999) identifies two popular methods. The first, used most notably by Putnam (e.g. Putnam (1995) but see also O'Brien et al (2005)), is to count the number of groups and group membership in civil society. However, counting such groups has proved difficult, and Portes (1998) criticises Putnam (1995) for the type of groups chosen. Furthermore, Fukuyama (1999) suggests it would be necessary to take into account factors that are difficult to quantify such as cohesion of the groups and how they relate to other groups in order to accurately measure social capital. The second method of measurement is to use survey data where indicators such as trust and civic engagement are utilised as proxies for social capital within the survey population, and had been widely employed (see, for example, Paldam, 2000; Reagans and Zuckerman, 2001; Beugelsdijk and van Schaik, 2005; Cooke et al, 2005; Iyer et al, 2005). The central problem with this approach is that there are no agreed upon indicators for social capital. Sabatini (2006) suggests that use of indirect indicators such as blood donation, voting turnout and teenage pregnancy leads researchers to confuse what social capital is with its outcomes, again producing circular arguments regarding the effects of social capital within a community. Other authors, such as Beugelsdijk and van Schaik (2005), identify trust and group membership as key components of social capital and use these as direct indicators. Tura and Harmaakorpi (2005, page 1115) reject this approach, suggesting that 'a person's social networks as well as the overall trust of a community are different, but equally relevant, *sources* of social capital and are not social capital as such'. Even if trust is accepted as an indicator of social capital, as Sabatini (2006, page 11) points out:

> Trust measured through surveys is a "micro" and a "cognitive" concept, in that it represents the individuals' perception of their social environment, related to the particular position that interviewed people occupy in the social structure. The aggregation of such data, however, creates a measure of what can be called "macro" or "social trust" which looses its linkage with the social and historical circumstances in which trust and social capital are located.

Essentially then, social capital is context dependent, which means the type of approach that aggregates survey data removes the "social" from social capital (Amin, 2006) and in doing so arguably misses the point of the concept. If social capital is linked to the social and historical circumstances in which it occurs, then social capital that is useful in one situation may be useless in another. For example, a scientist's considerable accumulation of social capital within academia may not translate to the business world. If this is the case a more pertinent question to ask is not how much social capital there is, but how social capital enhances actors' capacities to act or to access resources (Tura and Harmaakorpi, 2005). It is in this area where economic geography attempts to make a particular contribution.

Social Capital and Economic Geography

Social capital appears in several areas of economic geography literature (widely construed), particularly that focussing on regional economies. In such discussions we see a movement of focus from individuals, communities and civic society within cities as discussed above to regions, industries, firms and related organisations. Social capital is one of several concepts, and by no means the most frequently used, utilised to illuminate the workings of social relations present in economically successful regions and the ways in which they enhance innovation and economic growth (see, for example, Asheim and Cooke, 1999; Cooke, 2002; Keeble et al, 1999; Maillat et al 1994; Oinas and Malecki, 1999; Saxenian,1994; Storper,1997). Amin (2004, page 56) develops Putnam's conception of social capital to suggest that European regions with highly developed social capital are regions where society has been 'brought back into the art of governance' with social capital helping to secure economic benefits such as efficient public services, civic autonomy in social and economic life, an economics of association facilitated by reciprocity and trust, cost containment of social breakdown and conflict, and economic innovation and creativity based on social confidence and capability. More specifically, Garnsey and Heffernan (2005) suggest that social capital formation in the Cambridgeshire region has been facilitated by and contributed to local networking, and that it provides 'a store of mutual knowledge and trust that can overcome the intermittency of interactions and job turnover' (Garnsey and Heffernan, 2005, page 1139). They suggest that social capital is essentially non-tradable and stored locally, two characteristics that lead high-tech companies possessing social capital to become embedded in an area, even when they are part of global markets.

However, despite such attempts to theorise the workings of social capital much of the literature in which the concept appears is typified by a vague definition and conceptualisation of the term. For example, Cooke (2002, page 7) describes social capital as 'extra value gained from interactions with familiar, trusted networks of acquaintances' while Gertler (2000, page 746) identifies social capital as 'those characteristics of social structure or social relations that facilitate collaborative action, and, as a result, enhance economic performance'. Neither definition is particularly helpful for the researcher who wishes to operationalise the concept in the field or to work with it theoretically. Cooke (2002) does not make clear whether the extra value that he labels social capital is extra (surplus) value in Marx's sense of the word, nor how this value is produced. Gertler's (2000) definition again suffers from the disadvantage of identifying social capital with its effects, leading to circularity. This vagueness in defining social capital is so common that Markusen (1999, page 878) claims that she has 'yet to read an account of it...which distinguishes whether it is a stock or a flow concept or how it is produced and accumulated (since it is an analogue to physical capital)'. Vague definitions of the term 'social capital' result in ambiguous usage of the term and yet again conflation of the concept with its possible outcomes such as 'trust' and 'networks'. To add to the general confusion, the usage of the term 'social capital' overlaps with the usage of a number of other terms used to denote associated but non-identical phenomena, including 'untraded independencies', 'institutional thickness' and 'embeddedness'. The first term refers to 'the technological externalities that become a collective regional asset for the firms involved' (Oinas and Malecki, 1999, page 18). As described by Storper (1997, page 43) they are bound up with relations and conventions that 'have cognitive, informational, and psychological and cultural foundations'. Relations between organisations are shaped by conventions and may be understood in terms of the way they give or deny access to different kinds of action, a description that is very close to Bourdieu's (1986) version of social capital, except for the fact that it is a property of organisations and not individuals. The relations that are the source of untraded interdependencies underlie the coordination of organisations in a system and can make them more innovative and economically efficient. Oinas and Malecki (1999) equate the concept of untraded interdependencies and their associated conventions with that of institutional thickness. They define institutional thickness as 'specific characteristics of the social relations (in total) in which actors are embedded' (Oinas and Malecki, 1999, page 16). Institutional thickness is characterised by:

> - a strong presence of a variety sorts of organisations [sic]…;
> - high levels of interaction amongst the various organisations in a local area;
> - sharply defined structures of domination and/or patterns of coalition resulting in both the collective representation of what are normally sectional and individual interests, and the socialisation of costs and the control of rogue behaviour;
> - a mutual awareness that they are involved in a common enterprise.
>
> (Oinas and Malecki, 1999, page 17)

The interaction of different types of organisations in this definition is suggestive of Putnam's (2000) bridging social capital, while the collective representation of interests, control of rogue behaviour and awareness of common enterprise, is not unlike Coleman's (1988) network closure or Putnam's bonding social capital. In this sense institutional thickness can be seen as a concept which reconciles aspects of bonding and bridging social capital within the theoretical framework of the regional economy. Oinas and Malecki (1999, page 16) also suggest that the concept of institutional thickness is 'highly related' to that of embeddedness, 'if not the same'. Their conceptualisation of embeddedness is rather different from that of Granovetter's (1985) as they define embeddedness as 'structures of network relations of economic actors' (Oinas and Malecki, 1999, page 15), and seek to differentiate it from institutional thickness by arguing that it 'refers to the *nature of the relation to the total set of relations* from individual actors' points of view' (Oinas and Malecki, 1999, page 16, emphasis original). The unfortunate effect of this proliferation of seemingly interrelated terms is to leave the reader of such literature swimming through a kind of theoretical soup, which obscures rather than illuminates the ways in which social and economic relations are bound together.

However, despite the presence of many overlapping terms, some authors have worked to declutter the conceptual landscape of regional economic thinking. An example is Tura and Harmaakorpi's (2005) definition of social capital, which is based on their resource-based interpretation of the concept. They describe social capital in the following way:

> ...a social relation between *a* and *b*, *R*(*a*, *b*), is part of *a*'s social capital if and only if *a* has such action opportunities, or access to such resources, he/she would not have without the relation *R*(*a*, *b*)
>
> (Tura and Harmaakorpi, 2005, page 1116).

Thus, for Tura and Harmaakorpi (2005) trust, shared values, norms and expectations are *sources of* social capital if they are part of the social mechanism that links an actor's social relation with action opportunities or resources that he / she / they would not otherwise have had, but are not social capital in *itself.* For example, if I become a member of a club and as a result come to be trusted by other members of the club, which in turn leads to business opportunities that I would not otherwise have been offered, then my relations with other members of the club are part of my social capital, and the trust invested in me by my fellow club members is the source of this social capital. The resource-based view of social capital allows both individuals and collective actors to be in possession of social capital, but it cannot be produced or used by the individual alone. Furthermore, this view suggests that social capital is context dependent: it may be useful in one field of activity, but not in another. Tura and Harmaakorpi (2005) apply their conception of social capital to the regional economy in the following way. For innovation to occur in a regional economy the correct balance between bonding and bridging social capital is required. Diversity in 'cross-field connections' (Tura and Harmaakorpi, 2005, page 1120), which refer to any type of interconnection between different fields of social capital, is also needed. Cross-field interconnections can become a source of bridging social capital that allows actors in a region to exploit the resources of the different fields such as business networks, leisure activity groups, religious groups, public sector bodies and, most importantly for the purposes of this thesis, academia. Tura and Harmaakorpi (2005) do not discuss how the relations which make up social capital evolve so their definition could be considered somewhat static. However, the clarity of thinking in Tura and Harmaakorpi's (2005) discussion of social capital offers at least some hope for researchers hoping to make sense of the relationship between the social and the economic, and this definition is adopted in this thesis.

Using social capital

The concept of social capital, then, exists in many forms across the social sciences, from Bourdieu's (1986) essentially Marxist theorisation to Fukuyama's conservative interpretation. It is also does many jobs, going from being a tool in the reconciliation of metaphysical oppositions in early work by Bourdieu, Granovetter and Coleman, to a means justifying an oppressive status quo and an indicator for the wellbeing of communities. While some authors might argue that such a fuzzy concept has little explanatory value (Adam and Roncevic, 2003; Markusen, 1999) it nevertheless has become popular in the social sciences, leading Adam and Roncevic (2003) to suggest one of the concept's main benefits is to allow interdisciplinary and inter-organisational dialogue, although as this discussion has shown, this point of view may be somewhat optimistic given that the actors might well be speaking different languages. An optimist might also hope that the spread of the concept of social capital to the dominions of traditional economic thinking, such as orthodox economics and the World Bank, might introduce a little humanity into their worldviews (Paldram, 2000). Perhaps part of social capital's enduring popularity, despite the conceptual problems it faces, is that it *can* be all things to all people. However, with a little more clarity of thinking social capital could be usefully employed in economic geography, because as Tura and Harmaakorpi (2005, page 1116) point out:

> one needs a concept to clarify the social element of [economic] success and its differences between individuals, companies, communities, regions and countries. This is where the concept of social capital seems most promising.

Social capital and university-industry relations

Several authors suggest that social capital facilitates the development of university links. Dietz and Bozeman's (2005, page 363) study of the careers of scientists in US university research centres finds that 'those scientists who have spent a substantial percentage of their careers in industry jobs have more funding from industry and a higher rate of patent productivity'. They suggest that 'this may be due, at least in part, to the trust and social capital required for commercial activity' (Dietz and Bozeman, 2005, page 363). Carayannis et al (2000) examine government–university–industry R&D partnerships in the USA, Germany and France. They argue that '[t]he emergence of collaboration is facilitated by the sharing of knowledge across organisational boundaries, which promotes the formation of trusted relationships and builds social capital for further cooperation' (Carayannis et al, 2000, page 477).

Murray (2004) studies the role of academic inventors in US biotechnology spin-out firms. She finds that the academic inventor 'exploits his social capital (network) to build relationships between members of his social network and the firm' (Murray, 2004, page 656). Two elements are found to make up this social capital – 'the first is a *local laboratory network* that is shaped by the specific career experiences of the inventor training in different laboratories and building his [sic] own laboratory; the second is a cosmopolitan network of widely dispersed peers within his [sic] field who many constitute the invisible college of the discipline' (Murray, 2004, page 656). The firm draws on the local laboratory network as a source of on-going expertise and possible members of its scientific advisory board. The cosmopolitan network is used to embed the firm into broader scientific networks and to tap into them for specific expertise for particular goals. The inventor is used in order to form a link between the firm and the scientist the firm wishes to work with. Alternatively, the scientist may be asked to join the firm's scientific advisory committee.

Cooke (2002, page 7) argues that social capital plays a role in cluster building activities involving university – industry collaboration, because 'start-up firms benefit from proximity to a knowledge centre that is familiar to their founders as an academic community, with all the networking opportunities and inherited social capital implied by that', although Murray (2004) points out that such social capital may be lost if academic inventors do not maintain links with such companies. Cooke (2002, page 7) believes that both universities and corporations will 'benefit from interactions around research commercialisation'. These benefits come in both economic form and in the form of collective learning, which in turn leads to greater economic benefits. Collective learning requires pronounced trust between economic and social actors. Without trust secrecy prevails, and if organisations do not share knowledge they cannot learn from each other. Trust and learning can reinforce each other leading to a more efficient and effective use of resources. Trust, of course, is one of the sources of social capital. Trust and its associated social capital need not be initially present in the economic sphere but can form in this sphere through their original presence in the cultural sphere. This formation of trust and social capital occurs because people use their experience of making use of their many and various associations in the cultural sphere when taking part in the economic sphere. For Cooke (2002) then, trust is particularly important to social capital. His analysis of trust is heavily reliant on the work of Sako (1992). She breaks down trust into three categories: contractual trust, competence trust and goodwill trust. Contractual trust involves the keeping of oral or written promises, competence trust involves confidence that a supplier will do its job properly and goodwill trust involves mutual expectations of commitment to a relationship. Sako (1992) argues that contractual and competence trust are essential for goodwill trust, though Cooke disagrees with this. His argument is that goodwill trust can exist alone. As an example he uses the collapse of Barings' Bank. This, Cooke (2002) claims, was caused by the bank having excessive goodwill trust in an employee who was not doing his job competently nor doing what he was supposed to be doing. However, this critique is not entirely convincing since the goodwill trust of the bank was originally built on contractual and competence trust that the employee eventually betrayed.

Relational capital and university-industry relations

Maillat et al (1994) use the term 'relational capital' to refer to lasting relations existing between economic players in a network, which are necessary for innovation. These relations 'are not exclusively economic or industrial in nature' (page 35) but can be professional (e.g. from belonging to a professional association) or purely social. They involve reciprocal trust and mutual acquaintance. This description thus is very close to many authors' understanding of social capital, although it is more limited in membership and strategic in orientation. Grimaldi and Grandi (2003), drawing from a study of Italian incubator facilities, suggest that it is one of the assets offered by successful university incubators to their firms, as success facilities allow firms direct access to local economic and political institutions and individual actors.

Maillat et al (1994) themselves analyse relational capital within the context of the 'milieu'. They suggest that between members in a network there are more or less formalised rules that govern appropriation and competition between them. Storper's (1997) analysis of customs and conventions enriches their account. According to Storper (1997), unlike some of the more concrete elements in an economic system such physical capital or codified knowledge these customs and conventions are difficult, slow and expensive to create, and might be impossible to imitate. However, it might be possible to identify types of convention that commonly arise in response to certain practical economic problems.

Customs and conventions govern the technical relations that create a division of labour between different players in the network, with each member having its specific place within it. There are similarly rules of reciprocity, trust, the recognition of services provided between the network as a whole and the milieu, and also a collective feeling of belonging to the same milieu. This allows members of the network to gain not only financial resources, but physical and human ones too, in return to submitting to certain obligations, often non-financial in nature. The innovation networks present in a milieu mean a more efficient organisation structure develops within a region, which includes factors such as greater division of labour, more even distribution of responsibilities and rules governing partnerships. It is this organisation that allows for the creation of new activities. The reciprocal trust and mutual acquaintance are particularly important in the relational capital described by Maillat et al (1994), as these allow network members to become creative and to risk approaches that lead to innovation. This is because reciprocal trust and mutual acquaintance allow new forms of know-how to diffuse throughout the network. Maillat et al's (1994) work suggests that in order to collaborate effectively with industry within a cluster universities also must submit to the rules and obligations governing the industry.

Hagedoorn and Schakenraad (1990) look at relational capital in the context of three technologies that these authors regard as particularly important to the high-tech economy. They explore inter-firm cooperation all over the world between 1980 and 1990 in the biotechnology, IT and new materials industries and find that companies expect to gain a number of benefits from inter-firm relationships, which can be viewed as the accumulation of relational capital. For example, joint ventures are primarily motivated by the desire for expansion and new markets, followed by the desire to reduce the total innovation period and the desire to work with companies with complementary technologies. Other relatively important gains are the ability to influence existing market structures through the formation of a new company, the ability to monitor technological opportunities, the ability to rationalise production, the ability to perform basic research and more financial resources. Similarly, joint

R&D projects have two main motives, these being technological complementarity and reduction of innovation lead time. For IT companies, influencing the market structure is quite important too, while for biotechnology companies it is a lack of financial resources that is another deciding factor in motivating such agreements. For both biotechnology and new materials companies, monitoring of technological opportunities and performing basic research also appear to be important. However, Hagedoorn and Schakenraad (1990) admit that though the literature on cooperation between firms suggests the sharing of costs and risks is a benefit that firm seek to gain from co-operation, this is not a benefit the technologies they are studying rate as significant. This result may be an indication of bias in the data studied but could also be a sign that in the technologies studied long-term objectives are more important. This would support Maillat et al's (1994) suggestion that relationships within an innovative network may often be long lasting. Hagedoorn and Schakenraad (1990, page 14) claim that it is clear 'that in all three core technologies long-term strategic positioning is the major objective of nearly half or over half of the agreements'.

Hagedoorn and Schakenraad's (1990) account of relational capital is relevant to university–industry collaboration because the gains described such as knowledge of basic research, monitoring of technological opportunities and overcoming a lack of resources are ones that could be provided by university-industry collaboration as well as inter-firm collaboration, especially in regions with few highly developed high-tech companies (Cooke, 2002).

Relation Specific Capital and University-Industry Collaboration

Overlapping with the concept of relational capital is the concept of relation specific skill (RSS). Asanuma (1989, page 28) defines this concept as 'the skill required on the part of the supplier to respond efficiently to specific needs of a core firm. Formation of this skill requires that learning through repeated interactions with a particular core firm be added to the basic technological capacity which the supplier has accumulated'. Both relational capital and relation specific skill involve advantages gained through relations between economic players, but with relation specific skill these relations are exclusively economic or industrial and employee-oriented. Relation specific skill could thus be seen as a constituent of relational capital. Patchell and Hayter (1995) examine relation specific skills (RSS) and another related concept, enterprise specific skill (ESS). These concepts were developed by Asanuma (1989) and Koike and Inoki (1990) respectively. For RSS to be maintained it is necessary for each firm to recognise that their long-term development benefits from the on-going collaboration. During interaction firms become tied together by mutual learning, and they can develop both human and physical assets through the exchange of information between each other. Enterprise specific skill (ESS), on the other hand, is an increase in a worker's skill defined as something that contributes to an increase in productivity, while inputs from machinery and quantity of labour remain the same. This enhanced efficiency of labour is down to intellectual ability in breadth and depth gained from experience an on-the-job training, and it can ultimately contribute to RSSs, if suppliers and customers help each other generate skills through the sharing of information and thus assist each other's intellectual development.

Can the notion of RSS be applied to university-industry collaboration? Certainly it seems possible that repeated interactions between a university and a firm could lead to the exchange and accumulation of knowledge and thence to gains in human or physical assets. Exchange of information could enhance intellectual ability within each player (even if they may never admit it), leading to the development of ESS and RSS. However, it is rather difficult to see RSS developing between a whole university, as opposed to a research group or department of the university, and a firm. This is because university research groups and departments tend to function as separate entities and assets gained by one research group or department in a university may even entail loss of assets for another in the same university. Nevertheless, it could be useful in characterising some of what goes on in those universities that enjoy successful long-term collaborative relationships with industry.

Conclusion

As gains made through relations of reciprocal trust and interaction, mutual acquaintance and, more generally, a collective sense of belonging do seem to be important in successful university-industry collaborations (e.g. Brouwer et al, 1999; Gertler et al, 1995; Keeble and Wilkinson, 1999). The concept of social capital and its related concepts of relational capital and relation specific skill can be applied to university-industry relations, suggesting ways in which university-industry relations could be strengthened. The notion of relation specific skill suggests that these gains come about because of the development of human and physical assets in both organisations through mutual learning.

Concluding remarks

As sections one to three have shown, scientific practices and the spaces in which they occur have a history and this will impact on both the formation and nature of relationships between universities and industry. Understanding the conflicts between the internal and external constructions of science, the history of the social and spatial division of labour between the university and industry and the liner model of innovation is therefore essential if we are to comprehend the complex socio-cultural context in which university–industry interaction occurs in the present day. As the discussion of present day university–industry links in section four reveals, this context is an important determinate of universities' contributions to regional innovative capacity. This section argues that such contributions have been narrowly conceived in much of the literature, which tends to focus on knowledge spillovers. There is a need for a more detailed understanding of knowledge flows between universities and firms, focussing on the different types of knowledge flows, how knowledge flows occur and conditions that encourage such flows. Social capital appears to be a useful concept which can be used to address the last concern.

The issue of whether the increasing emphasis on university – industry interaction is 'good' or 'bad' is not covered in this chapter. This issue is under debate by academics in many different disciplines and in many different countries (Adams and Mathieu, 1999; Beesley, 2003; Carayannis et al, 2000; Castree and Sparke, 2000; Cooke, 2002; Demeritt, 2000; Feller, 1990; Freeman, 2000; Gwynn Williams, 1993; Heyman, 2000; Izushi, 2002; Muller, 1995; Roberts, 2000; Schuetze, 2001; Shane, 2002; Siegel, 2003; Smith, 2000; Tilling, 2002; van Geenhuizen, 2003). The commercialisation of the university can be resisted as detrimental to the education and research produced. It has been argued that commercialisation impedes science's advance towards truth and erodes researchers' ability to undertake independent critical standpoints, and serves only to benefit a privileged few. Alternatively it can be welcomed for its role in bringing new research opportunities and economic rejuvenation which benefits all of society (Cooke, 2002; Demeritt, 2000). This is an issue that has been deliberately ignored because such distinctions are constituted by the activities of academics and industrialists and therefore it seems inappropriate to use them to understand their activities (Latour and Woolgar, 1986). Rather, the thesis considers these and the other forces examined as they affect the processes of knowledge flow from one space to another.

Chapter 3

Studying knowledge relationships from both ends: developing and implementing a novel methodology

Drawing on recent debates concerning the commercialisation of public science, the role of higher education institutions in regional development and the existence of academic knowledge spillovers, the central aim of this project was:

- To understand the processes through which knowledge is transferred, transformed and translated from the space of academic science to that of industry within peripheral regions, using evidence from Wales.

In order to achieve this aim, four questions were identified which are rooted theoretically in the broader social science literature on university – industry interaction.

1) How are the links between university research and industrial R&D forged? In particular, what is the role of social capital in building and maintaining such links, and in easing the process of knowledge transfer, translation and transformation?
2) What is the function of university and industrial R&D in these relationships? In particular, how are the functions of university and industrial R&D governed by a spatial division of scientific labour and how does this affect the transfer and translation of knowledge across spaces?
3) How do differing discourses and perceptions of the world within academia and industry influence relationships between the two? In particular, how does knowledge change as it passes into different spaces?

4) What are the implications of university–industry interaction for regional economic development in the Welsh context?

To answer these questions it was necessary to operationalise them and to decide upon the most appropriate methods with which to approach them. The processes through which this was achieved make up the first section of the chapter. This section covers two issues. Firstly, lessons are drawn from how other studies have approached similar questions and the methodological implications that such studies have for the project in hand. Secondly, this section covers the research tradition within which the current project is located and describes how the techniques associated with this tradition are suited to achieving its aim. The second section describes the processes undertaken in order to carry out the research, including who was researched in the project, the sources of data, methods employed to collect the data, advantages and disadvantages of these methods and the ethical considerations that they entailed. The type of analysis performed and the procedures associated with this analysis are also discussed.

Previous studies: methodological strengths and weaknesses

A number of methods have been employed by studies into university-industry interaction. In the UK context a number of surveys have been commissioned by both the public and private sector to explore interaction between universities and industry or commercialisation of university research. These include the annual *Higher Education–Business Interaction Survey* published by the Department for Employment and Learning, the Higher Education Funding Councils for England, Scotland and Wales and the Office of Science and Technology, the annual UK University Commercialisation Survey published by AURIL, Nottingham Business

School and UNICO, and a survey on university-industry collaborations commissioned by the EPSRC from Sussex University (see, for example, Wright et al, 2003; Department for Employment and Learning et al, 2004; UNICO and Experian, 2004; Department of Employment and Learning et al, 2005). These surveys generally measure the frequency of different collaborative and commercialisation activities in UK universities, and also include attitudinal questions about the priorities of universities concerning collaboration and commercialisation activities, incentives and disincentives to staff for undertaking such activities and so on. The data is usually obtained from university administrators or academics and industrial practitioners. Having semi-official status conferred on them by their sponsoring bodies the response rates to such surveys are usually good. Thus these surveys succeed in providing a broad overview of the amount and types of collaboration and commercialisation taking place on a national and regional basis, and particular strengths and weaknesses in these areas. However, they cannot provide a detailed understanding of why these strengths and weakness occur. Also, despite the good response rates the robustness of some of the data is questionable, since universities do not always keep a record of informal collaboration or consulting activities undertaken by academics on a private basis (Wright et al, 2003; Department of Education and Learning et al, 2004).

Studies looking at the regional economic impacts of universities are numerous (e.g. Adams, 2005; Armstrong et al, 1997; Bleaney et al, 1992; Boucher et al, 2003; Charles, 2003; Florida, 2002; Goldstein and Renault, 2004; Gritsai, 1997; Hall, 1997; Huggins and Cooke, 1997; Keane and Allison, 1999; Lambooy, 1997; Meeus et al, 2003; Nieuwenhuis et al, 2003; Palomaki, 1997; Ricci, 1997; Roy, 2004; Thanki, 1999; van der Meer, 1997; van Geenhuizen, 1997; Vermeulen, 2003).

Those placing particular emphasis on the contribution of university – industry links to the regional economy, as opposed to focusing on universities as large employers of both skilled and unskilled labour, producers of skilled labour and providers of a market for local businesses and cultural or leisure facilities for local people[1], have employed a variety of methods including surveys, interviews, policy documents, patent citations and official statistics. For example, Huggins and Cooke (1997) and Adams (2005) both employ a quantitative methodology. Huggins and Cooke (1997) look at the impact of knowledge produced by the University of Wales Cardiff (now Cardiff University) on its region by reviewing surveys of local firms and analysing the functions and effectiveness of the Cardiff Innovation Network. For Huggins and Cooke (1997, page 326) the term 'knowledge impact' refers to 'changes in the quality of production factors induced by the knowledge produced at universities, resulting from research and the accumulation of human capital plus effects related to the university's services to the community'. However, Thanki (1999) criticises this characterization of the knowledge impact for lacking clear definition. Adams (2005) also employs a survey to measure the influence of universities on R&D laboratories in his study of academic and industrial knowledge spillovers to the R&D laboratories of US firms. He supplements his survey data by using citations made by patents of the firms under study to patents held by universities and other firms to estimate the distance that knowledge travels between them. However, the use of patent citations has been criticised as making untenable assumptions about the patenting process and the use of patents by firms. In particular, it has been argued that patent citations do not reveal knowledge flows between firms because they are usually made by the patent examiner or patent attorney, rather than the firm (Breschi et al, 2005; Doel et

[1] Exampled of this latter type of study include Bleaney et al (1992), Armstrong et al (1997) and Florida (2002).

al, 2005). Also, because patents must prove novelty to be granted, patents citations within a patent document are often made to illustrate the discontinuity of the knowledge contained from previous technological developments (Doel et al, 2005). Moreover, Thanki (1999) and Keane and Allison (1999) criticise quantitative methodologies that measure the economic value of universities to their local regions for giving 'no meaning to the nature and quality of local linkages' (Keane and Allison, 1999, page 899) and as providing no 'insight as to how well embedded these linkages and impacts might be' (Keane and Allison, 1999, page 899).

Gritsai (1997), Hall (1997), Ricci (1997), van der Meer (1997) and van Geenhuizen (1997), on the other hand, all use single or multiple qualitative case studies of universities and their past and present policies to determine barriers and incentives to establishing linkages between universities and local industry. While these studies provide a number of insights into the role social institutions play in encouraging or discouraging university-industry linkages, some lack depth, containing much information about the types of initiatives in place to encourage collaboration, but little analysis of how they actually function in practice. Keane and Allison's (1999) criticism of quantitative methodologies could be equally well levelled at the qualitative methodologies employed by these studies.

Keane and Allison (1999) propose a mixed methodology approach for looking at interactions between universities and their local economies. They suggest the use of analysis of planning documents, semi-structured interviews with university leaders and surveys of general, technical and academic staff and provide a brief case study of the University of the Sunshine Coast, Australia as an example. They find that this new university has embedded itself in the regional economy by encouraging the local community to use its amenities, adapting its extramural courses to local demands, and using local architects and landscapers to build the campus, as well as more conventional methods such as holding public lectures and forums, holding a register of expertise available within the university to the community and becoming involved in regional development initiatives. Boucher et al (2003)'s study of the degrees to which universities engage in the development of their regions takes a similar approach. They use a review of national policy and other documents and a series of interviews with national policymakers in higher education, key regional actors and university staff, along with a number of regional case studies to provide three types of result. Firstly, a national policy context for their research, secondly, knowledge of the nature of links between universities and their regions, and finally, more detailed information on a number of themes such as the role of universities in regional innovation strategies. The mixed methods used in these studies are specifically compiled to investigate 'the way in which knowledge is transferred from one group to another' (Keane and Allison, 1999, page 901) recognising the need for different sources and perspectives to achieve this aim.

Factors affecting relationships between industry and academic have been the subject of studies by Newby (1997), Benneworth (2001) and Kaufman and Todtling (2001). All three employ case studies, but Newby (1997) and Benneworth (2001) use qualitative analysis, while Kaufman and Todtling (2001) choose quantitative analysis. Newby (1997) looks at partnerships between industry and academia in suburban London and Greater London, using semi-structured interviews with potential industrial partners of universities or representatives who can speak for such potential partners. Benneworth (2001) undertakes a case study of a single long-term academic-industrial relationship in order to understand how it evolved and how the partners influenced each other. He uses documentary evidence and both semi-

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structured and unstructured interviews with key actors involved in the relationship. These studies both reveal cultural interactions taking place in university – industry relationships albeit in particular, individual situations. Kaufman and Todtling (2001), on the other hand, use statistical analysis of the results from surveys of several regions to investigate the way in which science stimulates innovation in firms. While their study is revealing of the patterns of knowledge transfer, it is less revealing of the processes behind it. Specifically, their data do not reveal why firms undertake different types of cooperation, e.g. consultancy, sponsored PhD projects and so forth. Thus the methods employed in these studies are complementary, since they illuminate different areas of one research field.

Ethnographic methods employed by studies into inter-firm interactions and the affects of organisational culture upon them have an obvious relevance to the current project because of its concern with separate organisations and organisational cultures and practices. For example, Saxenian (1994, page 209) describes the research method used in her classic comparative study of Silicon Valley and Route 128 as 'ethnographic in nature', involving 'empirical material accumulated over the course of nearly a decade living in and observing the two regional economies' that she describes. This empirical material includes in-depth interviews, often of the same person on different occasions, local and national industrial and trade press, corporate documents and public and private databases. Studies that have sought to examine the use of social capital connecting diverse groups (i.e. bridging social capital) are relatively few. As noted in Chapter 2, most studies have instead attempted to measure the amount of undifferentiated social capital present in a social group, community or region using indicators such as how trusting people are of each other, civic participation, membership of religious groups and number of contacts with different social groups (e.g. Beugelsdijk and van Schaik, 2005; Cooke et al, 2005; Iyer at al, 2005). The main problem with these studies is that while such indicators may measure *sources* of social capital, they do not necessarily measure social capital *itself*. McClenaghan (2000), Murray (2004) and O'Brien et al (2005) consider the more pertinent question of how social capital enhances actors' capacities to act or to access resources (Tura and Harmaakorpi, 2005), discussing bonding social, bridging social capital and their interaction. However, McClenaghan's (2000) and O'Brien at al's (2005) treatment of bridging social capital also seems somewhat one-sided. A relation between *a* and *b* may be social capital for *a* but not for *b*. However, to understand how the relation enables *a* to act in ways that otherwise would not be possible, or access resources that would otherwise be inaccessible, it would seem appropriate to consider both the roles of *a* and *b* since relations are by definition a two-way process. Despite this, neither McClenaghan (2000) nor O'Brien (2005) consider the other communities involved in bridging relations with the communities they discuss (people participating in Northern Irish adult education programmes and Native American Tribal colleges respectively).

Implications for the current project

From previous studies of university-industry interaction it is clear that a mixed methodology involving both qualitative and quantitative methods would be most useful for answering the research questions of this study. Given the focus on the construction and functioning of social relationships, qualitative methods are suggested for the production of in-depth results that such a focus demands. However, for the purposes of generalisability, comparability and policy relevance the broader scope of quantitative methods are also implicated. Past studies have also illustrated the danger of merely describing the numbers or types of interactions in existence rather than explaining them whether using quantitative or qualitative methods. However, a combination of methods, particularly those that involve actual engagement with the actors involved in university-industry interaction, as opposed to purely documentary evidence, appear to be the most effective way of avoiding this pitfall.

Previous studies of knowledge transfer between universities and industry have also emphasised one perspective (academic or industrial) over the other. For example, Huggins and Cooke (1997), Newby (1997) and Kaufman and Todtling (2001) focus on the industrial perspective, using surveys of firms or interviews with representatives of industry. Other researchers have focused on the academic perspective, using case studies of individual collaborative projects, such as Dodgson's (1991) study of the academic spin-out, Celltech, and Miller et al's (2002) examination of three collaborations undertaken by the School of Engineering at the University of Huddersfield. Also emphasising the academic perspective are case studies of university policy (Gritsai, 1997; Hall, 1997; Ricci, 1997; van der Meer, 1997; van Geenhuizen et al, 1997) and surveys of academics (Adams et al, 2005; Vaessen and van der Velde, 2003). However, since the current project investigates interaction between academia and industry, the development of a methodology that encompassed the perspectives of both sets of actors involved in university–industry interaction was deemed essential. It is not possible to understand the relationships between these two sets of actors by only focussing on one side.

Methodological Approaches

There are a number of different research traditions in which a project can be situated, each of which may be distinguished by different epistemological and ontological foundations. It is important to acknowledge the research tradition in which a project is situated as this has important implications for how the project is expected to proceed. This section therefore considers the different research traditions within the social sciences and, since this project is situated within the discipline of human geography, the methodological approaches which have been prominent in this discipline's history. It then goes on to explain how the project is situated with regard to methodological traditions.

Rationale of the project methodology

Most social scientists differentiate between qualitative and quantitative approaches (e.g. Bird, 1992; Brannen, 1992; Bryman, 1992; Bullock et al, 1992; Cornwell, 1988; Creswell, 1994; Creswell, 1998; Graham, 1997; Laurie, 1992; Philip, 1998; Philo et al, 1998; Qureshi, 1992; Smith, 1988; Yin, 1994). Quantitative research, as the name suggests, quantifies phenomena, while qualitative research is more concerned with the qualities of phenomena. Quantitative research is generally, but not necessarily, associated with a positivist philosophy, while qualitative research is generally, but not necessarily, associated with a non-positivist philosophy (Brannen, 1992; Bryman, 1992; Hammersley, 1992; Graham, 1997). Thus, quantitative research is often understood to assume the existence of a physical world independent of the observer and that the observers' senses give an accurate view of what this world is like. Qualitative research, on the other hand, is often understood to reject such assumptions (Robson, 2002). Despite the implied divide that such distinctions suggest, qualitative and quantitative research are, of course, not mutually exclusive and can be combined in a single study (Brannen, 1992; Bryman, 1992; Bullock et al, 1992; Creswell, 1994; Doel, 2001; Hammersley, 1992; Laurie, 1992; Philip, 1998). In fact, although the distinction between qualitative and quantitative methodologies is commonly accepted, the methodology literature fails to define it consistently. For example, Creswell (1998) that suggests the case study is one of five main qualitative research traditions in the social sciences, the others being biography, phenomenological study, grounded theory and ethnography. For Creswell (1998) the case study involves the detailed exploration of a bounded case or cases over time, using in-depth data collection and multiple information sources such as interviews, surveys and documents. Yin (1994), however, sees the case study as a method that can be used within qualitative, quantitative or mixed approaches. For him it is one of five main types of method, the other four being survey, experiment, archival research and interview, although these categories overlap because case studies may employ data from surveys, archival research and interviews. He describes a case study quite differently to Creswell (1998) as an empirical inquiry that 'investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident' (Yin, 1994, page 13).

As a discipline human geography has been characterised by successive approaches which have grown and then waned in popularity, these being areal differentiation, followed by the normative model building of the 1950's and 60's quantitative revolution and the variety of qualitative approaches taken following the emergence of Marxist, feminist and humanistic geographies in the 1970s and the cultural turn of the late 1980s (Gregory, 2000b; Pratt, 2000; Walmsley and Lewis, 1984). Whilst the spatial science of the quantitative revolution was associated with positivism, qualitative approaches have usually been associated with non-positivistic philosophies (Smith, 2000). For example, Gregory (2000b) suggests that phenomenology underwrote the theoretical concerns of humanistic geography, which favoured ethnographic methods for empirical studies. Since the cultural turn, human geography has been widely influenced by movements such as postmodernism, psychoanalysis and post-structuralism.

Clearly then, there are almost as many interpretations of different methodological approaches as there are researchers. There is not even a clear line to be drawn between whether an approach is to be considered qualitative or quantitative, nor between whether it is to be considered positivist or non-positivist. For example, as mentioned above, Creswell (1998) and Yin (1994) disagree as to whether a case study is a qualitative approach or not. Yin (1994) also discusses the importance of issues such as construct validity and reliability, which are usually associated with a positivist philosophy, as related to case study research. However, in her account of case study research, Cornwell (1988) rejects positivism. This debate within the literature, however, could be regarded as helpful, as it suggests there is not a marked divide between different approaches and hence justifies the combination of qualitative and quantitative methods. Robson (2002, page 43) suggests that an approach based on pragmatism in which 'truth is 'what works'' is one solution to overcoming the divide between positivist and non-positivist philosophies which provides a philosophical validation for the mixing of methods. It is this philosophy that probably bests describes the epistemological underpinnings of this project and is one that is quite widespread in human geography as a discipline. As Doel (2001, page 563) points out, 'most human geographers are now content to browse through the pic-and-mix selection of theory and practice for the eclectic *assemblage* that will suit the milieu to hand'.

The literature also suggests a general agreement of the types of method suitable for the current project, which requires tools for studying two social systems and their interactions, specifically, the construction of different spaces of knowledge and how differing discourses and views of the world within science and industry affect their relationships. In particular, ethnographic and survey methods are relevant for three reasons. Firstly, ethnographic methods are suitable for studying and interpreting 'a cultural or social group or system' (Creswell, 1998, page 58). Secondly, Gregory (2000c, page 816) claims that ethnographic methods have provided 'compelling accounts of the social construction of specific milieux'. Thirdly, ethnographic methods provide an in-depth view on a research problem not afforded by a survey (Gregory, 2000a), while a survey, with its broader reach, provides context and generalisability to the findings gained from the use of ethnographic methods (Robson, 2002).

Given the time constraints of the current project it was clearly impossible to apply in-depth methods to all university-industry interaction occurring across Wales. Instead ethnographic methods are used to gain detailed knowledge of a variety of representative cases of such interactions. This is the method Hirst and Zeitlin (1992) suggest is most suitable for researching the international economy following the Fordist era. Their theoretical approach is that of flexible specialisation, which:

> emphasises the contingency and complexity of the connections between social relations; it insists on the distinctiveness of national and regional routes to the establishment of such connections between social relations; it recognises the crucial role of strategy and bodies of ideas in constructing such routes, and it is aware that things could have been otherwise.
>
> (Hirst and Zeitlin, 1992 page 91)

Their claim is that 'only detailed case studies permit the close attention to context and strategy which is the hallmark of a flexible specialisation approach' (Hirst and Zeitlin, 1992, page 101). A similar approach is appropriate to this project since it is particularly concerned with the construction of social relations.

Hirst and Zeitlin (1992) suggest that there are two problems with the case study approach, those of interpretation and of representativeness, since arguably case studies do not provide objective indicators and are not statistically generalisable. These are criticisms of qualitative research that are much discussed in the methodology literature (see for example, Cornwell, 1988; Graham, 1997; Schoenberger, 1991; Yin, 1994). Hirst and Zeitlin (1992, page 101) meet the attack on interpretation by claiming that 'if there is an unavoidable degree of indeterminacy about the interpretation of case study evidence, this does not mean that there is no valid basis for discriminating among competing views'. Other authors have denied the possibility of truly objective indicators all together, arguing that all observation is theory-laden and that all theory is underdetermined by data (e.g. Evans, 1988; Kuhn, 1972; Philip, 1998). Such arguments point out that even simple observations, such as 'This is a chair', are not free of the experiences and interpretations of the observer, since it requires the observer to understand the theoretical concept of what it is to be a chair, to have experienced different types of chair and to interpret the object before him or her as a chair. Furthermore, the same data can lend support to different and competing theories.

As far as representativeness is concerned, Yin (1994) argues that qualitative methods aim for theoretical generalisability, while quantitative methods aim for statistical generalisability, which then becomes the basis for theoretical generalisability. Thus, while a case study may not be statistically representative of a wider population, it can still achieve the ultimate goal of theoretical generalisation.

Data collection and analysis

Identification of industries and sampling

Five industries were selected for study: aerospace, life sciences, opto-electronics steel and sustainable energy. These industries were chosen because of the roles they play in the Welsh economy. Historically, heavy industry such as coal mining and steel production was central to the Welsh economy (Kaufman and Todtling, 2000) and the steel industry was selected as an example of an older industry, that, unlike coal mining, still has a significant presence in the Welsh economy, contributing about 5% of Welsh GDP (UKSA, 2000) and is attempting to reinvigorate itself through research and innovation. The aerospace, life sciences, opto-electronics and sustainable energy industries were selected as they feature significantly in Welsh economic policy, such as the Welsh Development Agency's *Business Plan 2005-2008*, *Corporate Plan 2003/4 – 2006/7* and Future Technologies Programme, as the basis of the knowledge-based economy in Wales. Since the 1960s, the automotive, electronics, pharmaceutical and healthcare industries have grown considerably in Wales, supported directly by policy (Kaufman and Todtling, 2000). Building on these changes to the Welsh economy, the Welsh Development Agency identifies in its *Business Plan 2005-2008*, the aerospace and defence industries, the energy industry (including sustainable energy), automotive and motorsport industries, and technology and creative industries as sectoral priorities for business support, with attention also being paid to agribusiness, life sciences and financial and business services. In the WDA *Corporate Plan 2003/4-2006/7*, particular emphasis is placed on supporting the continued development of the aerospace industry. The Future Technologies Programme, run by the Welsh Development Agency using National Assembly and Objective 1 funding, has chosen agriculture (including agrifood), communication and services (including ICT and software), construction, healthcare, renewable energy and transport (including aerospace and automotive) as focus sectors for future technology opportunities in combined/convergent technologies, biosciences, electronics (including opto-electronics), information and communication technology, materials and nano- and micro-technology.

Care was taken to select industries that draw on a variety of different technologies and have different geographical concentrations throughout Wales, so as to account for different types of interaction occurring across the whole region. However, statistics for these five industries are not easily available. Even the number of firms in each industry is disputed: for example, Welsh Development Agency figures for the aerospace industry include firms that act as suppliers or consultants to aerospace firms but for which aerospace contracts comprise a very minor part of their business. This overemphasises the number of aerospace firms in Wales[2]. Of the five selected industries the aerospace industry is fairly well established, with some large manufacturing facilities in both the north and the south, most notably Airbus located at Broughton in Flintshire, and a few high-technology firms. 51 firms were identified in this industry. The opto-electronics industry is an established high-tech industry with a cluster of small firms in the northeast, which comprises both independent SMEs and subsidiaries of larger firms, such as Hoya Lens. 43 firms were identified in this industry. Life sciences, on the other hand, is an embryonic high-technology industry, with some MNC manufacturing facilities such

[2] See the Wales Aerospace Forum website for these figures: www.waf.com

as Norgine in Hengoed, south Wales, and Bristol Myers Squibb in Deeside, northeast Wales. 47 firms were identified in this industry. The sustainable energy industry consists primarily of independent SMEs and not-for-profit companies. Most sustainable energy companies are located in the more rural areas of Wales and have grown up organically. Until recently, there has been little policy intervention to promote the growth of this type of firm but several have been encouraged by the presence of the Centre for Alternative Technology, established near Machynlleth in mid-Wales during the 1970s. The sustainable energy firms undertake small-scale manufacturing and provide knowledge-based services, such as consultancy or turn-key installations. 58 firms were identified in this industry. The steel firms in Wales are either very large, such as subsidiaries of Corus and Celsa steel in the industrial areas of the south and northeast, or small companies located close to the steel mills, which provide testing and other metallurgic services. 18 firms were identified in this industry. For the purposes of this project a high-technology firm is one which bases its main product or service on recent scientific or technological developments, e.g. a sustainable energy firm might develop new products from recent developments in photovoltaics. A firm that provides knowledge-based services is one that is essentially selling knowledge. An example would be a sustainable energy firm that provided feasibility studies for the location of a new wind farm.

Following the choice of the industries to be studied firms in each of the selected industries were identified from sources including business directories, industry associations and fora. For firms to be included in the study their main product or service had to be aerospace, life sciences, opto-electronics, steel or sustainable energy related. The main product or service of a firm was defined as the product or service that the firm identified as its main product or service. This information was obtained from a combination of sources including firm websites, marketing literature and memberships of industry organisations. The use of SIC numbers was rejected because they are not sufficiently detailed. For example, a company that produces software solely for the purposes of air traffic control, which is clearly an aerospace related product, could be classified under the SIC number for computer software and would be excluded from the study if SIC numbers were used. Furthermore, firms listed under the SIC number for computer software could be anything from a cutting edge software producer to a shop selling computer games. A population of 208 firms was identified within Wales which included all types of facility: manufacturing, R&D and administrative.

Interviewing

Following the identification of firms in the industries selected for study, 44 in-depth interviews were conducted between March 2004 and February 2006 with firms in Wales interacting with Welsh universities and their academic partners, as well as technology transfer staff and policy developers / implementers. Because the emphasis of the study is on the contribution of Welsh HEIs to regional development in Wales as part of the regional innovation system, interactions between firms in Wales and HEIs outside Wales were excluded. Where firms agreed, their interaction was monitored for several months through multiple interviews, allowing insight into the development of the relationships between the firms and their academic partners. This meant the study included only interactions taking place during the data collection period, rather than interactions that had already been completed. An advantage of this approach was that it was possible to interview those working together on the project, whereas with already completed projects, particularly those involving research students, one or more people involved in the project were not available for interview. On the other hand, excluding completed projects meant that it was not possible to obtain post-collaboration reflections of participants on the long-term impacts of their collaboration. However, because many collaborative projects were the latest in an ongoing series, it was possible to obtain such reflections upon previous collaboration between the two partners. Interviews were also restricted to interactions with a technical basis as the study aimed to look at relationships between academic science, as differentiated from the arts, humanities or social science, and industrial R&D.

In-depth interviews were selected as the most appropriate method of providing an appreciation of the social processes involved in knowledge transfer (Rees, 2005a; Schoenberger, 1991). This methodology also has two major advantages. The paired interviews provide a dual perspective both on knowledge transfer between universities and industry and a two-way relational view on the role of bridging social capital in developing interaction between two different cultural groups. This project is able to provide a dual perspective on university – industry interaction and bridging social capital.

Interview technique

Interviews may be structured, semi-structured or unstructured. Structured interviews are those that have standardised questions and can restrict the interviewee to a limited range of responses. The interviewer will not normally have an ongoing relationship with the interviewee (Cornwell, 1988; Davies, 1999; Gerson and Horowitz, 2002). This structured interview was deemed inappropriate for the current project because the variety of interviewees and differences between their experiences required a more flexible approach to questioning. Instead, semi-structured and unstructured interviews were selected. Semi-structured interviews had several advantages. Because they are normally prearranged and the interviewer has some kind of schedule the process is comparable with a job or media interview and thus easily understood by prospective interviewees. It is also easier to arrange an interview with a busy respondent if it is possible to be given some idea of how long the interview will last and the type of questions that will be posed. The wording and order of the questions in a semi-structured interview may vary depending on the situation in which the interviewer finds her or himself. This allows inappropriate questions to be omitted and new topics to be introduced at the interviewer's discretion. The interviewee's responses are open-ended, allowing themes that might otherwise be overlooked come to the interviewers' attention. Semi-structured interviewing can involve a relationship between interviewer and interviewee that goes beyond a single interaction within an interview context, and an interviewee may be interviewed more than once. This allowed for the tracking of relationships as they changed over time. Unstructured interviewing was felt to be suitable in situations where respondents might be intimidated by or suspicious of a formal interview schedule as in this type of interview the interviewer has in mind certain topics and questions that she or he would like to explore and may direct conversation with informants along these lines but usually refrains from imposing a structure on the interaction (Mason, 2002). As is common when using unstructured interviews, they sometimes took place in the context of participant observation, were sometimes spontaneous rather than prearranged and were performed in addition to one or more related semi-structured interviews, so an ongoing relationship existed with most of the interviewees before and after the unstructured interview (Davies, 1999; Donovan, 1988; Longhurst, 2003).

Interviewing may be conducted face to face or over the telephone, but face to face interviews were chosen because they are usually considered more useful as informal and non-verbal communication can be lost over the telephone. Furthermore, no audio-taping facilities were available to record telephone interviews. Audio-taping preserves more information than note taking and allows the interview to be reconstructed verbatim. Note taking was only used during an interview if the interviewee did not wish to be audio-taped, since it can be off putting for the interviewee and disturb the flow of conversation. On one occasion the recording device failed and the tape was inaudible. In this case detailed notes were taken directly after the interview. This technique was also used after informal interviews if they were carried out in situation where audio-taping was impossible due to background noise or because of the spontaneous nature of the conversation (Creswell, 1998; Longhurst, 2003; Robson, 2002).

As is common in projects using ethnographic methods, interviewees were selected by purposive, non-random sampling (Parfitt, 2005), that is, because they were key informants or met certain criteria, i.e. they were involved in an interaction between a firm in Wales and a Welsh university, rather than with the intention of obtaining a statistically representative sample. Gaining access to interviewees was sometimes problematic. Gatekeepers, such as the academic and industrial supervisors of PhD students, occasionally provided the means of finding informants who were willing to be interviewed, but others, such as senior managers, discouraged informants from taking part in the project. Some individuals were not willing or able to make the considerable time commitment an interview demanded, a recognised problem with interviewing as a data collection technique (Robson, 2002).

As interviews can only be obtained from people willing to be interviewed, there is the problem that there might be something fundamentally different between those people interviewed and those not interviewed that would only reveal itself through in-depth interviewing. This problem is also common to surveys, as although the returned questionnaires may be statistically representative of the wider population (Scott, 2002), there still might be some non-obvious difference between respondents and non-respondents. Creswell (1994) and Robson (2002) suggest two methods to deal with this problem. Firstly, some non-respondents can be contacted to check if their responses differ substantially from those of respondents. This technique can be problematic, however, if the non-respondent refuses to answer even a short query. Alternatively the researcher can check if answers given by reluctant respondents, such as those who return a questionnaire in the last weeks of a given response period, differ the answers given by immediate respondents. This method assumes that final respondents are 'nearly' non-respondents, but this assumption can be questioned: the reasons why a respondent answers a questionnaire late or postpones an interview date might be quite different from the reasons why someone may decline to take part in the research process at all. Additionally, some authors have suggested that the flexibility of semi-structured and unstructured interviewing implies a lack of standardisation which, in turn, raises concerns about reliability (e.g. Robson, 2002). It is possible to introduce biases into interview data through poor questioning techniques, such as asking leading questions (Robson, 2002). However, Schoenberger (1991) suggests that accuracy, validity and verifiability of economic geography interview data can be maintained if the researcher uses validity checks such as questioning why a respondent's account differs from other accounts of the same phenomena and probing inconsistencies, and by interviewing more than one person from a firm (see also Davies, 1999). Further, she suggests verification checks should be carried out on the researcher 'to ensure that the interview is not inadvertently constructed to produce an answer' (Schoenberger, 1991, page 187). In the current project, a combination of these checks on the interview data obtained were made. Reluctant interviewees were identified as those who put specific time limits on the interview, requested interviews outside office hours, postponed interviews or only agreed to be interviewed after the intervention of a colleague or senior member of staff. The responses given by these interviewees were compared to those of interviewees who were unconcerned by the amount of time the interview took, were happy to be interviewed during office hours at a mutually convenient time, kept the initial appointment and agreed to be interviewed at the first request. No fundamental differences were found between reluctant interviewees and willing interviewees. As many people as possible involved in each interaction were interviewed: where possible more than one academic or company employee were spoken to, plus any technology transfer staff involved. Inconsistencies in their replies were noted and explored. Furthermore, the interview schedule posed similar questions in a number of different ways to avoid leading the interviewee. Like the case studies of which they can form a part, semi-structured and unstructured interviews have also been criticised for being non-representative and lacking objectivity. These accusations have been rejected by Valentine (2005, page 111) who argues that the aim of the interview is not to be representative but to consider 'the meanings people attribute to their lives and the processes which operate in particular social contexts'. She also suggests that objectivity does not exist in the social sciences because 'all research work is explicitly or implicitly informed by the experiences, aims and interpretations of the researcher' (Valentine, 2005, page 112).

The interaction between the interviewer and the interviewee is discussed at length by a number of authors (see for example Cornwell, 1988; Donovan, 1988; McDowell, 1988; Schoenberger, 1991; Davies, 1999). A fundamental quality of the research interview is 'the presumption of equality of the participants within the context of the interview itself' (Davies, 1999, page 99). This presumption can be undermined by differences between the interviewer and the interviewee such as social position, gender and age. According to McDowell (1988) and Davies (1999) if the interviewee perceives her or himself as holding a higher social status than the interviewer, they may attempt to take control of the interview and use it as an opportunity to instruct the interviewer on what they believe the interviewer should be told, or to be dismissive or patronising. This can be a particular problem for women interviewing men who are high in their professional hierarchy. In the current project, this situation occasionally arose in interviews with older, male academics in higher positions, who felt the need to instruct me on matters such as the necessity of publishing in high-impact journals, the type of data I ought to be collecting or how I should analyse my data[3], or were dismissive of the chosen methodology. Similar problems can arise in participant observation depending on the relationship between the participant observer and other participants (Hobbs, 1993). In this situation, I found it easier to steer the interviewee towards answering the questions posed by either accepting the advice proffered or by reassuring them that the research followed accepted disciplinary procedures. However, I also found, as McDowell (1988) suggests, that being perceived as unthreatening sometimes worked to my advantage,

[3] Stephens (2007, page 208) encountered a similar tendency for academic interviewees to 'adopt a pattern of a lecturer/student relationship' in his study of macroeconomists.

as I was given access to information that might be withheld from a researcher who was perceived to have greater authority. Some interviewees were willing to help out a student with her studies, whereas they would not have been willing to speak to a researcher from a government agency, a journalist or someone from the business world. Schoenberger (1991) suggests that in corporate interviews the interviewer is more likely to be able to control the direction of the interview if she or he is well informed about a firm and the business it is in, shows that she or he understands the issues being discussed and uses the same language as the interviewee. Being well informed should also encourage the interviewee to be more open and detailed. Thus, I prepared for the interviews by reading as much as possible about the firm in question and tried to use appropriate terminology during the interview itself. However, as commercial secrecy was a concern for many interviewees, I took care to represent myself as someone with an academic interest in the firm rather than someone from industry. Usually my personal views were not expressed while interviewing so as not to bias the interviewee's responses (Davies, 1999). Then again, personal experiences were shared where it was felt that they would help to establish greater understanding and lead to an improvement in learning for both the interviewee and the interviewer. Such experiences included attendance as a participant observer at Welsh Development Agency events and at academic conferences.

The decision to refrain from expressing personal views is not entirely straightforward because, as Longhurst (2003) argues, such a decision sometimes poses an ethical dilemma. This can occur when maintaining a non-judgmental position reproduces or even legitimizes the interviewee's morally unacceptable attitudes or behaviour through complicity. This dilemma arose in the current project where interviewees were involved in activities such as the manufacture of arms, involvement in the meat trade, the confinement of animals in unnatural environments for product testing, the slaughter of healthy animals following product testing and obtaining access to competitors' plans through deception. My ultimate decision rested on the fact that these activities, while in the opinion of the researcher are morally dubious, are not actually illegal. In this regard, Robson's (2002, page 71) advice to '[r]emember that while you have particular ethical responsibilities as a researcher, this does not mean that you have a privileged voice on what constitutes ethical behaviour in others' was accepted. Consequently, when interviewing companies with involvement in defence, the interviewer's convictions concerning such activities were not revealed. On the other hand, where interviewees raised concerns over the ethics of their activities, an understanding of the situation was sought through sensitive questioning.

In accordance with the decision to use theoretical sampling, as many firms as possible were contacted by telephone, e-mail or letter to ascertain whether they were currently interacting with any Welsh HEIs. Some firms were not contactable because their telephone numbers or addresses were not available or incorrectly advertised. Others did not answer calls and either did not have a voicemail service or did not respond to messages or written requests. If a firm reported any type of interaction with scientists or engineers in a Welsh university an interview was requested from the firm and permission obtained to contact the academic(s) and any technology transfer staff involved with the interaction to request interviews with them. If all parties agreed to be interviewed a series of in-depth interviews, lasting between an hour and two hours per partner, was conducted with the participants in the interaction.

A total of 44 interviews were conducted with 50 interviewees, of which 41 interviews useable. These 41 interviews involved 45 interviewees. The discrepancy between the number of interviews and the number of interviewees is due to the fact that some interviews involved up to three interviewees, while other interviewees were interviewed more than once. Interviews were deemed unusable if the interviewees' collaborative partners subsequently decided not to participate in the study. Interviewees from the useable interviews comprised 22 employees from 17 firms, and 14 academics and nine technology transfer staff from 7 higher education institutions and one government body. Six firms were located in southeast Wales (7% of firms in the selected industries located in this area), four in mid-Wales (22% of firms in the selected industries located in this area), four in southwest Wales (9% of firms in the selected industries located in this area) and two in northeast Wales (4% of firms in the selected industries located in this area). Three HEIs were in the southeast (three-fifths of the HEIS in this area), two in the southwest (half of the HEIs in this area), one in mid-Wales (one of two HEIs in this area) and one in the northeast (the only HEI in this area). The firms that agreed to participate comprised 3 aerospace firms (6% of firms in this category), 3 life sciences firms (6% of firms in this category), 2 opto-electronics firms (5% of firms in this category), 3 steel firms (16% of firms in this category) and 5 sustainable energy firms (9% of firms in this category). One drawback of the dual perspective approach is that it demands the cooperation of both parties, which is time consuming to establish. Non-cooperation removes the interaction from the study and where interactions are not performing to expectations, it is quite likely that at least one partner will be unwilling to discuss the experience despite assurances of confidentiality and anonymity. Although an unwillingness to discuss underperforming interactions might be expected to lead to a biased sample, a third of the firms interviewed had had negative experiences with the interactions in which they were currently involved. Interviewees were also happy to discuss negative aspects of otherwise positive interactions and to compare these positive interactions with less successful ones they had undertaken in the past. In Wales there are also a limited number of interactions between universities and firms within the selected industries. All of these factors mean that the number of firms interviewed is quite small. However, the sample still comprises over a third of the firms that reported current interaction with a Welsh HEI, and a range of different types of interaction with universities. The firms in the sample also include a range of different sizes and ownership, with six independently owned SMEs, 4 SMEs owned by a large national or international firm and five large firms that are subsidiaries of a national or international firm. Thus the sample is not biased towards a particular type of firm, HEI or type of interaction. Furthermore, as there are a number of interviews associated with each interaction, each instance can be analysed in considerable depth.

Interviewees were given an outline of the project and a participant informed consent form to sign. One copy of this form remained with the interviewee and one was kept as a record. In accordance with normal ethical practice (Robson, 2002; Longhurst, 2003) the form made interviewees aware that all primary data, such as interview transcripts and company documents not in the public domain, would be kept confidential, and in particular, material from a paired interview would not be shared with interviewees during later interviews discussing the same interaction. Interview data was anonymised and kept secure. All interviewees and their organisations remain anonymous in the thesis and any publications arising from the project unless they gave their written permission for their name and the name of their organisation to be used. However, as a woman going to interview unknown men alone and sometimes outside normal working hours I did leave a record of exactly where I had gone and who I had gone to interview which was accessible to my supervisor if necessary, a safety precaution suggested by Valentine (2005). All interviewees were informed that their participation in the project was voluntary and they could leave the project at any time. If interviewees wished to leave the project they were given the alternative of having all interview materials (e.g. an audio-tape) returned to them and any written data on computer or paper destroyed. Participants were also notified of their right to receive a copy of the project results, either as an abridged report or the complete thesis.

The paired interviews with participants in university – industry interactions were supplemented by five interviews with policy developers and implementers. These interviews were performed in order to better understand the policy context in which the interactions studied were occurring, and to better compare policy aims with how policy was being enacted on the ground. In addition to these interviews I attended as a participant observer a number of seminars and lectures aimed at promoting and diffusing WDA and WAG schemes encouraging university – industry interaction.

Participant observation

Participant observation involves the researcher participating and observing in the part of society she or he is studying. It does not, however, involve a strict set of rules to be followed. The researcher may be observing covertly or overtly, and may participate fully in the situation in which she or he is observing either covertly or overtly, or may be simply be a covert or overt observer (Lee, 2000). Each of these possibilities has its advantages and disadvantages. Observing without participating may allow the researcher to pick up on phenomena she or he would have missed had she or he been preoccupied with participating, but certain phenomena may only be obvious to an actual participant. Overt observation, even if the researcher is participating, may alter the behaviour of the people being observed, but covert observation can be considered unethical (Evans, 1988; Cook, 1997; Creswell, 1998). During my attendance at WDA and WAG seminars and lectures my observations were neither fully covert nor fully overt: if asked why I was attending the seminar or lecture in question, I gave a brief explanation of my project, but otherwise I remained anonymous. In this way, I avoided unethical behaviour but did not disrupt proceedings. Given that such events are essentially open to any interested parties attendance did not pose particular ethical dilemmas. As observation of a seminar or lecture is essentially participant observation, it was not possible to make a choice between participating and observing or simply observing. As with interviewing, the participant observer may have to decide whether to express a personal view and disrupt the observation process or risk condoning behaviour or attitudes they consider unacceptable (Devni and Hurst, 1999). Fortunately, in the current project, this situation did not arise during participant observation.

A problem common to all types of participant observation is that of gaining access to the part of society that the researcher wishes to observe. This is usually achieved by going through 'gatekeepers', that is, people who can legitimise the researcher's presence in a particular situation. Participant observation of meetings and joint work performed as part of interactions between universities and firms was initially proposed as part of the project methodology. Access was to be obtained by accompanying technology transfer staff and academics from the School of

Engineering at the University of Wales Swansea as they met with and worked with firms in Wales. However, the project to which I had been attached collapsed because of funding problems and it was not possible to find other gatekeepers who were willing to help me access such situations. Therefore, despite the valuable data that such observation might have yielded, this approach had to be abandoned. In the case of participant observation undertaken for the project, although the type of event I was interested in were generally open to anyone with an interest, they are usually only publicised to people who are deemed likely to have a specific interest in the topic. The gatekeepers that provided access to the events I observed were my supervisors, who as academics, frequently received notification of events encouraging them to interact with industry and detailed of how to register for them. Choice of events was determined by their relevance to the industries studied.

Data collection by participant observation involved the generation of detailed field notes from the observation, as is common practice with this method (Cook, 1997; Creswell, 1998; Laurier, 2003). These notes involved more than the simple recording of events. They were made taking into account the suggestions of Evans (1988, page 200) that the participant observer must suspend her or his belief in the reality of appearances, must adopt a 'critical, interpretive stance' and must be reflexive (see also Adkins, 2002 and Skeggs, 2002). This allowed a level of objectivity in considering the events under observation, whilst accepting that observations are always influenced by the observer. This fact is not necessarily a weakness in the research process: Kleinman (2002) points out that emotions can be a useful interpretive tool. In her study of a alternative therapy centre, she found that the unease she felt while observing members of the centre led her to a feminist interpretation of its organisation.

Verification and validation of the results were also considered using Evans' (1988) criteria. Verification is achieved if the participating observer can give instructions that enable other researchers to place themselves in the same situation and to have the same or a similar experience, a requirement achieved by providing this written account of the participant observation process. Validation of research using participant observation is internal to the research because 'whilst interpretations must be justifiable in terms of the cited evidence, they are still the product of the ability of the observer to participate meaningfully' (Evans, 1988, page 201). On the other hand, Devni and Hurst (1999) suggest that being too closely intertwined with the culture under study can prevent the researcher from maintaining distance from familiar phenomena. This can lead to importance aspects of the phenomena being overlooked. However, as a research student I was sufficiently part of one of the overlapping cultures observed (i.e. academia) to participate meaningfully, but not sufficiently involved in the type of overlap observed (i.e. the overlap of academia and industry) to be over-familiar with potentially important details.

Surveying

A survey was carried out in conjunction with the interviewing and participant observation with the aim of providing a context to the in-depth views of interactions given by the paired interviews. Specifically the survey aimed to gauge the representiveness of the experiences of firms in the selected industries. Also, interviews could not provide information on the differences between collaborating and non-collaborating firms, nor could they fully explain why some firms choose not to interact with universities at all. The questionnaire was designed to fill these gaps.

A self-administered e-mail or postal questionnaire was selected as the most suitable form of survey for the project. An interview survey was deemed too expensive and time consuming as it would have travelling the length and breadth of Wales to administer it. A telephone survey also had the disadvantage of being time consuming, and some firms had a policy of not taking part in telephone surveys before receiving an official letter or e-mail. On-line questionnaires were originally chosen because they were requested by a number of companies that agreed following a telephone enquiry to answer a questionnaire. The abridged paper questionnaire was chosen as a follow-up as it was thought a return to a traditional format might increase the response rate. However, it is not clear whether the increased response rate was due to the change in format, or whether firms that were not interacting with universities were more likely to answer a questionnaire specifically aimed at them. It is possible that potential respondents to the on-line questionnaire felt that as they did not interact their experiences were not really relevant to the project, even though the covering e-mail explained that the experiences of both interacting and non-interacting firms were being sought. Although this was unintended, results from the paper questionnaire suggested that respondents were using it as an opportunity to complain, either that they had been wrongly classified by the project, or because they had had bad experiences with Welsh universities. Providing this opportunity to air their views seemed to increase the response rate of the firms.

A census of the entire population was undertaken rather than a sample because the relatively small number of firms involved meant that such an approach would be quite manageable even if a 100% response rate was achieved. However, the small population also meant that a pilot questionnaire was impractical: given that firms were unlikely to answer two versions of the same questionnaire, testing the questionnaire, particularly with the very small steel population, would have removed too many potential respondents from the pool. Instead the questionnaire questions were developed from the semi-structured interview schedule and answers given by the interviewees, so it was ascertained that potential respondents would understand them.

The initial survey was conducted using an on-line questionnaire comprising two parts; one for interacting firms and one for non-interacting firms. It was e-mailed to all companies that had not been interviewed for which an e-mail address was available in July 2005. At 13% the initial response rate was disappointing despite a reminder e-mail being sent out in August 2005. Once initial analysis was begun it was clear that there was a particular lack of data from companies that were not interacting. To remedy this lack, a paper questionnaire consisting only of the second part of the initial questionnaire, i.e. that for non-interacting firms, was send out to all companies that had been identified as not interacting with Welsh universities in the initial telephone survey from which potential interviewees had been recruited for which an address was available. This mail out occurred in March 2006. The response rate to this questionnaire was much higher than that of the on-line questionnaire. Indeed a number of companies contacted me to inform me that they had been wrongly identified as not interacting with Welsh universities by the employee I had originally spoken with regarding the project, and some of these provided detailed information on their interactions.

In order to encourage participation the questionnaire did not ask for the name of the company. However, given the information on firm location and product given by each questionnaire, it was quite easy to match each reply to the firm it had come from. This procedure was performed to check the reliability of the answers. In order to guard against participant error, responses to any questions that could be confirmed by published data or other data collection for the project were checked against these sources. Validity of the questionnaire results was addressed in several ways. Construct validity refers to whether the questionnaire actually measures whatever it is designed to measure (Robson, 2002). In the current project the questionnaire was designed to measure the number of firms interacting with universities and to discover which reasons were most important to the decision to interact or not to interact. While the question of whether a firm interacts with a university might initially seem quite straightforward, in practice this occasionally turned out to be something of a grey area. For example, some firms considered sponsoring employees to undertake part-time degrees as interacting with a university. However, unless the employees are taking part in a training scheme specially tailored to the needs of the firm, paying the fees for part-time study on the behalf of a student does not necessarily mean the firm has a relationship with the university anymore than the Local Education Authority does when it pays the fees of undergraduates. A university does not usually consider the teaching of sponsored students as part of its Third Mission activities; rather it comes under the general teaching mission. This problem was dealt with by encouraging firms to disclose any connection they had with Welsh universities. Any connections that could not be considered interaction were excluded. Firms were also encouraged to give additional reasons why they chose to interact or chose not to interact if their reasons were not included in the questionnaire. Internal validity refers to the ability of the study to demonstrate a causal relationship between treatment and outcome (Robson, 2002). In the current study this causal connection would be between the reasons given for interaction or non-interaction and the actual interaction or non-interaction, i.e. that the questionnaire obtains 'valid information about the respondents and what they are thinking, feeling, doing, etc.' (Robson, 2002, page 231). The process of developing questions from the interview schedule, which had been revised as the interviewing process went along to restate ambiguous or incomprehensible questions, was designed to overcome this question. Again, space was left open-ended statements was left for companies who expressed reasons not included in the questionnaire.

External validity refers to the generalisability of the questionnaire (Robson, 2002). The complete census sample means that the questionnaire results should be generalisable to the total population of firms if the response rate is acceptable. The response rate and its implications are discussed in greater detail in Chapter 4. Many of the questions, such as those concerning the universities with which the firms have interacted and sources of finances they have utilised, are purely relevant to the region under study. However, many of the questions concerning reasons for interaction and non-interaction are not context dependent and therefore should be generalisable to firms in other areas of the UK.

Secondary research: documentary analysis

Documentary analysis was also used to supplement the interviews, participant observation and survey, although it was not a major part of the project methodology. The rationale for its use followed Schoenberger (1991), who suggests that use of corporate documents to supplement interviews can increase verifiability of the data collected. This approach can be used regardless of whether the researcher regards the documents as a reflection of reality or not.

Documentary analysis has a number of uses. May (1997, page 157) suggests that it can 'allow comparisons to be made between the observer's interpretations of events and those recorded in documents relating to those events'. Further documents 'can tell us a great deal about the way in which events were constructed at the time, the reasons employed, as well as providing materials upon which to base further research investigations' (May, 1997, page 157). In the current project qualitative analysis of a variety of documents provided a contrast between the promoted view of integrating science and industry and practice on the ground, and to reveal underlying assumptions behind policy. Use of official statistics, which might also be considered a form of documentary analysis, can also provide a social and policy context to a study (White, 2003), and were used for such a purpose in the project.

Documents include written texts and photographs (Lutz and Collins, 1993; May, 1997). Documents may be primary (produced by an eye witness), secondary (produced by a non-eye witness) or tertiary (for example, indexes, abstracts and bibliographies). They may also be produced for public disclosure or private, produced for use in research or produced for personal use (May, 1997). The documents used were official statistics published by WAG and the Office of National Statistics, literature provided by firms and the technology transfer and commercialisation centres of universities, and more general guides to interaction that are available from a variety of learned societies and university-industry associations. They included statistical bulletins and publicly available data sets, private reports, conference proceedings, promotional literature and published guides, and thus fall mainly in the categories of primary or secondary documents.

Documents can either be viewed as a reflection of reality or 'representative of the practical requirements for which they were constructed' (May, 1997, page 163). If the researcher takes the second approach she or he must engage with unstated meanings within a document which can tell us more about the social world that produced the document than regarding it as a simple reflection of reality. The first approach is usually associated with positivism and quantitative analysis and the second with non-positivist movements such as postmodernism, post-structuralism and critical theory. It is also associated with qualitative analysis. This project takes the approach that documents are not necessarily a reflection of reality, although they are used to provide factual details, such as the number of people involved in certain interactions, the location of firms, and economic statistics for the region under study.

Analysis

Interviews and field notes were transcribed fully and coded, allowing categories to be established. Audio-taped interviews were transcribed verbatim; that is, including non-verbal communication such as pauses, laughter, 'ums' and 'ers' and so forth. Editing out such apparently unimportant forms of communication can change how an interviewee's words are interpreted and, therefore, such forms were retained to avoid misrepresenting the participants. The interrelationships between these categories were then explored. The approach took elements from grounded theory, but is not purely based on grounded theory, and follows Robson (2002) and Cope (2003). Robson (2002) suggests that while such an approach has been accused by more recent traditions, such as post-structuralism, of being overly reductionist and positivistic, it can still be useful in applied research. Thus it seemed suited to the current project which has several applied elements. The approach was also appealing because, as Cope (2003) argues, qualitative research can sometimes fail to make clear how certain results were achieved. She puts forward the view that 'researchers need to be much more open about their data collection, coding and interpretation' (Cope, 2003, page 457) and suggests that a grounded theory-based method of coding is one way of ensuring a systematic methodology. In grounded theory categories arise from the data. Next '[r]elations between categories and their properties are then formulated in hypotheses which are in principle subject to verification' (Bulmer, 1984, page 255), which in turn generates theory. This is not a linear process, however. The researcher constantly returns to the data and adds new data for fresh insights (Robson, 2002). Bulmer (1984) notes three criticisms of this approach in its pure form. Firstly, it asks the researcher to ignore existing theory and facts when allowing categories to arise from the data, yet as all observation is theory-laden such a practice is essentially impossible. Secondly, it is not clear where categories are sufficiently formed to stop the process of building data into categories and categories into theory. Thirdly, the link between data and theory is unclear: theory refers to categories and hypotheses. Bulmer (1984) suggests that the third criticism implies that grounded theory successfully generates concepts but fails at generating testable hypotheses (see also Silverman, 1993). While it might be argued that the last criticism assumes a rather outdated notion of Popperian falsification as the preferred mode of generating theory, and the second ignores the possibility of data saturation, when collecting new data no longer brings new insights (Robson, 2002), the first is deeply problematic. Robson (2002), however, suggests that a grounded theory influenced approach can draw on sources other than the researcher's interaction with the data to form categories, such as concepts developed by previous researchers or from prior experience in the research setting or similar settings. As the project progresses, Robson (2002) argues, the researcher should move from describing data to interpreting it and the research should become more focussed. These tasks can be achieved by looking for patterns and analysing them so as to understand a culture, identifying key events that may act as a metaphor for social values or modes of being and test sources and sets of information against other sources and sets of information. Cope (2003) suggests that following identification of categories and patterns, analysts should consider four themes in the data: conditions, interaction among the actors, strategies and tactics, and consequences. Her recommendations for analysis are similar to those of Robson (2002). She describes a process where descriptive coding of data is followed by interpretive coding which draws on the theoretical literature and indicate developing themes in the project. A series of memos is built up during the interpretive coding process. The coding and memos are then used to build themes which serve as topics in the final product. Once themes have been built it the researcher loops back to the original research questions which can then be evaluated or refined. The coding process must be fully disclosed to the reader in order to ensure methodological transparency.

Coding and theorising were performed using NUD*IST. NUD*IST is a program that has text retrieval, code-and-retrieve and theory-building functions (Richards and Richards, 1991; van Hoven, 2003). Computer assisted analysis was considered advantageous for several reasons. The transcribed interviews and notes from fieldwork generated a considerable amount of data, which if printed out for traditional cut and paste coding would have consisted of a large amount of paper that would have been difficult to keep organised and is not easily portable (van Hoven, 2003). Storing and coding documents on computer enabled better organisation of the project and allowed it to be transported easily from one workspace to the next. The provision of coding as well as searching functions by NUD*IST allowed for much quicker coding of documents than simply using a word processing program such as Word, since it is possible to automatically identify certain patterns and store them in one place for later retrieval and examination using NUD*IST. The use of computer-assisted qualitative analysis has also been credited with bringing greater rigour to the processes of sorting and analysing qualitative material. On the other hand, some authors have argued that greater rigour can be equated with an increasingly reductionist and positivistic approach to analysis (Richards and Richards, 1991). This is because computer-aided analysis can lead to detail being sacrificed for scope due to the increased volume of data that can be handled. There is a danger of the researcher failing to read the interview data and field notes in sufficient depth and therefore not absorbing it. Furthermore, the relationship between data and researcher can become reified in that identifying and naming material found in the data becomes a simple, straightforward and unproblematic process. Theoretical artefacts become 'things out there' (Seidel, 1991) in the world and the number of times they appear becomes an indication of their importance. However, if the researcher is aware of such problems, it becomes possible to guard against them. It should be remembered that the reduction of data to categories of artefacts out there in the world is quite possible without a computer and that no computer program can remove the necessity to think about how to categorise data. There is also the concern that certain programs enforce a particular type of analysis on the researcher (Richards and Richards, 1991; Robson, 2002). For example, Tesch (1990, page 303) suggests there is a danger that:

> [a] researcher might design the entire analysis process around the functions a computer makes available... The analysis would be done a certain way because the computer favours that way. As a result the computer would be allowed to invade the researcher's conceptual territory or to influence unduly the direction of the process.

However, while this may be the case with other types of program, NUD*IST, although initially designed to be used with a grounded theory approach, is not confined to one methodological approach (Robson, 2002). In addition to the above objections, computer aided analysis stands accused of distancing the researcher from her or his data (Seidel, 1991; van Hoven, 2003). For some researchers this may simply be because it reduces the physical engagement with piles of paper and numerous files (Seidel, 1991). Conversely, some authors suggest that the sight of large disorganised heaps of paper lead to feelings of loss of control and unfamiliarity with their data (van Hoven, 2003). Richards and Richards (1991) and Seidel (1991) also argue that the ease with which users of computer aided analysis can move between texts and codes allows more fluidity in the research process and greater engagement with the data.

The statistical analysis of the questionnaire results was kept as simple as possible in accordance with the view that 'simple statistics are more easily understood and more convincing' (Dorling, 2003). Thus most of the figures presented are in the form of frequency counts, cross-tabulations and location quotients. To enhance speed and accuracy it was performed using SPSS (Robson, 2002). Statistical analysis packages have a longer history than qualitative analysis packages and their use is less controversial. However, authors do warn use of a program such as SPSS does not prevent mistakes such as using inappropriate tests for the type of data collected or poor research design (Robson, 2002; McKendrick, 2003). All data were checked for accuracy before analysis. The on-line questionnaire had the benefit of saving all findings directly to a spreadsheet which could be imported into the program but there were some participant errors, e.g. firms that had submitted two entries, one half completed and one fully completed. Data from the paper questionnaires, on the other hand, had to be entered manually, so here was the possibility of inputting errors. For this reason entries were checked against the paper questionnaires following inputting.

Conclusion

In summary, then, past studies and an examination of different research traditions suggested that detailed case studies employing ethnographic methods would be most appropriate for answering my research questions. These case studies involved paired interviews between actors involved in individual cases of university – industry interaction in five Welsh industries, both on the university and industry sides. Interviews were supplemented with documentary evidence provided by the firms and universities. To contextualise these interviews a survey of firms in the industries selected for study was performed. This survey was supplemented with official statistics and policy documents. With these methods combined, the policy implications of the research findings were also addressed. In particular, the recruiting of interviewees was challenging and time-consuming. However, a number of benefits were obtained, namely a dual perspective of university – industry links which gives greater insight into relational phenomena such as social capital and knowledge exchange.

Chapter 4

Interactions between universities and firms from selected industries: characterising the Welsh experience

The aim of this chapter is to examine the extent, type and factors influencing interaction between Welsh universities and firms from the aerospace, life sciences, opto-electronics, sustainable energy and steel industries in Wales, as a means of understanding and contextualising the in-depth data from the paired interview case studies presented in Chapters 5 and 6. Three central issues are addressed. Firstly, given the project's proposed relevance to peripheral regions in general, the Welsh experience of interaction is compared and contrasted with the experiences of other regions. Using data drawn from the initial telephone survey of firms, the online and postal questionnaire, and the semi-structured interviews described in chapter 3, the chapter discusses findings on the structure of the industries selected for study. Specifically, the number of firms present in each industry, their age, number of employees, number of R&D personnel, ownership and origins are revealed, and the influence these characteristics may have on firm – university interaction within Wales is explored in the light of previous research findings. These findings are used to create a tentative model predicting patterns of collaboration within the selected industries. The actual extent and types of interaction present are then discussed in relation to the predicted patterns. Secondly, the motivations and impediments experienced by both academic and industrial partners to interaction across the sectors are also considered with a view to understanding the division of scientific labour between the two. Thirdly and finally, given that non-engagement between firms and universities in Wales has been problematised in Welsh policy, the reasons for non-engagement between firms in Wales and Welsh universities are explored for the selected industries.

The influence of industry structure on firm – university interaction

The five selected industries are quite different in average size and ownership as well as their geographical distribution within Wales. Previous research suggests that these factors will influence the amount of interaction between universities and firms (Beise and Stahl, 1999; Fontana et al, 2004; Shane, 2002; Sternberg, 1999). Additionally, technology and market factors are likely to affect firms' propensity to interact with universities. Specifically, manufacturing firms are thought to be more likely to interact with universities than service-sector firms (Broström and Lööf; 2006), as are science sector firms,[1] firms that receive government funding for innovation, firms with a higher R&D intensity and more innovative firms (Beise and Stahl, 1999; Fontana et al, 2004; Mohnen and Hoareau, 2003; Rothwell and Dodgson, 1991). Since the five industries also differ in the types of facility present (e.g. whether manufacturing, service-based, R&D or administrative), the number of high-technology firms, eligibility for government innovation funding and R&D intensity, it is likely the propensity of firms to interact with universities will also differ. Thus previous research implies that the potential for interaction in the sample of firms will be varied.

A total population of 208 firms was identified using the methods described in the preceding chapter. As explained in this chapter, the numbers in individual

[1] Mohnen and Hoareau (2003, page 135) define science sectors as industries 'with a higher intensity of innovation and R&D' than non-scientific sectors. In their study, science sector industries are 'those that produce chemicals, machinery and equipment, vehicles, electrical and electronic produces, computer services and engineering services' (Mohnen and Hoareau, 2003, page 135). Non-science sector industries in their study are manufacturers of food, textiles, wood and paper products, plastic, non-metallic mineral products, metals and furniture, providers of utilities, wholesalers, transport, telecommunications and financial intermediation.

industry categories are small compared to figures cited by the Welsh Development Agency. However, the WDA include figures suppliers that serve the aerospace, life sciences and opto-electronics industries as only a small part of their business. The 208 firms identified in this research include only those firms whose *main* business is in the selected industries. The number of firms found in each industry, the number of subsidiaries and their location are shown in table 4.1. The number of firms identified in each industry includes a range of activities, including manufacturing, R&D and administration. Geographical distribution is broken up into firms in north-east Wales (the unitary authorities of Anglesey, Gwynedd and Conwy), north-west Wales (the unitary authorities of Denbighshire, Flintshire and Wrexham), mid-Wales (the unitary authorities of Ceredigion and Powys), south-west Wales (the unitary authorities of Pembrokeshire, Carmarthenshire, Swansea and Neath Port Talbot) and south-east Wales (the unitary authorities of Rhondda Cynon Taff, Merthyr Tydfil, Bridgend, Blaenau Gwent, Torfaen, Cardiff, Caerphilly, Newport and Monmouthshire). Measuring the number of steel firms in Wales proved difficult given the structure of the Corus Group plc, which has a number of subsidiaries in Wales. The main subsidiary of the Corus Group plc in the UK is Corus Steel UK Ltd. However, the Corus Group plc is divided into four divisions. There are Corus Strip Products, Long Products, Aluminium, and Distribution and Building Systems. Each division contains a number of separate business units some of which are not legally separate entities but operate separately and some of which are legally separate subsidiaries. Therefore, there are 12 facilities belonging to the Corus Group plc in Wales, six subsidiaries and seven business units. Several of the legally separate subsidiaries operate out of the same facility as one business unit. Therefore, table 4.1 shows the number of separate firms in Wales, but the locations of the facilities are used to calculate location quotients as this gives a more accurate view of how firms are distributed within Wales. For the purposes of surveying the amount of university – industry interaction present in the steel industry questionnaires were sent to Corus business units, since these are the separate industrials actors in terms of interaction.

Table 4.1: Structure of selected industries in Wales

Type of firm		Opto-electronics	Aerospace	Steel	Sustainable Energy	Life Sciences	Total (%)
Number of firms		43	49	14	56	46	208
Ownership of subsidiaries		Thales 3	Magellan 3 BAE 2	Corus Group plc 6 Caparo Tube Group UK 3	EIS Group 3	Bristol Myers Squibb 2	22
Location quotients* (number of facilities)	Northeast	2.33 (23)	1.2 (14)	0.46 (2)	0.15 (2)	0.83 (9)	50 (22.9%)
	Northwest	0.9 (3)	0.5 (2)	0	1.35 (6)	1.64 (6)	17 (7.8%)
	Mid	0.56 (2)	0.71 (3)	0	2.55 (12)	0.26 (1)	18 (8.3%)
	Southeast	0.80 (14)	1.20 (25)	1.39 (12)	0.64 (15)	1.20 (23)	89 (40.8%)
	Southwest	0.12 (1)	0.68 (7)	1.4 (6)	1.91 (22)	0.84 (8)	44 (20.1%)

*A location quotient > 1 suggests that an industry is over-represented in an area, whilst a location quotient < 1 suggests that it is under-represented.

(Source: fieldwork)

Unsurprisingly, table 4.1 shows that the majority of firms identified are located in the more densely populated southeast, which is also home to five HEIs (Cardiff University, University of Wales Institute Cardiff, Royal Welsh College of Music and Drama, University of Glamorgan and University of Wales Newport), and is linked by the M4 motorway to the high-technology agglomerations of Swindon and Reading in England. It is firms in this southeast region of Wales that may be expected to have greater potential for collaboration. The proximity of firms in south-east Wales to HEIs might be expected to facilitate greater interaction and the development of social capital and thus collaboration between firms and universities

(Beise and Stahl,1999; Sternberg,1999), an issue considered in Chapter 5. Outside the Swansea – Neath – Port Talbot conurbation, southwest Wales is mainly rural, as is much of mid-Wales. Therefore, firms located in these areas are likely to have both fewer universities and HEIs close by with which to interact and less well developed transport infrastructure to connect them to each other. Location quotients of 2.55 and 1.91 for sustainable energy firms located mid-Wales and southwest Wales suggest that there are concentrations of this type of firm in these areas, especially mid-Wales. Therefore, these firms have a lower potential for interaction. This potential appears further decreased when it is noted that expertise which is directly relevant to the sustainable energy industry, such as research into photovoltaics, biofuels or hydrogen cells is usually located in departments of science or engineering disciplines, but two of the HEIs in southwest Wales, Coleg Sir Gâr and Trinity College Carmarthen, and one in mid-Wales, University of Wales Lampeter, have no faculty of science or engineering. The University of Wales Aberystwyth in mid-Wales also has no engineering department. There is also a notable concentration of opto-electronics firms in north Wales. Like sustainable energy firms, these firms are likely to draw on expertise in the sciences and engineering. Firms in north-Wales have only two proximate HEIs, University of Wales Bangor and North East Wales Institute of Higher Education (NEWI) with which to interact. However, these institutions do have faculties of science (Bangor and NEWI) and engineering (NEWI). Therefore, potential for interaction in opto-electronics would appear higher than for sustainable energy companies.

Other factors that might affect the amount of interaction between firms and universities are firm maturity, size and origin, i.e. whether the firm is an academic spin-out or not. Data on the age, origins and size of firms are not always as easily available as data on the numbers of firms present and their locations. For example, firms websites do not often reveal when the firm was established, the number of staff employed by the firm or whether the firm was originally a university spin-out. Thus, questionnaire and interview data are presented to give a more detailed illustration of the structure of the selected industries. All interviews with firm employees included questions on firm age, origin and size, resulting in 17 responses from this source. For firms in the population that were not interviewed, age, origin and size were measured by questionnaire. Of the 155 questionnaires sent out 50 replies were received, a response rate of 32.26%. Together these sources elicited a total of 67 responses. This rather low response rate appears to be fairly standard for a survey in this research area. For example, Beise and Stahl (1999) report a response rate of about 20% for a survey of innovation covering approximately 11500 firms from German manufacturing industries, Fontana et al (2004) report a response rate of 20% for a survey of university – industry collaboration covering five industry sectors in seven EU countries, while Chapple et al (2005) report receiving 50 usable responses from a survey of 122 British university technology transfer offices, i.e. 40.98% of the population surveyed.

Given that some authors recommend a response rate of about 90% for non-biased results (Robson, 2002), it could be suggested that the results of the questionnaire and interviews are not statistically valid. However, an argument can be made for using them to illustrate the structure of the selected industries and to make some theoretical generalisations about these industries (Robson, 2002). Since there appear to be no significant differences between respondents and non-respondents it seems reasonable to assume that the respondents' answers are quite representative of the general population. The initial respondents to the questionnaire do not differ from the respondents that required one or two reminders to reply. That is, both initial and later responses are show similar variations in the location, industry, size and age of their firms, and in whether they have any interaction with Welsh HEIs. If late responders are taken to be nearly non-responders, then respondents and non-respondents are likely to be similar. Similarly firms that agreed to be interviewed, although purposively selected for interview because of their interaction with Welsh HEIs, vary in age, size, location and, obviously, industry. Secondly, representation from each industry is sufficient for analysis, roughly in proportion to the total response rate of nearly one third of the total population. Thus, 13 replies from aerospace firms represents 25.49% of the industry in Wales; 17 replies from life sciences firms, equates to 36.17% of the population of life sciences firms; 13 replies from opto-electronics firms equates to 30.23% of the population of opto-electronics firms; six replies from steel firms represents 42.86% of the population; and 18 replies from sustainable energy firms represents 32.14% of the population of sustainable energy firms. Thirdly, the data from the questionnaire and interviews can be combined with published sources, such as firms' annual reports, to give a more accurate illustration of industry structure and interaction with Welsh HEIs. Data on the age, size, number of R&D employees and origins of the firms in the selected industries are thus presented in tables 4.2 to 4.6.

The distribution in age of the companies shown in table 4.2 implies that the aerospace, life sciences and opto-electronics industry are fairly well established, with most companies over 11 years old. This suggestion is supported by the fact there are some large aerospace manufacturing facilities in both the north and the south, most notably Airbus located in Broughton, Flintshire, and a few high-technology SMEs.

Table 4.2: Age of firms from selected industries in Wales

Age of firm	Type of firm					Total
	Aerospace	Life sciences	Opto-electronics	Sustainable Energy	Steel	
Less than 3 years	1	0	1	6	4	12
3-5 years	1	2	3	2	0	8
6-10 years	3	4	3	5	0	15
11-20 years	2	6	2	3	0	13
Over 20 years	6	5	4	2	2	19
Total	13	17	13	18	6	67

(Source: fieldwork)

Table 4.3: Number of employees in participating firms from selected industries in Wales

Number of employees	Type of firm					Total
	Aerospace	Life sciences	Opto-electronics	Sustainable Energy	Steel	
Less than 10	2	6	5	14	2	29
10-25	3	2	1	2	1	8
26-50	2	2	2	2	0	8
51-100	1	1	1	0	0	3
101-250	2	3	1	0	0	6
251-500	2	3	0	0	0	5
501-1000	1	0	1	0	1	3
Over 1000	0	0	0	0	1	1
Missing	0	0	2	0	1	3
Total	13	17	13	18	6	67

(Source: fieldwork)

The opto-electronics industry has an established high-technology cluster of firms in the northeast, which comprises both independent SMEs and subsidiaries of larger firms, such as Hoya Lens (Hendry and Brown, 2006; Hendry et al, 2000; Hendry et al, 2003). Life sciences is an established industry, with some MNC manufacturing facilities such as Norgine in Hengoed, south Wales, and Bristol Myers Squibb in Deeside, northeast Wales and some high-technology SMEs. In comparison with the well established aerospace, life sciences and opto-electronics industries, table 4.2 shows that sustainable energy industry is a more recent industry in Wales where 44%

of firms have been established in the last five years. This may be because, until recently, there has been little policy intervention to promote the growth of this type of firm although the older firms in this industry were encouraged by the presence of the Centre for Alternative Technology, established near Machynlleth in mid-Wales during the 1970s. Indeed many sustainable energy companies are located in the more rural areas of Wales and have grown up organically. The industry consists primarily of independent SMEs and not-for-profit companies, undertaking small-scale manufacturing and providing knowledge-based services, such as consultancy or turn-key installations. Unlike firms with large factories, such outfits do not require large numbers of employees which usually requires an urban location on which to draw. The sample of steel firms in table 4.2 shows a division between firms more than 20 years old and those less than three years old. This division is mainly due to the continuing presence of several subsidiaries and facilities of Corus Group plc. Since its creation by merger in 1999, Corus has closed its sizable R&D facility in Port Talbot and this site has been taken over by the Welsh Development Agency, who let the premises to small steel-related companies. According to Shane (2002) mature firms are more likely to interact with universities and other higher institutions than start-up firms. Unfortunately he does not define the term ‘start-up firm’, but assuming such firms to be less than three years old, this finding suggests that more interaction may be found in the aerospace, life sciences and opto-electronics industries than the steel and sustainable energy industries with their greater number of recently established firms.

Several studies have found that larger firms are more likely to interact with universities because of greater financial resources, better external communications, greater absorptive capacity and because universities look more favourably upon them as research partners than SMEs (Beise and Stahl, 1999, Fontana et al, 2004; Kaufman and Todtling, 2000; Mohnen and Hoareau, 2003, Rothwell and Dodgson, 1991). Absorptive capacity is thought to be positively influenced by the presence of in-house R&D in a firm (Beise and Stahl, 1999; Mohnen and Hoareau, 2003; Rothwell and Dodgson, 1991). These studies disprove a corollary of the suggestion that SMEs have a greater need to look externally to innovate (Simmie, 2005), presumably because many do not have 'a formal R&D effort on an appreciable scale' (Rothwell and Dodgson, 1991, page 127), namely that this need implies a greater likelihood of interacting with universities than large firms which have their own in-house R&D. (It is quite possible, of course, that such SMEs would like to interact with universities, but have problems identifying suitable expertise or find that universities do not wish to interact with them (Beise and Stahl, 1999; Rothwell and Dodgson, 1991). Therefore, at first sight these studies suggest that the predominance of SMEs in the sustainable energy industry apparent in table 4.3 would be indicative of low levels of interaction. On the other hand, it should be noted that the larger firms in the above sample are virtually all the manufacturing facilities of high-technology firms that undertake the bulk of their R&D outside Wales, suggesting that these facilities are unlikely to undertake much R&D. The sizable minority of subsidiaries present in the selected industries is shown in table 4.4. The division of labour between manufacturing facilities in Wales and R&D facilities elsewhere is implied by figure 4.1, which shows that just over a third of all firms have no R&D staff at all. Therefore, taking into account size and R&D capacity, and assuming that the presence of R&D capacity enhances propensity to interact with universities, we would expect aerospace and sustainable energy firms to have a particularly reduced potential for interaction and opto-electronics to have a less reduced potential for interaction.

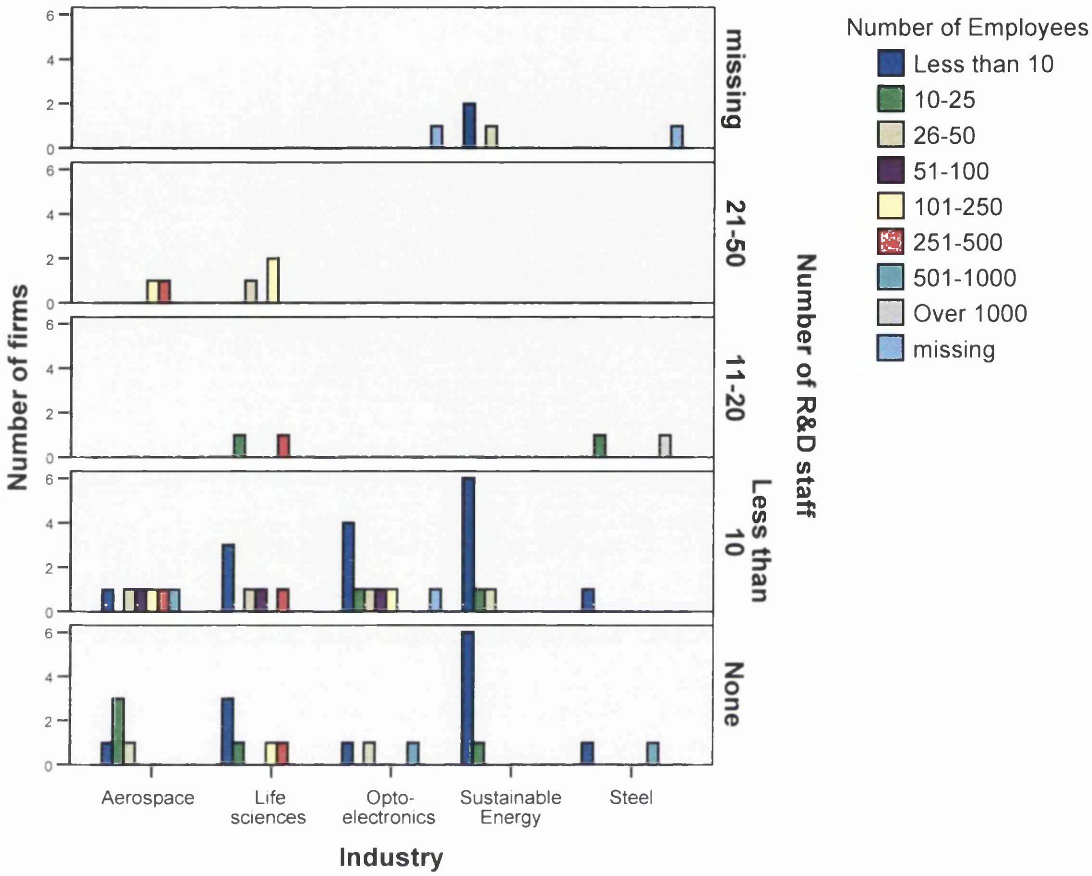

Figure 4.1: Number of R&D employees as a proportion of total number of employees for selected industries in Wales

Table 4.4: Number of subsidiary and academic spin-out firms in selected industries in Wales

Ownership or origin of firm	Type of firm					Total
	Aerospace	Life sciences	Opto-electronics	Sustainable Energy	Steel	
Number of subsidiaries	7	6	6	3	8	30
Number of spin-outs	0	1	1	3	0	5

(Source: fieldwork)

Academic spin-outs are also more likely to interact with universities, due to previous or continuing links with colleagues and research in university departments and an awareness of the academic research culture of the local universities (Rappert et al, 1999). Table 4.4 shows that spin-outs are present in opto-electronics, life sciences and sustainable energy, but no such firms were found in the aerospace and steel industries, suggesting there may be fewer links in these industries as a consequence.

From these initial findings, we would expect to see less interaction in the sustainable energy industry due to the small size, relative newness and locational peripherality of the firms present in this industry compared to the other industries although this sector also has the greatest number of academic spinouts. However, although the other industries have some larger and older firms, the amount of interaction may not be very high because of these firms do not have in-house R&D in Wales. The aerospace and steel industries have an added disadvantage of having no university spin-outs among their population which would provide ready-made university links. Whether these assumptions are supported is investigated in the next section.

Engagement with Welsh universities by firms in the selected industries

The following discussion focuses on the extent of engagement with Welsh universities in the selected industries and the factors impacting on engagement. It seeks to ascertain the levels of interaction and collaboration within the selected industries, and seeks to compare these levels with those found in other regions. The patterns of interaction and collaboration are explored taking into consideration the influences of industry structure discussed above. These levels of engagement between universities and firms and the patterns such engagement shows are important for the purposes of contextualising the Welsh experience. The discussion then moves on to motivations and barriers to interaction and collaboration. Specifically, the findings suggest that while the development of intermediary commercial centres within universities is often put forward as a way of overcoming barriers to interaction, it often serves to reinforce the division of labour between academia and industry.

Extent and patterns of interaction

It is quite difficult to compare the rate of interaction found in the selected industries with previous studies for several reasons. First, these studies have often addressed different industries, second, have tended to focus on one particular type of interaction such as research joint ventures (e.g. Link and Scott, 2005) or collaborations leading to project or process innovation for the company involved (e.g. Biese and Stahl, 1999; Kaufman and Todtling, 2000), and third have questioned firms as to whether they have ever had any interaction with universities rather than looking at a fixed time period (e.g. Keeble et al, 1999). These surveys have also found rates of interaction that differ significantly from one study to the next. As an indication, Kaufman and Todtling's (2000) survey of a wide range of firms in the deindustrialised regions found that 39.8% of Styrian firms, 29.6% of Basque firms, 24.5% of Welsh firms and 23.2% of Tampere firms had universities as innovation partners within their region. On the other hand, Kaufman and Todtling (2001) found only 8.9% of 517 firms located in Wales, Wallonia, Baden-Wuttenberg in Germany, Styria in Austria, the Basque Country, the Aveiro region in Portugal and the Tampere region in Finland reported having a university as an innovation partner, although they suggest approximately 34% of firms in certain German regions had relations with science institutions, defined as universities, technical colleges and contract research organisations. Similarly, Biese and Stahl (1999) found that 9% of German manufacturing firms introducing a product or process innovation between 1993 and 1996 received support from public research for their innovations, rising to 16% for R&D intensive industries. In comparison to both these surveys the 55 out of 130 firms who have some kind of interaction with Welsh universities found in the present study seems high. It is possible that this survey suffers a bias in reporting towards interacting firms, but this is not likely given that one mail-out specifically targeted non-interacting firms. It is more likely that having a university as an innovation partner or using public research to introduce a new innovation is quite different from interactions which could involve activities otherwise beneficial to the firms involved. In fact, of the 29 firms who described the contribution that interacting with a Welsh university had made to their business, only 19 firms could be described as having using the interaction to help innovate, and innovations included contributions to bespoke products and the creation of a new business as well the new products and processes covered by Biese and Stahl's (1999) survey. The remaining ten firms used universities to evaluate or validate their products, to provide testing services necessary for compliance with industry regulations or to gain consultancy revenue.

As table 4.5 shows, amongst the steel firms that responded to the survey interaction with Welsh universities is universal, a contrast to the other industries where interaction is undertaken by a minority of firms. Furthermore, it appears that despite having newer and smaller firms, rates of interaction in the sustainable energy industry are similar to the other industries. The high interaction rate seen in the steel industry is partly due to the fact that Corus sponsors an engineering doctorate scheme with students at four universities in Wales. This scheme provides skilled staff for the company's facilities in Wales. However, the fact that all steel firms responding to the survey interact with Welsh universities is at first sight surprising given the industry's image of declining, low technology manufacturing. One explanation drawn from the interview data is that traditional steel making companies in the UK are forced to innovate with their products as they cannot compete on the basis of simply providing the cheapest steel, thus leading to a greater likelihood of interaction. Additionally, most of the companies are also large and conduct in-house R&D giving them the financial resources and absorptive capacity necessary for interaction – as we have seen these are both important factors for encouraging interaction. The four smaller firms engaged in providing metallurgic services or metal products with interaction are highly innovative, another factor connected with a propensity to collaborate. Two provide services not widely available in the UK, one conducts R&D as its main business and the last has invented a combined product and process that is new to the world.

Extent and patterns of collaboration: the innovation process, academic partners, funding and type of activity

Table 4.5 shows firms undertaking substantial collaboration with Welsh universities as a sub-set of those undertaking interaction with Welsh universities. Substantial collaborative activities were defined as those involving some sort of formal contract between the firm and the HEI(s) with which they were working. Activities reported fitting this definition included: hiring academic staff as consultants to the firm for specific projects; receiving student work placements; sponsoring research students; participation in government funded university-industry research consortia; product testing; joint Objective 1 / 2 funded projects and joint ventures. Less substantial interaction included attendance of employees at university seminars for local businesses, attendance of employees at public university lectures, informal advice given by academics, lending equipment to students for their studies and sponsoring employee study at a university. Several companies were also in informal talks with academics that might be the basis of a more substantial collaboration. Indeed interviews revealed that there were often informal talks between the company and the academic before a project was formalised by the university industrial liaison office; companies usually approached academics directly with a specific problem or project in mind rather than going though the industrial liaison office first.

Table 4.5: Engagement with Welsh universities by opto-electronics, aerospace, steel, sustainable energy and life sciences firms in Wales

Industry		Opto-electronics	Aerospace	Steel	Sustainable Energy	Life Sciences
Number of businesses with interaction of any type, 2004-2006		8	11	10	8	12
Number of businesses with collaboration with a university, 2004-2006		5	8	9	8	11
Stage of innovation process on which collaboration focussed	Basic research	✓	✓	✓	✓	✓
	Applied research	✓	✓	✓	✓	✓
	Product development	✓	✓	✓	✓	✓
	Problem solving	✓	✓	✓	✓	X
	Testing	X	✓	✓	✓	✓
Response rate to survey (number of firms replying shown in brackets)		65.1% (28)	78% (32)[1]	77% (10)[2]	47% (24)[3]	63.8% (30)

1. 10 firms from the aerospace population were not surveyed
2. 7 steel businesses were not surveyed
3. 5 firms from the sustainable energy population were not surveyed

(Source: fieldwork)

Table 4.5 also shows the stage of the innovation process on which substantial collaborations focussed. The innovation process is best conceptualised as non-linear, involving feedback loops between stages, so the stages displayed in the table should not be interpreted as steps following on from each other. The stage of basic research refers to research undertaken without a specific commercial aim, although the company involved usually hopes that useful knowledge may be an outcome. Applied research refers to research carried out with a specific commercial aim, e.g. to produce knowledge that could be developed into a new product or perhaps to develop a new instrument or process. Product development would involve taking existing knowledge to create a new product or to improve an old one, and might also involve the construction of a prototype. Problem solving refers to work undertaken to address some type of finite problem experienced by the company. This might include production problems with production processes, with products in development or existing products. Testing refers to both the application of routine procedures to test products or parts, and the development of new tests for products or parts. Testing may be used by a company to further develop and refine a product or they may have to demonstrate that the product reaches certain standards before it is saleable. Alternatively, independent testing may be a marketing tool used to give a product credibility or it may be used to identify why products have failed when in use. In practice these categories are rather difficult to separate, as the line between basic and applied research is often blurred, especially in academic subjects such as engineering, which are by their very nature applied, and within biotechnology or pharmaceutical companies who may conduct basic research in order to develop new products (Dodgson, 1991; van Geenhuizen, 2003). Indeed these products may actually be the outcomes of what would often be considered basic research, such as previously unknown genes (van Geenhuizen, 2003). Applied research may blur into product development if results feed directly into a new product, such as is possible with the development of algorithms by computer scientists. Testing may also be used as part of product development. However, table 4.5 does show that collaboration can be relevant to companies in all stages of innovation, rather than being purely confined to basic research and applied research as is suggested by the linear model of innovation. No life sciences companies reported making use of universities for problem solving. This may be because larger firms tend to be subsidiaries that have expertise within the parent company from which to solve problems, even if this expertise is not in Wales. Furthermore, the smaller firms tend to license their ideas rather manufacturing products. Additionally, there may be lack of suitable expertise within Welsh universities. Opto-electronics firms did not make use of universities to undertake testing, possibly because more firms in this sector than in other sectors provide knowledge or distribution services, such as consulting and supplying other organisations with products made elsewhere, which do not require testing, or that testing expertise needed by these companies is less likely to be provided by universities.

A total of 35 interacting firms revealed the type of academic school or department with which they were collaborating (see table 4.6). There is some blurring between the categories as interactions included one with an engineer working in a business school and three interactions with an institute of medical engineering and medical physics, which do not fit satisfactorily into either the 'physical science' 'biological science' or 'engineering' categories. The break down of departments and schools taking part in interaction shows the difficulty of delineating 'applied' and 'basic' research. Most academic interviewees felt that their research was 'applied', apart from one computer science researcher. Nevertheless, many of the projects involved substantial intellectual problems. Working with industry was also thought to contribute to the teaching curriculum. Academic engineers, unsurprisingly, expected most of their undergraduates and postgraduates to go into industry once they had completed their studies. For this reason, one went as far as saying:

> I do not understand how you can meaningfully educate engineers unless you have very close links, um, with the kinds of industry that will eventually be employing them. I think an education which is divorced from that, well, let's just say it's lacking something, in my view.
>
> (Head of school, male, south-Wales university)

Table 4.6: Academic fields of study taking part in interactions with selected industries

Academic field of study	Type of industry					Total
	Aerospace	Life sciences	Opto-electronics	Sustainable energy	Steel	
Physical, natural, computer & biological sciences	2	8	4	3	1	18
Engineering	4	2	0	3	4	13
Business / Innovation	0	2	0	0	0	2
Social sciences, architecture and arts/humanities	1	0	1	1	1	4
Total	7	12	4	8	6	37

(Source: fieldwork)

The interviews and questionnaires revealed that 10 firms had utilised external funding available for firms interacting with universities. The types of funding utilised are shown in table 4.7. The most common type of funding was a Knowledge Transfer Partnership (KTP). Four firms had benefited from European Structural Funds. Given the huge number of funding schemes available to Welsh firms for undertaking collaboration with universities this fairly low take-up might be considered surprising. Interviews with technology transfer staff, academics and firm employees suggested, however, that the sheer number of schemes available to firms is confusing. Furthermore, the process of applying for grants is usually too complicated and time consuming for smaller companies for whom time spent on grant application means less time bringing in other revenue with a guaranteed return. Grants also often take a long time to be processed by the authorities, which can be difficult to reconcile with the timescale required by many firms. In addition to these disincentives, many SMEs are not eligible for certain types of funding because they are subsidiaries of larger companies; being a subsidiary excludes them from the funding even if they do not receive any funding from their parent company. European Structural Funds are also not available to firms outside eligible areas. These types of funding problems are discussed at greater length in Chapter 7.

Table 4.7: Sources of funding utilised by firms in selected industries interacting with Welsh universities, 2000-2005

Type of funding	Type of industry					
	Aerospace	Life sciences	Opto-electronics	Sustainable Energy	Steel	Total*
HELP Wales	0	1	0	1	0	2
GO Wales	0	1	0	0	0	1
Objective 1 or 2	0	1	0	3	1	4
Overseas students' award	0	1	0	0	0	1
Research council award	0	0	1	0	2	3
KTP	1	3	0	1	1	6
Government research consortium	0	0	0	0	1	1
EU CRAFT	0	1	0	0	0	1
Missing	0	1	0	2	3	6
Total	1	8	1	7	14	25

* Some firms utilised more than one funding source

(Source: fieldwork)

Of the 55 firms reporting engagement with Welsh universities, 47 (85.5%) firms were undertaking substantial collaborative activities between 2004 and 2006. The types of activity undertaken in substantial collaboration found in each industry are shown in table 4.8. Several of the collaborations involved more than one type of activity, therefore the number of activities undertaken is greater than the total number of collaborations. For example, one company became involved with a university to take advantage of Objective 1 funding, resulting in the formation of a second company and the recruitment of a PhD student. Sponsoring university research was the most common type of collaboration; this included sponsoring both PhD students and university staff, sometimes contributing 100% of a student's fees and maintenance or paying for a research assistant to working exclusively for them. Student placements usually involved MSc projects. The Knowledge Transfer Partnership (KTP) scheme can also involve study towards a higher degree but in a less traditional format. This government funded scheme involves a graduate associate employed by the university working on a specific one to three year project for a firm which can also be written up for a further qualification. The associate is usually based at the firm with an academic supervisor who visits the firm for half a day a week. After the project's completion, the associate is often employed by the firm.

Table 4.9 shows the aims of the collaborations undertaken by firms with universities. Firms choose to sponsor university research in the hope that collaboration will ultimately make a contribution to new products or processes by providing relevant knowledge or product development, or to solving problems experienced by the firms. Sponsoring university research can be a relatively inexpensive way of doing this, especially if the firm is topping up the maintenance grant of a research student. For instance, the opto-electronics company OE2 had decided to sponsor two PhD students on related projects, in the hopes that these projects would lead to an updated product for the firm by the time that the patent on their current technology expired, while the large steel company, S1, had implemented the results of a doctoral project that had succeeded in solving a problem with a particular coating that had tended to peel in hot climates. However, despite their projects' strategic importance to the firm, OE1 noted that the scope of these projects was slightly restrained by the academic requirements of a PhD project. S1, which had sponsored several doctoral projects, also found that a project that had appeared relevant to the firm's needs when it began could be quite irrelevant by the time it was completed, due to the lengthy minimum candidature period of such projects. Student placements can be another way of obtaining inexpensive R&D, although they can also be used purely as a way of building a good relationship with a university. Thus for CE5, an academic sustainable energy spin-out, the MSc students conducting projects at the firm acted as its chief source of R&D. On the other hand, the large steel company, S2, took student placements because they wished to develop a closer partnership with their local university and hoped that such placements would act as a recruitment tool. The results of these students' projects were not thought to be directly relevant to the company. Independent evaluation of products is favoured both for reasons of prestige and convenience. An academic endorsement can mean greater credibility for a product and a number of universities have set up commercial centres to provide local testing services at a rate cheaper than that of a private company. Therefore S5, an SME that has developed a novel steel product, employed a local university to evaluate their product. They used the independent academic evaluation as a marketing tool, convincing initially sceptical multinationals, such as

Ford and Jaguar, to adopt their product. In contrast, the aerospace company, A2, used a university commercial centre to test products that had failed in use because it

Table 4.8: Type of collaboration with Welsh universities by selected industries in Wales

Industry		Opto-electronics	Aero-space	Steel	Sustainable Energy	Life Sciences	Total
Type of sub-stantial collabo-ration	Sponsoring university research	4	3	4	3	3	17
	Use of university services, e.g. product testing	0	2	3	1	2	8
	Consultancy from university	4	0	1	1	1	7
	Objective 1/2 project	0	0	2	2	0	4
	Students placements	0	0	0	2	2	4
	KTP	0	0	0	1	2	3
	Research project with firm and university as equal partners	0	0	1	1	0	2
	Contract to perform research for the university	0	0	0	2	0	2
	Commercial-isation of research	0	0	0	1	1	2
	Member of government funded research consortium	0	0	1	0	0	1
	Company staff on academic advisory board	0	0	1	0	0	1
	Academic on advisory committee	1	0	0	0	0	1
	Joint Venture	0	0	0	0	1	1
	EU CRAFT project	0	0	0	0	1	1
	Member of staff lectures at university	0	0	0	0	1	1
	Unknown	0	2	0	0	1	3
Number of substantial collaborations		9	7	13	14	15	58

(Source: fieldwork)

provided a cheaper and more convenient service than that of a consultancy organisation. These benefits were felt to outweigh the fact that reports received from a consultancy organisation could be presented as received, whereas the reports received from the university centre were incorporated into a larger report written by the firm. Other types of collaboration, such as government funded research consortia and EU projects are competitive and have long and complex application criteria and procedures, which may explain their low numbers. It was over a year before steel-related service company, S3, and its academic partner saw their Objective 1 project get underway, although the project did allow S3 to spin-out another company. Links such as the university spin-in firm or the cases of academics or company members sitting on company or university advisory boards seem to be the result of long running and well developed relationships between firms and universities. For example, the academics sitting on A2's advisory board were from universities with which the firm had had long-term collaborative projects, from which they had recruited skilled staff and from which they had obtained testing and design services.

Motivations for and barriers to interaction: universities and firms

Of course, the relationships that companies form with universities are not one-way; universities also aim to achieve certain results though working with firms. Interview data summarised in table 4.10 present motivations given by both industrial employees and academics for working together. These interviewees also suggested a number of impediments to interaction which had limited the extent of the interaction, prevented certain aims from being achieved or restricted further interaction between the partners. Thus table 4.10 demonstrates some of the tensions that arise when two

Table 4.9 Aim of collaboration by firms in selected industries in Wales

Industry	Opto-electronics	Aerospace	Steel	Sustainable Energy
Development of new product / solution	✓	✓	✓	✓
Enhanced image of company's corporate responsibility	✓	x	x	x
Independent evaluation	x	✓	✓	✓
Improved company strategy	x	✓	x	x
Recruitment of skilled staff	x	x	✓	x
New company	x	x	✓	✓
Use of specialist equipment	x	x	✓	x
Consultancy revenue	x	x	✓	x
To save the company time	x	x	x	✓
Prestige for firm	x	x	x	✓
To take advantage of available funding	x	x	x	✓

(Source: fieldwork)

socially, culturally and economically distinct spaces are brought together through interaction. As far as motivations and impediments from the point of view of academia are concerned these findings broadly match those of D'Este et al's (2005) survey of university researchers in the UK. The table is arranged to show similarities in the motivations and impediments to interaction perceived by academia on one side and industry on the other. For example, both parties are likely to be looking to access expertise, knowledge or information that is not available internally within their organisation. Thus a firm may look for academic expertise that can solve a technical or logistical problem, or knowledge which can be harnessed to allow entry into a new market. The academic on the other hand, may be interested in obtaining a new research problem, attracted by the idea of working with real world data or by the possibility of moving into a new research area. Relations between academics and firms would thus appear to allow both actors to access resources that they otherwise would be unable to access; i.e. they are a form of bridging social capital (see Chapter 6). However, though the academic and industrial objectives are *prime face* compatible, a number of factors are at play that prevent these objectives from being easily realised, such as different requirements in terms of the knowledge generated, differing priorities and timescales, and issues such as mistrust of the other party and problems communicating.

Table 4.10: Motivations and impediments to collaboration between Welsh universities and firms in selected Welsh industries

Motivations for collaboration		Impediments to collaboration	
Universities	Firms	Universities	Firms
Access to expertise, knowledge or information – e.g. problem / data for research, new field of research	Access to expertise, knowledge or information – e.g. problem solving, new market to be accessed	Industry problems not viewed as interesting academically, industrially-funded research not respected.	Perception that knowledge / expertise of universities is not useful, or problems finding knowledge / expertise needed
Training researchers (enrolment, project)	Gaining skilled employees	RAE-returnable research and teaching a priority	Research timescale too long for firms
Funding for research	Payment for contract work	Research Council funding more prestigious	Lack of resources to fund interaction
RAE returnable publications, enhanced IP	Improved product or process, enhanced IP	Problems communicating/exchanging info., differing objectives (PhD v product, timescale)	
Contribution to Welsh economy (i.e. 3rd Mission)	Contribution to Welsh HEI and local community	Preference for working with large companies	Mistrust of universities

(Source: fieldwork)

The existence and effects of a spatial division of labour on interaction are evident in the left side of table 4.10. Previous research has shown that scientists who eschew publishing and peer recognition in favour of activities such as consulting and patenting may be penalised by academic work evaluation systems (Beesley, 2003;

Lomnitz and Chazaro, 1999). Indeed the British Research Assessment Exercise (RAE) does just this: consultancy is normally deemed ineligible for evaluation because it applies existing knowledge as opposed to producing new knowledge (RAE, 2005). Lomnitz and Chazaro (1999) suggest that such penalisation occurs because the favoured type of knowledge production in universities is basic research as opposed to applied research, whilst Beesley (2003) claims that this state of affairs has arisen because the linear model of innovation is still alive and well in policy making circles (Beesley, 2003). There is some evidence for these claims in table 4.10, although most academics felt that attitudes to industrial interaction were changing. A number of academics said that they had initially undertaken interaction with companies because they enjoyed the experience rather than because they were encouraged to do so by their employer. However, with the introduction of the third mission to the academic remit, i.e. a further responsibility, beyond research and teaching, to contribute to society, interaction with companies was now officially endorsed. It was the enjoyment factor that motivated these academics to continue with such interaction, because notwithstanding the university's official endorsement of such activities, they were still felt to be less academically prestigious. Despite the universities' changing attitudes towards interaction, academic interviewees usually felt that interaction should not interfere with their RAE research activities. The knowledge output from academia is regulated by notions of prestige, which dictate which types of research problem are worth solving and which types of funding are valuable, and the most valuable are those that appear to be divorced from the commercial world. Some academics do not consider industrial problems academically interesting because these problems may be seen as routine, trivial or not needing true research to solve them, as they will not lead to publications in peer reviewed journals that are needed for a favourable evaluation in the RAE. They also favour Research Council funding over industrial funding because Research Council funding is looked upon more favourably by the RAE, although some of the academics interviewed felt that in recent years Engineering and Physical Sciences Research Council (EPSRC) had encouraged interaction by requiring industrial involvement in the projects that it funds. Furthermore, different knowledge requirements can lead to conflict when a company sponsors a PhD: the student may be expected to produce one type of research to satisfy academic standards and another to contribute the development of a commercial product. For example, the director of a north Welsh life sciences SME explained why his company employs a research assistant in addition to sponsoring PhD projects:

> If it's a studentship you have to have in mind that they need an academic thesis and that might not necessarily be relevant with all your objectives with the industrial side of it [...] We want a facility to respond quickly and to have it within our powers to change the work programme like that, because you never know which is going to be the most important project. It could change within a phone call, and, yes, it's that ability to switch and react that you just couldn't get from a PhD studentship.

Companies, on the other hand, may perceive university research as ceasing to be relevant to their work once they get to the stage of taking their idea to market, or become frustrated by what they perceive as a lack of focus on the side of academic researchers.

Many of the impediments were due to the development of different working practices as a result of the established division of labour. As far as academic publications are concerned, companies may feel that the information that they contain is out of date by the time it reaches the public domain. This applies to research council funded and other publicly funded work and is not necessarily due to embargoes placed on the publication of academic work in order to protect the university's or a sponsor's intellectual property. Rather it is because of the lengthy academic publishing process. The in-depth research necessary for a PhD project also requires a timescale that does not always suit the commercial timescales of a company. Different working practices can also lead to communication problems between the two parties. For example, because of commercial secrecy companies may be reluctant to give certain data to their academic partners, such as the composition of a material that they wish the partners to study, impeding the academics' ability to carry out the study. Alternatively, academics may be disinclined to contact their industrial partners, even after requests for information. Furthermore, many academics and technology transfer staff interviewed expressed a preference for working with large firms. This is because even the smallest university in Wales is considerably larger than the average firm, and as large organisations, universities feel more at home working with other large organisations, who usually have more resources available to fund university projects on the scale they are used to acquiring from academic funding sources, and are closer in organisational structure. SMEs may be intimidated by universities, particularly if they do not know exactly where to go for the expertise they require. The industrial liaison offices in most Welsh universities are small and SMEs do not always appear to be aware of them. In addition, some SMEs expressed a mistrust of the motives that universities had with small companies, suggesting that often they chose to work with SMEs because it allowed them to access European Structural Funds, rather than from a real desire to benefit such firms. As discussed in Chapter 7, such suspicions are not always totally without foundation.

University intermediary centres: deepening the spatial division of labour?

The preference universities show for performing long-term research projects with large companies has been addressed by the policy makers and universities. In recent years the establishment of intermediary centres within universities for the provision of testing services, routine analysis and short-term research projects for firms has been encouraged by the WDA[2] and by the use of European Structural Funding. These centres allow universities to take up work from companies that they would otherwise consider not academically interesting, too short term or not bringing in sufficient funds. They include the CETICs, the Welsh Centre for Printing and Coating and AquaCulture Wales at the University of Wales Swansea, the contract research group at the National Centre for Product Design and Development Research (PDR) at UWIC, and the University of Glamorgan Commercial Services Office (UGCS ltd.). Most of these centres employ business managers and/or technology transfer staff to deal with the administration and marketing side of running such centres. Some also employ research staff who spend the majority of their time on contract work for the centre. These centres could be seen as a further stage in the division of labour between university research and industry. Within them the less academically fruitful industrial work is to some extent separated from the 'true' academic research, i.e. research that will lead to publications or PhDs. Some centres, such as the PDE department in the University of Glamorgan, even have their own building, separating them physically from spaces where traditional university research and teaching take place. The presence of business managers and administration staff makes a part of the university more commercially oriented: a type of half way house between academia and industry, allowing the spaces of

[2] Although the WDA has now been subsumed into the National Assembly, it still carries out the same activities as it did as a separate body.

academia and industry to become blurred without letting the space of academic research become too closely in contact with that of industry. However, such centres are not immune from the traditional demands of university work. For academics that work both for such centres and who also must contend with the demands of producing RAE research, dividing time between them can still be difficult. One senior academic described how he had ceased heading one such centre because he was contracted to spend half of his time working within the centre and half of his time working within his department, but was still expected to be returned as a full member of staff for the RAE and needed more time to concentrate on publishing for a successful return. This state of affairs could be interpreted in the light of Massey et al's (1992) contention that attempts to integrate academia and industry are often impeded by the simultaneous maintenance of the traditional division of labour been high-status mental labour in academia and low-status manual labour in industry, thus reinforcing rather than reducing the barriers to collaboration. Here the division of labour is being maintained by the RAE and its focus on publication in top ranking academic journals as opposed to practical applications of knowledge.

Intermediary centres have also ended up providing services to firms other than those which were originally intended to benefit from their establishment, as the academic preference for long-term research projects combines with a market driven model to prevent smaller businesses from accessing the services provided. For example, WDA funded operations such as the CETICs were originally designed to focus on providing services to SMEs in Wales. However, as one interviewee described, the CETICs must become self-supporting within a fixed number of years. Most Welsh SMEs could not afford to use these centres' services without subsidies. Since these subsidies would not be available after the CETICs' funding ended the operation for which he worked had turned to providing services for large companies as these were the types of company that could afford the services provided by the centre. Many of firms were located outside of Wales because Wales has a limited number of large companies. The adoption of a market model for such centres may prevent centres from achieving one of the central aims of policymakers – that of stimulating innovation within Welsh firms and thus encouraging economic growth. Interestingly, the one centre that reported significant success working with Welsh SMEs had used this work to publish in management journals covering the area of product development in SMEs as well as technical engineering journals, effectively appropriating what might be non-academically interesting problems in the field of engineering into the academic arena by posing them as a social science issue. This type of knowledge transformation is discussed at greater length in Chapter 7.

Kaufman and Todtling (2001, page 802) suggest another reason why intermediary centres may fail to encourage innovation in firms that use their services, regardless of their size and location:

> [R]educing the barriers blocking cooperation between institutions belonging to the [science system and the business system] should not try to make all the operating principles of science-linked organisations similar to those of the business sector. This is often part of strategies to reorientate universities towards short-term applied R&D and an increased share of industrial funds. Adjusting the science system's modes of interpretation, decision rules, objectives, and specific communicative standards to those of the business sector eliminates exactly the factor which stimulates innovation: diversity. [...] Bridging – making one system's operation understandable and, thus, its output usable for another system – is required.

In other words, while intermediary centres encourage firms and universities to work together, they may not increase the innovativeness of firms or harness the knowledge within universities. Rather, it is the differences in the organisational practices of firms and universities created by the division of labour between them that sparks innovation. Communication and interaction between people with different knowledge, specialities, skills and motives increases the likelihood of combining these qualities in new and unexpected ways, thereby producing novel ideas. For example, four of the five firms interviewed that had worked with an intermediary centre had not done so with an aim to developing a new product or processes. Only one had used such a centre for rapid prototyping. The non-linear, loopy view of innovation suggests that the failure testing, product testing and consultancy revenue provided by university centres for three of the four firms should be seen as part of their innovation processes. However, radical innovation involving the development ideas for completely new products did seem more likely to come from long-term research projects.

Non-engagement with Welsh universities in the selected industries

The Lambert Review (2003) criticises British businesses for failing to respond to universities' efforts to reach out to them. This review attributes responsibility for failing to capitalise on possible university – industry links to industry rather than academia. Consequently it is pertinent to examine the reasons given by non-interacting firms for their non-engagement with Welsh universities. Therefore the online and mail-out questionnaire asked companies that were not engaged in interaction with a Welsh HEI during the period 2004 to 2006 why they were not so engaged. Results from this questionnaire contrast the problems and obstacles encountered by interacting firms with those that had been experienced by non-interacting firms.

Responses of the non-interacting 39 companies that answered the question about why they did not interact with Welsh universities are summarised in table 4.11. The most common response given by nearly half of the companies (46%) was that the company conducted its R&D in-house, implying that these firms did not consider bringing in external expertise in the form of collaborative partners necessary. There are several reasons why this could be the case. Some firms, particularly the larger ones, may have self sufficient R&D teams, although 15 out of the 39 companies have no R&D employees and 21 have less than ten, making this an unlikely explanation for many firms. Firms with low R&D intensity are more likely to feel that any R&D that they do is too incremental and/or low technology to benefit from academic input. The firms may never consider approaching a university unless they discover a problem that they cannot solve. Nearly a quarter (23%) of firms said that they would not know where to go to begin interaction even if they felt it would be helpful to the firm, implying that either Welsh HEIs do not always succeed in publicising their expertise or that if they do succeed in publicising their expertise they do not have an obvious gateway through which this expertise can be accessed. Just over a fifth of companies (21%) said that their R&D was conducted outside of Wales, reflecting a spatial division of labour between their manufacturing activities and R&D. 18% of companies said that they did not need R&D and so had no need to interact, suggesting the presence of low-technology manufacturing with R&D elsewhere. It might also include distribution firms, service firms and training firms that may not consider work towards changing or expanding their activities R&D as such. An equal number felt that funding issues prevented them from undertaking interaction. These could mean a lack of resources within to fund interaction, and larger companies who have cut spending on interaction due to increased competition from low cost economies. 18% companies also said that the expertise they required from an interaction was not present in Welsh HEIs; this could either be because the companies have particularly unusual specialist needs or the lack of science and engineering departments in Welsh HEIs relative to the number of institutions. The former situation was certainly the case for one life sciences firm which stated that, in their very specialist business, expertise was mainly found outside of Wales or with oil companies. They had an academic partner in a non-Welsh institution. The other firms citing this reason for non-engagement were all in areas with universities with science and engineering departments, apart from one located in Pembroke Dock, also making the latter explanation less likely. An additional 13% companies had made enquiries to a Welsh HEI or HEIs but had found that academics or others contacted at the university had not been interested in interacting with them. The interviews with academics who have undertaken interaction with companies suggest that this could be because of a lack of academic interest in the problems presented to the university by the companies in question, i.e. that they were considered an application of existing knowledge rather than fundamental research, and thus unlikely to result in material for publication for the benefit of academics. The amount of money that particularly smaller companies are willing to part with may also not be sufficient to raise interest from universities. A possible conflict of interests arising from interaction and concerns about IP only affected a couple of life sciences companies. This result might reflect the importance of intellectual property to certain types of firm in this sector, e.g. pharmaceutical and biotechnology firms. The two firms that felt interaction was not relevant to their business were a distribution firm and a holding company for a group of related companies who had had brief interaction with Welsh HEIs. The firm that found they wanted a different type of interaction to their prospective academic partners complained that Welsh HEIs were always looking to place sandwich year students with them, a type of interaction they did not wish to undertake.

The numbers involved in table 4.11 are small, so it is difficult to speculate on the distribution of reasons for non-engagement with universities over the industries studied. However, the reason that firms cite most often, that they have R&D in-house, shows a fairly equal distribution over the aerospace, life sciences, opto-electronics and sustainable energy industries. It is also interesting to note that life sciences firms are most likely to cite funding issues as a reason for non-interaction with universities. Possibly they are more likely to want to undertake a substantial project involving basic research, which may be more costly. As discussed above, these firms did not cite problem solving as a reason for interacting with a university and life sciences companies who did undertake interaction included several substantial projects such as sponsorship of PhDs, a KTP, funding of a university-based research assistant, a joint venture and an EU CRAFT partner. These are all projects that need a financial or time commitment that might be difficult or onerous for a small company with limited resources, and the majority of firms answering the questionnaire were SMEs.

Thus it appears that most of the reasons that non-interacting companies give for not forming relationships with Welsh universities are similar to the impediments to interaction expressed by interviewees from firms that were interacting. The question then arises as to why some firms find it worth while to overcome these obstacles and why some do not. The interview data suggest that existing social ties play a part in surmounting the difficulties. In particular, the most common reason why many firms do not interact with universities is that they simply do not consider university research necessary to their business, whether they have their own in-house R&D, R&D outside Wales, no R&D at all, or consider university research irrelevant to their business. Only one firm that was interacting with a university gave the irrelevance of university research to their product development process as a reason why it did not have more interaction with academia. The difference between this firm and the non-interacting firms that perceived university research as unnecessary or irrelevant to their business is that it did find collaborating with a university useful for bringing in consultancy revenue which in turn helped to finance the company as it developed its product. In other words, the lack of relevance of university research to this company's product development was the reason their collaboration with the university was restricted to a project with university research centre through which the firm provided consultancy to other firms. Their collaborative work with the university had come about because of previous links the firm had with the Engineering Department at a local university: two of the firm's staff had completed their PhDs at this department.

Table 4.11: Reasons given for non-engagement with Welsh universities by firms in selected industries in Wales

Type of firm	R&D in-house	Do not know where to go	R&D outside Wales	Expertise not present	Funding issues	R&D not needed	Academics or university not interested	Conflict of interests	IP concerns	Not relevant to business	Cost higher & time-scale longer than inter-acting with another firm	University and firm want different forms of inter-action
Aerospace	4	2	2	3	1	2	2	0	0	0	0	0
Life sciences	5	3	3	2	5	1	1	2	2	0	0	1
Opto-electronics	5	2	1	1	1	3	1	0	0	1	1	0
Sustain-able energy	4	2	2	1	0	1	1	0	0	1	0	0
Steel	0	0	0	0	0	0	0	0	0	0	0	0
Total	18	9	8	7	7	7	5	2	2	2	1	1

(Source: fieldwork)

The importance of social ties is also apparent in the stories of firms that did interact with universities but had problems finding the expertise that they required for formal collaboration. For example, an interviewee from an aerospace SME described how they were searching for expertise relevant to their business. They attended university seminars aimed at Welsh firms but had failed to find an academic partner for a product development project they wished to carry out, primarily because when the academics at a seminar they had attended could not help, they did not know where else to go. Other firms described using existing social ties with a university to track down relevant expertise if they did not know where to go: first asking ex-colleagues, former lecturers or friends who worked in academia where best to go and then getting in touch with recommended contacts. In other words, social ties are important for overcoming imperfect knowledge and uncertainty as to location and relevancy of expertise in their decision making regarding academic partners. For the company in question their main problem was finding a way into such a web of contacts when they did not have any existing ties at a university. The importance of social ties is explored further in Chapter 6.

Discussion and conclusions

In conclusion, the number of firms in each of the selected industries is quite small; smaller than official estimates suggest. The potential for interaction in each industry is mixed. For sustainable energy firms the number of small, young firms located in areas with few HEIs close by with which to interact suggests a particularly low potential. Firms in the aerospace, sustainable energy and steel industries interacted with universities at all stages of their innovation processes, though life sciences firms did not make use of university expertise for problem solving and opto-electronics firms did not use universities to provide testing services. Firms tended to engage most with schools and departments in the physical, natural, biological and computer sciences. They made surprisingly little use of funding schemes aimed at encouraging interaction, possibly because these schemes are deemed by firms to have complex and lengthy application procedures and have very strict criteria for eligibility.

Firms that do carry out substantial collaboration with HEIs are mainly sponsoring university research which is a relatively cheap way of obtaining knowledge and expertise from universities. Testing services were also popular. Both firms and academics put forward a number of motivations for their decision to collaborate and also a number of impediments that had affected or limited their collaboration activities. There are many benefits to collaboration – such as research income for HEIs and funding for firms or production of trained researchers for HEIs and recruitment of skilled staff for firms – that show basic similarities between the two spaces and are quite compatible. However, the impediments to collaboration cited by firms and academics – particularly to do with the definition of academically prestigious work and disagreements over how projects should be conducted – reflect the different working practices between firms and universities and the continued fragmentation of the innovation system. The establishment of centres within universities specifically dedicated to interacting with firms and employing staff solely on such projects points to the development of a further division in scientific labour. However, insomuch as these centres still draw on the expertise of academic researchers they do not always avoid the problems associated with combining academically prestigious research with the demands of industry. The centres' market driven model also means they often do not reach the firms at which they are aimed. There is some evidence that centres with a focus on short term commercial contracts are less likely to lead to the development of new products and processes than long term, more traditional academic projects, although these centres can still contribute incrementally to the innovation process. Barriers to interaction presented by non-interacting firms are similar to the impediments put forward by interacting firms and academics. The most common reason for non-interaction by firms is that working with a university is not seen as necessary or relevant for R&D. It is possible that social ties are a reason why some firms overcome the perception that university research is irrelevant to their business and some do not.

This research finds little evidence to support Gibbons et al's (1994) suggestion that the traditional division of labour between universities, industry and other organisations is breaking down and being replaced by a radically different way of performing science involving a search for knowledge for application, an absence of disciplinary boundaries, a heterogeneous set of practitioners (academics, industrialists, consultants and government researchers), a transient and heterarchical structure, and a socially accountable and reflexive method of quality control. Rather, it supports Whitley's (2000) suggestion that regarding changes in the way scientific labour is divided in the manner of Gibbons et al (1994) is a severe oversimplification. For Gibbons et al (1994), Mode 2 knowledge production means a blurring of the previously distinct boundaries between production of basic research in universities and applied research outside universities. While the interactions involved heterogeneous sets of collaborators coming together for transient projects, the hierarchical structures of university research remain in place, as senior academics manage research performed by post-doctoral researchers and post-graduate students, with additional management input from their industrial collaborators. Quality control for the academic collaborators still involves publication in refereed journals and peer review in the form of the RAE. Moreover, while problems may be presented by industry, often they must fit with academic ideas of what type of problem is interesting for interaction to occur. As well as being applied the research usually involves an element of 'knowledge for the sake of knowledge', i.e. it would still be of interest to the scientific community even if it did not have the applications that it possesses. Whitley (2000) argues that there are considerable differences in the 'institutional arrangements governing research and education' (page xvii) across the minority world, which have also varied over time. Contending that academic interest in use-oriented research and human-made objects is not a new phenomenon, Whitley (2000) suggests that disciplinary boundaries within academia have never been completely rigid and a variety of practitioners have been involved in science throughout its history. The academic interviewees had noticed a change in university and funding council policy towards research involving non-academic partners, which usually tends to be more applied research. However, they did not see this as being a radical change in the way they were producing scientific knowledge, since many of the institutional arrangements they had experienced in the past remained in place. Whitley's (2000) suggestion that, for political and economic reasons, there has been an increase in the amount of explanatory instrumental research being carried out within the academic science community in parts of the minority world is more in keeping with the experiences of these interviewees. This type of research is one of four ways of performing research that have been in existence since the beginning of science – theory-directed explanatory research which involves no consideration of use of the phenomena explored but concentrates on explanation, instrumental research which involves no consideration of reasons for the phenomena explored but concentrates on their use, explanatory instrumental research which involves consideration of use of and reasons for the phenomena explored, and classificatory research which involves the systematic exploration of phenomena without consideration of their use or general explanation of their behaviour. These other types of research still remain in place with many academic interviewees producing theory-directed explanatory research type publications from explanatory instrumental research. This translation of one type of knowledge into another is explored further in Chapter 6.

Chapter 5

Forging links between academia and industry: the role of social capital, trust and communication

As discussed in Chapter 2, the concept of social capital is notoriously fuzzy and its definition has been widely debated (Adler and Kwon, 2002; Beugelsdijk and van Schaik, 2005; Markusen, 1999; Tura and Harmaakorpi, 2005). In the following discussion I adopt Tura and Harmaakorpi's (2005) definition of social capital as presented in Chapter 2. As argued in Chapter 2 their interpretation has the benefit of being precisely defined. Moreover, the recognition that social capital is context dependent has direct relevance to the field of university – industry links. Indeed, Tura and Harmaakorpi (2005) illustrate this facet of social capital with the example of the distinguished academic who finds that the social capital that is so useful to her in the international science community is virtually useless in the world of business. Their definition of social capital is also formulated with application to study of the regional economy in mind, and conceives of the ideal regional innovation system as having the correct balance between bonding and bridging social capital.

This chapter seeks to understand how links are forged and maintained between universities and industry in Wales, using the concept of social capital and related notions of trust and communication. Drawing on the 15 case-studies of relationships between firms and universities in Wales described in table 5.1 below, it firstly considers why certain types of relationships have a particularly important role in the development of links between firms in Wales and Welsh universities, and argues that these relationships can be considered as types of social capital. It then considers how communication and trust contribute both to the formation of bridging

Table 5.1: Summary of case-study relationships between firms and universities in Wales

Industry	Firm	Number of employees in Wales	Age of firm	Academic spin-out?	Location of firm / academic partner	Type of interaction	Length of relationship
Aerospace	AS2	101-250	Over 20 years	No	Southeast	Testing, prototyping	5-10 years
	AS3	Less than 10	Over 20 years	No	Mid-Wales / Southeast	Attendance at university seminars	Fleeting
	AS4	251-500	Over 20 years	No	Southeast / Southwest	Testing & evaluation	More than 10 years
Life sciences	LS1	26-50	11-20 years	Yes	Southeast / Southwest	Sponsored research	More than 10 years
	LS2	Less than 10	11-20 years	No	Northeast	Sponsored research	More than 10 years
	LS3	10-25	5-10 years	No	Southwest	Testing & evaluation	Less than 1 year
Opto-electronics	OE1	501-1000	5-10 years	No	Southeast	Sponsored research	5-10 years
	OE2	Less than 10	11-20 years	Yes	Mid-Wales	Sponsored research	More than 10 years
Steel	S1	501-1000	5-10 years	No	Northwest and Southeast / Southwest	Sponsored research	More than 10 years
	S2	501-1000	Less than 5 years	No	Southeast	Sponsored research, student projects	Less than 1 year
	S3 & S4	11-20 & less than 10	Less than 5 years	No & yes	Southwest Wales	Joint Objective 1 project	Less than 1 year
Sustainable energy	CE1 & CE2	21-50 & less than 10	Over 20 years & less than 5 years	No	Mid-Wales / Southeast	Consultancy to university for Objective 1 project	1-4 years
	CE3	Less than 10	Less than 5 years	No	Mid-Wales	Sponsored research, commercial use of academic research	1-4 years
	CE4	Less than 10	5-10 years	No	Southeast Wales	Joint Objective 2 project	1-4 years
	CE5	Less than 10	Less than 5 years	Yes	Southwest Wales	Students placements	1-4 years

(Source: fieldwork)

social capital, its maintenance, and its conversion into bonding social capital, and to the maintenance of bridging and bonding social capital. In order to illustrate how these factors work together, three detailed case studies of collaborations with varying records of success are presented.

Forging links: the importance of enabling relationships

Despite there being little tradition of performing R&D in Welsh industry, firms in Wales do see benefits available from working with universities. However, it is perhaps not surprising that firms do not undertake extensive or systematic searches for academic expertise with which to collaborate. Links between the firms studied and Welsh higher education institutions did not usually involve a deliberate attempt to develop bridging social capital, that is, relations across groups that allow access to resources otherwise unavailable, through a concerted effort by firms to establish strategic links through spatially extensive searching for academic expertise to contribute to in-house R&D. Rather, existing relationships were used by firms and universities to establish links with each other. As can be seen from table 5.2, the nature of these relationships vary: they may be personal acquaintances (e.g. friends), former colleagues or students, academic network members, industry network members or cross network ties formed in intermediate spaces between industry and academia, such as conferences, seminars, public lectures and regional development committees. Of these meetings between people from different organisations in intermediate spaces, especially conferences and regional development bodies, play a particularly prominent role in the forging of links between different spaces. Relationships between former colleagues and students organisations also prove a fertile source of links. Bridging social capital is evident in the context of relations developed through professional activities such as attendance of conferences or involvement with regional development scheme advisory committees. The source of this bridging social capital is the presence of individuals from academia and industry in spaces in which there is an overlap of interests between the two. This bridging social capital is often converted into a form of bonding social capital, that is, relations within groups that allow access to resources otherwise unavailable, as partnerships are self-reinforcing: if one project works well, firms tend to go back to the same university with another, often forming a fairly close knit network of contacts. This was the case for all but two of the thirteen case-study firms that had a long running relationship with their academic partner. For instance, AS4, a large aerospace firm located in south Wales formed a relationship with a local university after taking part in a programme, known as the Teaching Company Scheme (TCS), where a postgraduate student from the university had worked full time for the firm on a project, supervised by an academic from the university, who visited the firm for half a day a week[1]. This had led to an ongoing relationship with the university and the firm. Although it no longer carried out lengthy R&D projects, the firm still used the university to perform investigations on faulty parts produced by the firm – the university has become part of the firm's regularly used network of contacts.

University technology transfer staff and academics recognise that projects often arise from an ongoing relationship between the university and a firm. For this reason, academics involved with specialist technology transfer centres, which unlike traditional university departments are able to spare the extra resources needed, will consider taking on projects that would normally be considered routine or lacking in original research content. As one technology transfer employee from a south Welsh

[1] The TCS was a forerunner to the KTP scheme described in Chapter 4.

Table 5.2: Initial relationships between academic and industrial partners

Initial relationship between partners*	Aerospace	Life sciences	Opto-electronics	Steel	Sustainable Energy	Total
Professional acquaintance between individuals at firms and university, e.g. attendance at public lectures, conferences, membership of regional development bodies	1	1	1	1	3	7
One partner approached the other with proposal of undertaking sponsored research project	1	2	1	1	1	6
Former research student(s) / employees of university at firm	1	1	1	0	2	5
Firm spun-out of university / joint venture	0	0	1	1	1	3
Personal acquaintance between individuals at firms and university	0	0	1	1	1	3
Professional acquaintance between individual at university and intermediary working on behalf of firm	0	0	0	1	0	1

*There may be more than one type of relationship initially present. Firms may have more than one academic partner.

(Source: fieldwork)

university put it, taking on such projects can enable a university to 'to get a foothold in a larger company' in the hope of performing more original research for them in the future.

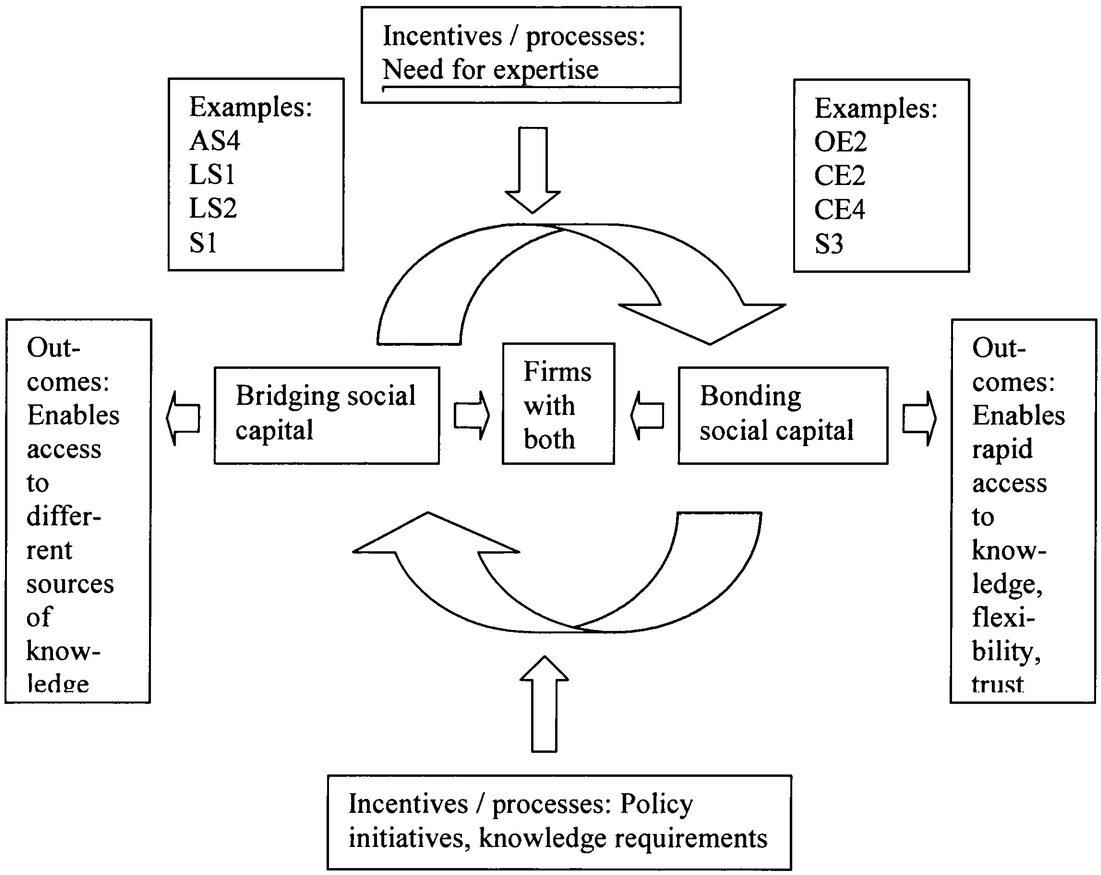

Figure 5.1: Interrelationships between bonding and bridging social capital

The utilisation of personal contacts such as former colleagues or friends, on the other hand, seems more a case of converting bonding social capital into bridging social capital, as these contacts become gateways between the spaces of academia and industry. Such is the case for a small sustainable energy consultancy in mid-Wales, CE1, with their interaction with a university in south Wales. The link between the two organisations had been established following a chance meeting of a consultant from the firm with an academic collaborator of her former PhD supervisor. The consultant found that the project with the university allowed her useful contact with other academic institutions with which she did not have previous personal contact, and access to academic literature, previously unavailable. Her social capital therefore helped to overcome the limited time and financial resources of her firm and provided access to new publications, new researchers and recent projects that would otherwise remain inaccessible because she was no longer part of the academic world. For their part, the research group gained access to expertise on the socio-economic impacts of their research, which was unavailable from their academic contacts.

If an initial project is successful, the bridging social capital can then develop into bonding social capital, as firms return again to universities for further projects, developing relationships between firm employees and academic researchers who may have met during the initial project, or may have not met before but are aware of the success of previous work. Such was the case for OE2, a spin-out opto-electronics company located in mid-Wales. OE2's founders were personal acquaintances, one of whom worked for the local university as a lecturer. The academic founder continued working for the university while the other founder became the technical director of the firm. The founders' relationship allowed OE2 to build a very fruitful relationship with the academic founder's department involving the sponsoring of several PhD students whom he supervised. After approximately a decade of such collaboration the academic's research interests evolved in a direction less useful to the firm and the firm employed its own in-house researcher rather than sponsoring further PhDs. However, the academic continued to lend the firm equipment used for their in-house research free of charge and provide advice on an informal basis. Through this relationship the firm came to know employees at the university's industrial liaison office and attended various university functions. Thus, when the firm wished to develop their product in a different direction, they turned to another department in the university and sponsored a PhD student in this department. These interrelationships between the different types of social capital are conceptualised in figure 5.1 above.

However, the development of bridging social capital from bonding social capital does not always guarantee an ongoing relationship. In the case of CE1, both the academic and industrial partner admitted there had been a difficult working relationship during the project. CE1, who had worked with another environmental consultancy firm, CE2, on the project, felt that the research group had not provided them with data that was essential to the success of the project and could only be provided by the academic partners. Both firms also felt that the research groups' ideas about what they wanted from the project were unrealistic given that the project had been allocated a fixed sum of money as part of a larger Objective 1 project. Furthermore, these ideas lacked focus; the research group was uncertain of the project's central remit and continually suggested additions and alterations. The research group, on the other hand, was disappointed by what they saw as the firms' inflexibility in their approach to the project. As a result there were no plans for the relationship to continue once the project had finished: unlike the case of OE2, no ideas for further work together had arisen out of the project. However, the project had allowed both firms involved entry into a new field of work and had allowed them to them to form useful contacts within this field with whom future collaborations are planned.

While the origin of links may be found in the personal and professional relationships between firms and universities, more formal indicators such as university or firm reputation and expertise are often used to justify the choice of partner *ex post*. For example, one steel company employee explained the selection of a department as the firm's academic partner primarily in terms of university reputation:

> ...the Civils Department or Research Department was, I think, awarded two years in a row... the best...research department or something like that in terms of [the firm's product], or in terms of civil engineering...which caught my eye a couple of times and as I knew one or two people there anyway...it was quite a simple decision.
>
> (Steel company employee, male, south-Wales)

Despite this emphasis on research expertise (the details of which are noticeably a little vague), his knowledge of the department and who to contact came through personal and professional links:

> I used to work for...a structural engineering company here...and...I worked for seven years so I knew one or two of the professors at [the local university], not just from people that I was working with and talking about them, but from going to evening lectures and hearing them talk and meeting them at those various functions. I also have a friend of mine who is a lecturer in the department as well.
>
> (Steel industry employee, male, south Wales)

Firms venture outside their network of personal and professional relationships when they require expertise that these relationships cannot provide. One source of information about university expertise is the Centre of Expertise (CETIC) scheme, whereby certain research centres within Welsh universities receive accreditation from the WDA in certain areas of expertise. Academics also mentioned firm enquiries coming through to them from the WDA and associated organisations such as Know-How Wales, and through their university's industrial liaison office. Some made visits to firms which were arranged by technology transfer staff in the university who made contacts through attendance at industry events, cold calling and other promotional activities. Though many of these contacts and visits were local or at in least in Wales, some were elsewhere in the UK.

Forging links outside Wales

In contrast to collaborative links with partners inside Wales, the choice of an academic partner outside Wales is more often informed by research group reputation in a particular area of expertise than by personal contact: a direct formation of bridging social capital. The sources of this bridging social capital vary. One steel company employee claimed that his firm's primary means of finding academic partners was through their publications, though the firm's collaboration with a local university had been established through personal and professional contacts. As well as publications and technical magazines, companies also mentioned the internet as an important source of information on academic expertise outside their range of contacts. However, one steel company did sound a note of caution regarding such sources. They relied on their long-term academic partners to assess potential new academic partners' credibility. As an interviewee from the firm stated:

> …we have lists of academics that could work on things but you just don't know. It's one thing being Dr. So-and-so and you have expertise in whatever but understanding whether they're actually good or not, it's difficult to work out.
>
> (Steel company employee, male, south-Wales)

Firms also learn about certain research groups' specialisms through diffuse industrial or academic networks rather than through some form of codifiable process. Particularly pre-eminent research groups in a relevant field will be well known in such networks and so collaborations established by these more remote connections usually involve a more obvious linking of interests between the firm and university than those between local partners. Thus, more remote connections may be particularly well known in their field of research. For example, a sustainable energy firm employee suggests that his firm's contacts with universities arise from word of mouth:

> I think a lot of it is word of mouth, isn't it? Getting in contact with people. It's through people with connections to people, networking, meetings. There's no real, it's not a structured thing, is it? In a sense it's purely networking.
>
> (Sustainable energy company employee, male, mid-Wales)

Thus, personal and professional contacts may be considered social capital belonging to universities and firms, when thinking about the formation of links between universities and industry because without such relations both academics and firms find it difficult to access the resources they want.

Firms without personal contacts in local institutions find it difficult to find complementary expertise to meet their needs. There appear to be two reasons for this difficulty. Firms may find accessing partners via the university's industrial liaison office a slow and inflexible procedure. OE2, for instance, whose close relationship with the firm's founder, an academic who still worked in the local university, has been described above, found that when the academic left for a university in England the firm was no longer able to access the equipment and informal advice they had been able to access through him, as they did not know anyone else in the department on a personal level and did not feel they could ring someone they did not know to discuss a simple problem or borrow a few test tubes. Going through the industrial liaison office to obtain such equipment and advice was considered too slow and inflexible because the office was not able to deliver an answer instantly, while a personal contact could. Whilst a slow and inflexible procedure may not be too much of a problem when setting up large long-term projects which may have major returns, it is not seen worthwhile if the firm would like a simple piece of advice or service.

Possibly more problematic is the fact that, despite the efforts of industrial liaison offices and commercial research centres, firms are not sure which institution to approach, or who to approach for expertise within an institution. For example, AS3, despite a brief but very fruitful interaction with a consultancy firm working with a local university, was unable to find appropriate expertise when looking for an academic partner to develop a product wanted by a large multi-national customer. They approached academics from a local university after attending a seminar for firms in Wales held in conjunction with the university and the WDA. However, when these academics could not help AS3, the firm did not know where else to go as they did not know the areas of expertise of other local universities, nor who in these universities to approach to enquire about relevant expertise. This is perhaps not surprising as commercialisation efforts within Welsh universities is fragmented: each academic institution taking part in the study had a small industrial liaison office[2], plus a number of other technology transfer staff attached to separate commercialisation centres within the university, either externally funded, such as the CETICs, or self-financing, which are independent from the industrial liaison office. This fragmentation is evident within the University of Wales Swansea, for example, which, when the study began, had no central record of contracts entered into by university staff with firms and other organisations.

In essence there is a problem with communicating expertise present in Welsh universities to local firms: this perhaps could be seen as a lack of bridging social capital. However, this lack is not purely down to the difficulties caused by the fragmentation of commercialisation services. This fragmentation is exacerbated by pressures that firms face attempting to compete in the global economy. These pressures are faced by both SMEs and large manufacturing companies. Therefore,

[2] For example, at the start of the project one university had an industrial liaison office consisting of one full-time employee and one part-time employee, although this expanded to a commercialisation office of 12 during the project's progress. Another university had a commercialisation office of approximately four employees. These numbers are in sharp contrast to the largest commercialisation office which employed approximately 50, although the work of this division included managing all research grants for the university, including those from non-industrial sources.

an interviewee from AS4 explained that financial constraints on the firm coupled with a lack of information on the activities of local universities meant that his company no longer worked with two of the universities closest to his firm:

> I think that as it stands at the moment I don't envisage anything new with either [University X] or [University Y]. I guess, you know, that, um, what's not happening is that our, me, I'm not that familiar with where either of those two universities are driving their industry-related activity. So, and, you know, that might be just as much my problem for not keeping abreast of, um, what's happening as their problem for not telling us...But a lot of it is about communication....You've only got to look at or hear the press in terms of companies like Rover to understand that manufacturing industry in general in the UK is under severe pressure. Because there are, you know, there's a lot of activity in the Far East, everyone's saying well, we're a high-cost manufacturing environment and there are cheaper ways and cheaper places to do it. That puts an awful lot of pressure on manufacturing businesses that remain to become more and more competitive and the way to do that is you slim and you're leaner and you're, don't operate with very much in the way of excess resource, so everyone is focussed on today's issues and today's problems and achieving this month's performance figures. And, you know, I've been, I've worked for [the company] for 23 years, um, and it's a very different environment today than it was, you know, even 10 years ago and, you know, you had time to pop down to [University Y] and talk to a few people and see what was going on and read a few more of the, um, databases and websites and that sort of activity.
> (Aerospace company employee, male, south-Wales)

At the other end of the scale, an interviewee from a three person sustainable energy company described the problems faced by a technology transfer scheme run by a local university with which it was involved:

> ...in small companies people tend to have very, very little time to look at anything outside of the day-to-day activities and keeping the company running. Um, so you really need to get in there and, um, be effective in communicating what it is you are offering.
> (Sustainable energy company employee, male, south-Wales)

Issues concerning communication as a means of forming bridging social capital are therefore discussed further in the next section, which also considers the role of communication in creating and maintaining bonding social capital.

Communication from technology transfer centres and industrial liaison offices: building bridging social capital

Technology transfer staff in university technology transfer centres and industrial liaison offices tended to see their role in developing university – industry relationships in terms of communication. They were conscious that companies are often unaware of what a university can offer them. According to one interviewee:

> I think communication is key because business typically communicates one way and academia communicates in a totally different way, and therefore I guess what we're trying to do is kind of build bridges between those two types of communication and that's what we see our job to be, so, you know, how can we translate academic language into a language that would help business, other organisations understand what it is we're doing and how that might be of benefit to them.
>
> (Technology transfer employee, male, mid-Wales university)

This individual explained that the industrial liaison office in which he worked had only recently become more proactive in marketing the university to companies. Previously, the office had tended only to react to companies which approached them or had already established links with academics in the university. Their new strategy, however, was hampered by limited resources. Such observations were repeated in several instances. Academics and technology transfer staff recognised that industrial liaison offices in Welsh universities, even the biggest ones, are small in comparison to the university they serve, so their efforts tend to be constrained. Asked whether there was an identifiable process that companies go through when setting up work with the university one technology transfer employee from an industrial liaison office replied:

> Well, there should be, but the university is a big old thing…and it depends on who the company contacts.
>
> (Technology transfer employee, male, south-Wales university)

University centres dedicated to promoting university – industry interaction in a particular field, on the other hand, were able to focus their particular research expertise. Formal accreditation, such as ISO9001, signals the centres' professional approach to industry. Typically such centres employed full time technology transfer staff who had previously worked in industry and who used a three step system to communicate their activities to firms, leading from introducing the centre to a firm or giving information to discussion to assistance. The initial step involves leafleting and cold calling firms or meeting them at networking events. Next, if a firm expresses interest the centre will discuss its problems and offer some advice. Then the two will formulate a project which the centre will undertake for payment. In such centres it appears to be quite common to get as far as step two. However, reaching the stage of paid work is more difficult. Unsurprisingly, firms are quite likely to accept free advice but when it gets to the point of engaging in contractual work only highly motivated companies, such as those with a particularly troubling problem, are likely to get involved. In the words of one male technology transfer employee from a south Wales university, 'you can't sell to a company that doesn't want to be sold to'.

Nevertheless, relatively informal dialogue between the company and the research group does seem to be a precursor to many relations, so it is possible that such approaches by technology transfer staff may sow the seeds for a more formal relationship some time in the future. However, though the number of firms had approached universities for informal advice before undertaking more formal work, they had usually approached academics directly, some receiving referrals between colleagues if they had originally approached someone who lacked the necessary expertise. Informal dialogue then sometimes developed into something more concrete.

Communication and relational capital

Communication was also identified as an important part of the process of maintaining well functioning relationships, which may be seen in terms of converting bridging social capital into bonding social capital. More specifically, this bonding capital can be seen as relational capital, since it consists of lasting relations in an economic network. As we have seen with CE1 and CE2, a lack of communication may lead to the break down of collaboration. Most interviewees described using a mixture of face to face meetings, telephone calls and e-mails to keep in touch, with conference calls being popular for long-distance collaborations. Face to face meetings were thought to be particularly important. One academic from a mid-Wales university commented that video-conferencing did not seem to be popular among the companies that they worked with, even though most were computing companies:

> Interviewer: Would they rather you come in person, do they?
> Academic: Oh yes.
> Interviewer: Yes.
> Academic: I think so. Mmm, I think it's important, personal contact when you, certainly if you try and negotiate something or are trying to get a contract.
> (Professor, male, mid-Wales university)

Large-scale collaborations, for example, those involving sponsorship of several post-graduate students often involve a fixed sequence of presentations and interim reports before the submission of a final report, and the KTP scheme in fact requires collaborators to complete a fairly rigidly set number of face-to-face meetings. However, even small and proximate collaborations involve the taking of formal minutes at meetings and the exchange of reports. Because of these reporting procedures the partner who eventually received the final report always reported knowing most of the contents before they actually read it. The end result of each collaboration was virtually always in the form of a written document, i.e. it was codified knowledge. However, in many projects there was an obviously exchange of tacit knowledge during the codification process. Interviewees described visits of researchers to their partner firm and of firm employees to universities in order to acquire the types of knowledge that could not be communicated in writing or even by oral explanation. Such visits included those by academic researchers to their industrial partner to examine and use the products they were studying in order to better understand how they worked, firm employees to universities in order to work side by side with a research student in the laboratory and to examine the results of experiments or tests. Of course, where such face-to-face information exchange was particularly important to the project's success the proximity of the firm to its partner university became more significant. Where the type of work conducted is less practical and more virtual – for example, the development of computer programs or the use of remote sensing images – proximity becomes less important. So for a life sciences firm who employed a research assistant in a local university:

> … it's easier to look and discuss than I'd say something we had funded in London. It's easier to manage, it's quicker to respond and to go and have a look. If X, our research assistant, phones up and says 'Oh, I've found something strange, something interesting – it doesn't look normal' and then you've got the ability to be there in 10 minutes and check it out. So that can be critical.
> (Life sciences company employee, male, north-Wales)

But for an academic working in a computational area of research, distance was not such a concern, unless frequent company visits were enforced by the contract he was working on:

> ...the company in the Midlands are probably one of the only big companies in the UK doing sort of computer designed reverse engineering type projects and products and that, so it's natural we talk to them. Um, so if they were further a field we would still be talking to them and exploring potential products. For those sorts of things you're going to get meetings once, twice, three times a year....We're not spending a lot of time and with modern communications we can do other sort of things...e-mails, phone.
>
> (Senior lecturer, male, south-Wales university)

Of course, the ease of communication described in the above quote is also down to a form of cultural proximity – the interviewee sees the relationship as 'natural'. This feeling of belonging to the same knowledge community allows the development of another source of both bridging and bonding social capital, trust, which is discussed in the following section.

Trust: its formation and development

In some cases the less substantial interaction in which academics and firms are involved are used to build bridging social capital between the two parties and can be the basis for more substantial collaborations. Fleeting and informal links thus can be thought of as one form of Tura and Haarmakorpi's (2005) cross-field connections. As we have seen above attendance of employees at university public lectures can not only be used to build a firm's understanding of the type of expertise provided by the university but also allows the development of trusted contacts, prompting employees to turn to the university if a specific opportunity for collaboration arises. There is little evidence that there is a deliberate process whereby the parties test each other to establish trustworthiness. So while some companies develop ongoing relationships with a university following a short-term contract, it is not necessarily the case that the company was testing the university's capabilities before trusting them with a larger project. Indeed some companies undertake a large project with a university as their first project. However, there does often appear to be a period where the two parties learn to trust each other. As one technology transfer employee said of developing a long-term relationship between the university and a company:

> …there has to be trust on both sides. The university has to show it's capable of delivering what it says it can, and the company, university has to be sure that the company is going to be around and isn't going to disappear off.
>
> (Technology transfer employee, male, south Welsh university)

In other words, it appears that as Sako (1992) suggests, both parties are developing *contractual* and *competence trust* in each other which is the basis for goodwill trust.

For academics, trust in their industrial partners can sometimes be based on the perception that these partners are partial members of the academic world. So the presence of industrial actors at an academic conference seems to confer on them trustworthiness for some academics. In this case it appears conferences act as legitimising spaces as far as the development of trust is concerned. Alternatively, the presence of former academics in a firm can increase their academic partner's confidence in them. Ironically, while industrial partners with no academic partners may have a strong faith in scientific method when it may in fact be questioned, industrial partners with an academic background may be more sceptical of the techniques employed by scientists. So LS3, whose central rationale is the development of a sustainable method for producing animal food, justified the highly unsustainable testing process of their product with the statement 'for the scientific side it has to be done the way it is'. The employee of CE2 who has a PhD and has worked in academia, on the other hand, had less confidence in the methods employed by her former colleagues to undertake industrially relevant work. She questioned whether small scale demonstrations carried out by academic institutions could be generalised to the large scales required in 'the real world'. Of course scepticism is one of Merton's (1975) scientific norms, so it may be that a faith in scientific method is the basis of trust for companies in their academic partner, trust for academics in their industrial partner is more rooted in the industrial partner's ability to question the scientific method because of this shows membership of the academic world. According to one academic, constant questioning by research partners is a necessary part of producing good research and a project may suffer if the industrial partner has a hands-off approach. He suggested that:

> The problem with industry is sometimes that you may, you know, follow through a two year project and you get to the end of it and then, it isn't until then that somebody says 'Oh, well, what about such and such?' and you go 'Mmm, yes, didn't think of that', um, and you find that you've drawn a lot of conclusions based upon perhaps a slightly dodgy assumption at the beginning and that obviously can be a problem...
>
> (Senior lecturer, male, south Welsh university)

For industrial partners the initial trust they place in their academic partners seems to be founded in notions of scientific authority. Firms often appear to invest a certain amount of faith in their academic partner on the basis of a belief in scientific expertise and scientific method. Thus, for example, they are happy to let their academic partners select PhD students and additional members of staff to work on joint projects. While the firms' confidence in their academic partners' decisions is usually well founded in this area, sometimes it can lack justification. One steel company employee stated that 'there's no point doing something with University A where there's no academic that has expertise to do it'. However, his academic partner from University A confessed that at the beginning of the collaboration with the company in a particular field of metallurgical research:

> We didn't know anything about it particularly but we started doing research projects using the [collaboration] as a vehicle and that then brought us into contact with other academics in the world of [that area of research] ... and because we had the [collaboration] and the support of [the company] and we were doing some interesting work it

> kind of set up a credibility if you like, which we wouldn't have had if we were just, you know, a couple of boys working in the lab by ourselves, you know, with no industry support, so it has led them into, you know, us establishing academic networks…
>
> (Senior lecturer, male, south-Wales university)

Thus, in this case it appears that the company belief in the research group's expertise in a particular area of metallurgy was not well founded at the beginning of their collaboration, but it was this belief that allowed the research group to develop real expertise and credibility in the field in question. However, for CE1 and CE2 who, when they started their project with University B, thought that their academic partners were world leaders in the research area of the project, the realisation that their confidence was unfounded undermined the relationship. The interviewee from CE2 described her feelings following her attendance at a large conference addressing the research area of the project:

> …they send one member of the faculty but no poster, no nothing no presence really, which was a real surprise, because if you're an academic department that's what you do. It's your bread and butter and I didn't feel they'd done that. So that kind of made us a little wary about where they were going with it.
>
> (Sustainable energy employee, female, mid-Wales)

Rather tellingly, interviewees from industry who expressed confidence in the expertise of their academic partners were rather less confident in academic publications. Lack of confidence in academic publications arose because articles were often seen to have become out of date by the time they were published. Furthermore, results that might be valid at an experimental scale may not work at an industrial scale. So one life sciences company employee complained that:

> When you come out of a laboratory and do a research paper and say you've found this, you've found that and you've found this, you actually go out in the commercial world and try and turn that into what you achieved in the laboratory and it just doesn't work.
>
> (Life sciences employee, male, south-Wales)

Given such doubts, it is easy to see why personal contacts with known and proven expertise are preferred.

Trust in maintaining relationships: compromise and equality

There was some evidence that industrial and academic partners in ongoing relationships are willing to accept some negative consequences of their partnership in return for staying on good terms and continuing to receive the benefits from the partnership. Such behaviour might be seen as evidence for the existence of mutual commitment to the relationship, or goodwill trust. For example, Academic C described how, in his university's written agreement with a nearby life sciences SME the university reserved the right to publish the results of work sponsored by the firm, and so could force the firm to allow publication of results when the firm did not want to publish. However, neither Academic C nor his colleagues had ever made use of this clause, as they were anxious to keep on good terms with the firm. They were also willing to wait long periods for the firm to vet articles prior to publication.

There was sometimes the tendency for partners to characterise their relationships using kinship metaphors. So one technology transfer employee said of academic spin-out firms:

> ...a spin-out is bit like a *child*, you know, we consider ourselves to be the *mother* of a spin-out company and we have a kind of affection towards it which is, you know, the child going out into the big bad world and is independent...So you want to see it succeed and you want to help it as much as possible.
>
> (Technology transfer employee, male, mid-Wales university, emphasis added)

More common was to characterise the relationship in terms of a marriage. One technology transfer employee went as far to contrast an ongoing relationship between his university and a firm with a short-term contract in terms reminiscent of Dore (1983):

> We liken it to, um, the difference between a one night stand and a marriage. We'll do both. We prefer the marriage, though.
> (Technology transfer employee, male, south-Wales university)

Interestingly, only one set of collaborators saw their relationship in terms of friendship, perhaps an indication that most collaborators saw their partnership in terms of a formal union of different parties. The collaboration in question involved a sustainable energy SME and a university in mid-Wales. A male company employee described their relationship with their academic collaborator as one where 'we'll wander round, go out for drinks and things'. The academic collaborator involved suggested that one factor implicated in the success of their collaboration was that he and his closest collaborator / friend in the company both disliked conflict. Industrial and academic interviewees were more likely to characterise their collaborative relationships with organisations in their own sector (i.e. other firms if they were from industry or other universities if they were from academia) in terms of friendship. These relationships tended not to involve formal contracts. The use of these marriage and friendship metaphors suggests not only an expectation of commitment on both sides, but also an equal relationship. Where the relationship did not place collaborators on an equal footing it functioned less smoothly. In particular, attempts to impose the system of academic hierarchy upon firms did not go down well. CE2's respondent reported feeling intimidated when faced with a team containing two well respected professors, who, she thought, treated her and her collaborator as if they were research students and did not respond well to being informed that their companies could not perform such a large project for the sum the university could pay.

Failure of trust

Although the ways through which trust between partners is developed and maintained are quite complex the most common reason why relationships run into difficulties is quite simple. Usually it is failure of one party to maintain contractual or competence trust. Despite the fact that most projects involve written contractual agreements there is still room for misunderstanding. Since both parties look to gain from a project, there is often the assumption that they will co-operate with each other wherever necessary, and contracts are not always as tight as they could be. As the interviewee from CE2 said of their written agreement with their academic partners:

> ...you just assume, they were all enthusiastic, we thought that would be fine, you know. They want to see this done as much as we do, it's their job to get it done, that's part of their work package.
> (Sustainable energy employee, female, mid-Wales)

In particular, as is apparent in the case of CE2, exchange of information can be problematic. In their case, repeated requests to their academic partners for information necessary to complete the project remained unanswered, despite the fact there had a been an agreement for the university to provide the firm with this information. The firm eventually began to suspect that the university did not have the necessary data, and they began to question whether the university would honour the payment agreement. The university's non-response to their e-mails led to the project slipping down the firm's list of priorities; eclipsed by more enthusiastic and demanding customers. For Dr Norris, who had been supervising PhD students sponsored by a large defence / aerospace company, the opposite problem occurred – the company was unwilling to give the university the necessary data to complete the projects underway because of fears over commercial and military secrecy. In these cases there has been a perceived failure of both contractual and competence trust, since one half of the relationship feels that written or spoken promises have been broken and because of these broken promises they have had problems completing the projects to a satisfactory standard. In both cases the relationships eventually broke down completely. OE2, on the other hand, suffered a failure of contractual trust but managed to maintain their relationship with the university. This occurred because the firm had an exclusive license of a particular patent held by the university, but when this patent had been infringed by another firm the university had failed to defend its rights. As a result OE2 felt its business was suffering and was involved in legal action with both the university and the infringing firm, which was costing the firm a considerable amount of money. Because the main disagreement was with the university's industrial liaison office, the working relationship with the academic partners continued. However, the disagreement had considerably slowed the drawing up of the most recent contract between the firm and the university, since firm had become much more conscious of possible loopholes that the university might use to exploit the firm.

As well as failure of contractual and competence trust, discourses of power also seem to be at the root a more generalised mistrust between actors in the regional innovation system. Specifically, these are moral discourses concerning power in the regional development system and use of regional development funding. Thus, the perceived appropriation of regional development funding by universities and government bodies to fulfil their own agendas is a cause of resentment. For example, three sustainable energy SMEs felt that local universities had used them in order to obtain regional development funding. In comparison to such companies, universities are large and wealthy organisations and are thus considered undeserving of such funding. However, it is because they are large and wealthy that they are able to bear the costs of the lengthy application procedures involved in obtaining the funding. So one company complained that:

> …we were going to be involved in a research project with…the university and it was under the Knowledge Exploitation Fund and it's been crazy because we were actually providing the, um, knowledge and the input there, yet it was the university that was getting all the funding for it, but it had to be undertaken at the university and to be seen to be sort of done there…
>
> (Sustainable energy company employee, female, south-Wales)

Another suggested that:

> …it wouldn't surprise me if the reason that the university brought us in was just to tick a box on a European funding form that a local SME needs to be in with the project just to make it, um, be able to receive the funding.
>
> (Sustainable energy employee, male, south-Wales)

The use of regional development funding in order to simply survive or enhance an individual's or company's power, whether it be by an SME, an academic or a politician, without having some overall purpose was seen 'fundamentally as wrong', 'really not good for anybody' and 'to the detriment of Wales'. Individual gains were seen to be at the expense of a (somewhat vague) overall good, which could only be achieved by tacit cooperation to use resources for the best purpose.

Combining social capital, communication and trust

The factors described above do not work in isolation. They are thus demonstrated working in conjunction in the three case studies presented below. While social capital could be identified in all the partnerships, these three cases have been selected because of their contrasting natures. Case study 1 discusses a very new relationship which had had some difficult teething troubles. Case study 2 examines a long running relationship, which might be considered the most successful of the three.

Table 5.3: Summary of links between social capital, communication and trust and their contribution to the development of university – industry relationships in three case studies

Case study	Types of social capital present	Communication	Trust
1	Bonding social capital has enabled development of bridging social capital	Start of project characterised by protracted discussions concerning the formal terms of the relationship; once underway face-to-face communication enhanced by seconding university staff to work on site at the company part-time	Initial use of bonding social to form the link important in developing competence trust; negotiations over formal terms of contract have produced foundations for development of contractual trust; shared interests suggest potential for goodwill trust
2	Bridging capital that has developed into bonding social capital	Spatial proximity enhances knowledge exchange through face-to-face communication, enabling the development of relational capital; lengthy relationship with staff exchanges has enhanced cultural proximity which in turn enhances communication	Strong goodwill trust based on relational capital and cultural proximity: commitment to an ongoing relationship which is seen as mutually beneficial; both sides willing to bear minor disadvantages in order to maintain the relationship
3	Bridging social capital with limited development into bonding social capital	Communication has a stop – start nature: mainly takes place in the context of formal interaction, ongoing communication between formal projects not strong	Competence trust based on previous experience, but company feels that the university is not able to fulfil work to a sufficiently rapid timescale

(Source: fieldwork)

Case study 3 describes a relationship that, despite existing for several years, had failed to grow and exhibited a stop-start nature. Table 5.3 summarises the links between social capital, communication and trust in these case studies.

Case study 1: Expanding bonding social capital into bridging social capital through trust building and communication

S3 and S4 are small subsidiaries of a larger company that provides services to the steel and other industries from several sites across the UK. S3 had been present in south-Wales for just over a year and a half at the time of interview and employed 13 people, while S4 was not yet a year old and employed 4 people. S4 had been formed as the result of a collaboration between S3 and a local university using KEF funding with the aim of providing independent testing and evaluation services to industry. The idea for S4 came from S3's industrial partners, who identified a need for the services it provides. Originally the project had involved another local university but this university had ceased to play an active role following staff changes at the institution. S3 approached the WDA for help in finding a new academic partner, which for the purposes of using the available KEF funding had to be located in an Objective 1 area and also needed to have academic credibility. The WDA were able to establish a link between S3 and University Q because a WDA employee was a former colleague of an academic at University Q and thus was aware of his expertise. However, the link was only achieved after discussions between the University Q, the former academic partner, the firm and the grant giving body. The project provided funding which enabled the university to purchase equipment which would be located on the same site as S3 to be used by both S4 and the university. S4 was to use S3's contacts to draw in contracts. Depending on requirements, contracts would be performed either jointly by the university and S4 or singly by S4. The university also had access to the equipment for their research, and had seconded two members of staff to work on the project on site, one for four days a week and the other for two days a week. As well as access to the laboratory on S4's site the university had set up a technology transfer network to promote the technology used at the laboratory to Welsh companies, and to enlist other Welsh higher education institutions for research implementation and funding purposes. This networking process had resulted in a PhD project based on S4's site, a new post-graduate course at the university, to which S4 staff contributed lectures on the technology used by the laboratory, and various publications. The university did not have a commercial objective in the project, so its aims were educational and research oriented, as evidenced by the new post-graduate course, their wish to establish local industrial training programmes with S3, the development of a PhD project and the publications based on the collaboration. The university school involved in the collaboration had a fairly low RAE ranking and hoped that its involvement with the new laboratory would enable it to expand its research expertise and increase its RAE ranking. The formal basis of the collaboration was a three-year Memorandum of Understanding and this had been extremely protracted in its formulation as the negotiations had become extremely complicated and bureaucratic. IP arrangements for individual contracts were to be decided on a project by project basis. The respondent from S4, the principal project leader, felt that as a knowledge-based organisation there was little difference between working with other companies and working with universities, although he noted that academics were more focussed on theoretical research application while industry was more concerned with the practical application of research results to make or save money. He felt that both S3 and University Q had similar aims regarding helping and advancing local industry in order to improve local economy. The academic respondent felt that working with industry was in fact easier than working with academics from other institutions, because such collaborations often involved conflict resulting from institutions jockeying for position. He had a strong personal commitment to providing a practical education to the undergraduates at his institution and also to using academic knowledge to help local SMEs as part of an attempt to contribute to the development of the Welsh economy. Indeed, he saw collaboration with industry as arising naturally in his subject area and as highly beneficial to his institution, especially in educational terms. Interestingly, he had previously worked in industry and his opposite respondent in S4 had previously worked in academia. It was this similarity in outlook that seems to have eventually overcome initial difficulties with the project.

Case study 2: Bridging social capital leading to bonding social capital based upon goodwill trust

LS2 is a north-Wales life-sciences SME established in the early 1990s, which develops both pharmaceuticals and medical devices. It describes itself as a 'virtual company' as it consists of a relatively small number of personnel in a single set of offices, which coordinates the partnerships with other organisations through which all stages of product development, manufacture and sale are achieved. From early in its conception LS2 has enjoyed a relationship with a research group from a proximate university. This had begun with the research group performing measurements and sample analysis for the company's founders, and once the company had obtained funding, evolved to the company sponsoring several PhD studentships, joint TCP and TCS (KTP) projects, and funding a research assistant based at the university. A senior member of the management had originally completed his PhD with the research group and been a member of staff at the university before eventually moving to work for the company. The research group leader's motivation for getting involved was partly to gain research income but also to secure research students and produce publications. He had worked with industry throughout his career, specifying enjoyment and learning from companies as benefits. For these reasons, he was willing to undertake TCS (KTP) projects, although they often did not involve original research. Though he remarked that collaborating with industry had been quite unusual when he had begun, he had noted a stronger drive towards doing this type of work. The company had chosen the joint strategy of long-term research projects carried out as PhD studentships and a more flexible work programme for their research assistant to provide both in-depth basic research and the ability to respond rapidly to specific problems. The close proximity of the firm to the university was important to the success of the research assistantship, since it allowed for the face-to-face communication necessary for quick exchange of tacit knowledge. Generally, the working relationship between the firm and the department has been very positive: this was one of the relationships that was characterised by the firm's respondent in terms of a marriage. The firm admits that the PhD projects have been slightly constrained by the fact that they must produce a thesis suitable for submission at the end and this might not be entirely relevant to the firm's needs, but the firm had been aware of this from each PhD project's conception and it has not been a problem for either side. Each PhD project had originated with the research needs of the firm and they had tended to raise questions which had led to further projects. The danger in this situation would be a pattern of 'lock-in', where the company ceased to look outside for new ideas. However, LS2 seems to have avoided this situation and also had some close, although not quite so extensive, links with other universities that were fairly proximate given its reasonably rural location, since the research group at University R could not provide all the expertise relevant to the firm's products.

Case study 3: Opening communication channels through bonding social capital

OE1 is a large opto-electronics firm, owned by a multinational company. It has been in existence for approximately a decade. The firm has had links with University S for several years and this relationship has included sponsoring PhDs, taking on student placements and sponsoring student prizes. As a result, a few years ago an academic involved in these collaborations left University S to take up a position within OE1. The most recent collaboration between the two has involved the sponsoring of a research centre within the university. The firm is also considering sponsoring a PhD student within the centre. From this investment, the firm hopes to receive consultancy from academic staff and the rights to any sponsored PhD, both of which would go towards providing new solutions for the company's contractual work for other organisations. The firm's academic collaborator wishes to gain money for research and a PhD studentship. The firm's point of contact into the university on this occasion had been through the commercialisation office. However, the engineer within the firm involved in the collaboration was the former academic from University S and had had a good working relationship with the academic partner during his time at the institution and was already aware of the expertise of the academic department. This engineer admitted that the firm had been good at engaging with the university but had had problems making this relationship grow. Primarily this was due to the length of time the university took to produce information required for the firm's contractual work with other organisations. Thus the main benefits to the firm were goodwill returns from supporting a local institution, access to skilled employees from the university and the availability of academic publications which would otherwise be extremely expensive to purchase. The firm's academic collaborator confirmed that the amount of money the firm was willing to provide for consultancy from the university restricted the amount of work that the university was willing to do for the firm. He felt that industrial funding did not have the same prestige as research council funding, but was a useful alternative source of funding that for as long as industrial research fitted with his department's overall research strategy.

Firms in comparative perspective

In case study 1 the collaboration had started badly with the initial academic partner dropping out. To find another partner they trusted, the firm had looked to an intermediate who used bonding social capital to forge bridging social capital between two separate organisations. The intermediate acted as an arbitrator and seems to have signalled to the firm the university's legitimacy as a partner through knowledge of their expertise. For the university, the regional development aspect of the project, emphasised through the involvement of a regional development body as an intermediate, plus the academic credentials of the project – a very well equipped laboratory open to the university and the willingness of the firm to contribute to the educational mission of the university – appealed. The presence of firm employees with experience in academia and academics with experience in industry, combined with a willingness to embrace each other's objectives helped to get the project underway. A lengthy period of negotiation was necessary before it got off the ground, but the presence of firm employees lecturing at the university and academics based on the firm's site suggests the opening of communication channels and the possibility of developing bonding social capital between the two organisations.

In case study 2 different working practices in industry and academia had not posed a problem because the two sides had been aware that they had different goals and worked to create projects suitable for both their needs. This process was assisted by the long relationship that had existed between the company and the university. This had originated from bridging social capital built by the firm's founders that had developed into bonding social capital as the research group and firm became closely linked by the exchange of employees. The firm and university now perceived each other as trusted collaborators in a mutually beneficial relationship. Both parties were willing to compromise to maintain this relationship – the firm was willing to accept that PhD theses would not always be completely relevant to the firm, while the research group was willing to take on research that was not necessarily going to lead to original research publications. They were also willing to except a two-year publication embargo on PhD theses. Here social capital had allowed two different spaces of knowledge to work together, helped by goodwill trust which was maintained by compromise and face-to-face communication.

In case study 3, the differing timescales of industry and academic work meant that the firm did not see their collaborations leading to direct financial rewards through the application of academic knowledge to individual problems. Thus collaboration was limited to one-off projects and one project did not feed into another, meaning that the relationship had a stop-start nature. Collaboration was seen more in terms of corporate responsibility to the local area, and acquiring skilled employees from the university. However, the movement of an academic from the university to the firm, bringing with him trusted relationships to his former colleagues seemed to promise hope for converting bonding social capital into bridging social capital and thus a more continuous flow of knowledge between the two organisations. In this case it would appear that different cultures and working practices were co-existing somewhat uneasily, but a gradual growth in social capital might be paving the way for a less arms length relationship between the two parties.

Conclusions

The utilisation of both bonding and bridging social capital discussed in this chapter highlights the importance of cross-field connections between the different spaces of knowledge, and the overlapping spaces where these connections occur allowing the development of bridging social capital. They also illustrate a certain amount of fluidity in the relations that make up bonding and bridging social capital, as one may develop into another. While they have often been sharply distinguished from each other as ties between homogenous groups as opposed to ties between diverse groups or as strong, dense ties versus weak, loose ties (O'Brien et al 2005; Tura and Haarmakorpi 2005), in practice it is hard to make such definite distinctions. Groups are rarely completely homogenous or heterogeneous, and ties may strength or weaken over time, thus allowing interchange between bonding and bridging social capital. Nevertheless, the concept of bridging social capital does appear useful for characterising the formation and maintenance of links between academia and industry.

Within the Welsh industries studied, personal links are very important in forging relationships between universities and industry in the region. The use of personal links formed through professional activities, such as attendance at conferences or participation on advisory panels suggest a process of converting bridging social capital into bonding social capital. In this case, a period of trust building is usual. On the other hand, the use of longstanding personal links such as former colleagues and friends suggests a process by which bonding social capital is converted into bridging social capital. This bridging social capital may then be converted back to bonding social capital, as a research group become members of a network of familiar contacts to be approached by a firm when the need arises, or vice versa. Communication is important in these processes. Strategic searching by firms for expertise does not seem to be a primary concern: even non-regional links seem to usually involve academics who are very well known in their field and so are known to firms through word-of-mouth. Thus it does appear that proximity does have some effect on the propensity of universities and firms in Wales to work together as academics and industry employees are more likely to know people in nearby firms or HEIs through personal or professional networks. Official 'third mission' departments within universities that aim to act as a bridge between firms and academics, such as industrial liaison offices and commercial research centres, are not always instrumental in communicating their university's expertise to companies. Often a firm will go through the industrial liaison office to reach as someone they already know, or specific expertise they are already aware of, rather than to look for it, and the industrial liaison office acts only to formalise collaborations by drawing up contracts between the firm and university. This is perhaps a sign of the immaturity of the knowledge-based economy in this region: commercialisation efforts by Welsh universities are fragmented and may not be particularly flexible, while firms do not systemically search for academic expertise, partly because pressure to remain competitive means any tasks perceived as non-essential are avoided. In such an environment, utilisation of both bonding social to create bridging social capital and bridging social capital to create bonding social capital is useful to both firms and universities.

Chapter 6

Knowledge flows between academia and industry: transfer, construction, translation and transformation

In the preceding chapter we saw how bridging and bonding social capital have a role to play in developing and maintaining relationships between university and firms in Wales, allowing access to resources of information, data and expertise that would be otherwise unavailable. Access to such resources leads to flows of knowledge between academia and industry as actors in both areas learn about aspects of the world that they would not otherwise know about. However, the ways in which these knowledge flows operate remain unexamined. Thus this chapter aims to explore how knowledge actually passes between the two spaces of knowledge under consideration in this project, namely academia and industry, i.e. its form and how it is transformed

Chapter 4 showed that these spaces are constructed quite differently as far as norms, objectives and working practices are concerned. This chapter begins by examining the extent to which the spaces function according to differing underlying principles which render working together problematic, and the processes that work to overcome such tensions, enabling knowledge flows. In particular, it explores the ambiguous position that the modern Welsh university occupies as both a commercial actor and a public institution, and argues that the way that its employees are able to function in both worlds and overcome seemingly incompatible frames of reference is through a translation of interests. The chapter then goes on to consider the forms that these knowledge flows take. Specifically it examines how knowledge is constructed during interaction between academia and industry, how it is translated as it passes from one space to another and how it can be ultimately transformed by different perceptions and usages in the different spaces.

The university as commercial actor and public institution: divergent roles?

As demonstrated in Chapter 4, there is an increasingly complex division of labour between industry and academia in Wales. In common with most universities in the rest of the UK, Welsh universities receive both public funding, in this case from HEFCW, the research councils and other public bodies, but also are increasingly reliant on research funding from industry and have also been increasingly encouraged to enter the commercial world directly through commercial centres, spin-out companies and patent licensing agreements. Thus the existence of commercial centres and the various technology transfer and licensing divisions allows the distinction between the university into the academic university, centred around research and teaching, and the commercial university, centred around commercial services, with the aim of allowing the university to function both as a commercial actor and a public body. However, Chapter 4 also showed that, on the commercial side, some academics are uncertain about their university's relationship with the commercial world. There is recognition that even commercial centres are not quite part of the business world in the same way as private sector companies working in the same sector. One professor noted of such a centre with which he worked:

> [W]e've got to be very careful [about performing maintenance work on software that we have created for companies] because we don't want to become just a maintenance house, which is, you know, not very exciting work and, um, it's specialised in its own way. [...] We are a funny sort of commercial outfit and the work we really want to do is to get contracts from industry to do research for them, but because that's pretty rare, because either they usually want to keep it in-house if they're big enough, you know, quite often [our work with companies has] not got a lot of original IP in it, um, but of course we

> do that sort of work because we want to keep a mixture in the centre anyway, and [...] it leads to other things.
>
> (Professor, male, mid-Wales university)

Implicit in this quote is the fundamental contradiction between the university as a commercial enterprise and the university as a public body: essentially the academic university and the commercial university are functioning according to two different and conflicting frames of reference, since they have different underlying principles. The profit-driven ethos of the commercial university pushes the centre towards performing routine work which will keep the centre running as a commercial outfit, while the academic university demands the production of original knowledge. This individual's career, like most academics in Britain, is concentrated upon getting the knowledge that he produces into the public domain through publications in order to contribute to a favourable Research Assessment Exercise outcome for his department. Smaller projects with companies that simply involved the application of standard techniques which did not produce new knowledge could not contribute to publications. Larger projects that might have been of greater academic interest because they did produce original knowledge ran into the problem that companies work on exactly the opposite remit of the university. Whilst the university continually strives to release more and more knowledge into the public domain since the amount of public funding it receives is based on its success in this area, companies generally wish to keep it to themselves in order to maintain an advantage over their competitors and also for patent[1] purposes. Firms are therefore likely to internalise the production of original knowledge if possible, or if they do contract it out to a university, to put in place provisos that prevent the university from releasing it into the public domain. It appears that Merton's (1970) norm of communism is

[1] A discovery cannot be patented if it has already been released into the public domain.

still inscribed into the academic evaluation system even as government policy and funding bodies exert pressure upon academia and industry to treat academic knowledge as a commodity, which normally entails the opposite of communism, i.e. secrecy. Thus universities in this study find themselves awkwardly positioned between the public and private sector. This is something that even deepening divisions of labour between the academic university, the commercial university and industry cannot resolve, because commercial divisions remain part of the university and thus almost always have some connection with the research and teaching missions of the university. This is the case for commercial divisions if they are located in separate buildings from the academic university and even if they are not on the same site.

Of course, this semi-public versus semi-private existence is not new for many universities in Wales, even though Wales is historically not particularly noted for its academic entrepreneurship. For example, one academic interviewee had received funding for research work from a large steel company in Wales for approximately thirty years, whilst two of the spin-out companies participating in the research were established between 1989 and 1990. However, the increasing emphasis on commercialisation over the last five to ten years, plus the introduction of student tuition fees, has made the university appear more commercially oriented. Indeed, the university as an entire organisation was often seen as a business by interviewees working in the commercial university, with such individuals characterising their place of work as a business or company. This characterisation of the university as a business may be seen as a deliberate, positive management choice or the result of outside political influences. Contrast the description given by one member of technology transfer staff of his division's industrial accreditation and expertise with the rather more apologetic stance taken by one of his peers in a neighbouring institution. According to the former:

> ...from the beginning we decided that if we were going to be serious about working with industry then we had to conform to industry standards of quality, cost and time. [...] The people who deliver support to industry are full time at that post, most of them have come from industry themselves. Um, we are ISO9001, 2000 accredited, we have, you know, international standards. Those international standards are in place to help us assure that we can deliver to those standards of quality, cost and time, and it's as simple as that.
> (Senior technology transfer employee, male, south-Wales university)

The latter interviewee, on the other hand, was not so whole-heartedly positive about the similarity between his institution and the companies it works with, expressing regret that it could not hand out advice for free:

> [Some companies] have this expectation that universities are there to give them things for free, and we're just not. We're companies just like they are, unfortunately, pretty much, these days.
> (Technology transfer employee, male, south-Wales university)

With the adoption of a commercial organisational image, whether perceived as an internal decision or as imposed from outside, comes the expectation that similar working practices will also be adopted. In fact a minority of interviewees from universities and companies had experienced little difference when collaborating with a partner from industry or academia as opposed to a partner in their own sector, with one male employee from a south Welsh sustainable energy company going as far as to say that 'when we're working with the university, it feels very much like we're dealing with a commercial company'. Perhaps unsurprisingly, interviewees from firms that expressed this opinion were all from companies that were working with the commercial university, i.e. commercial centres, as opposed the academic university in the form of research groups or individual academics.

However, the experience of the university as a commercial actor with corresponding commercial working practices is by no means universal. Other firms and indeed university divisions complained that their academic partners did not do things in an appropriate way or were not 'professional' in their dealings with companies the same way as other industrial partners. These criticisms were not limited to the academic university but were also made of the commercial university. One particularly pertinent example was the way that Lucy, an employee of CE1, and Brenda an employee of CE2, had come to be working together on the same project with their academic partner. They described the way the research group had brought CE1 into the project having already contracted CE2 to perform the study on their behalf:

> Lucy: ...[T]hey rang me and said they were doing this project with Brenda at the moment.
> Brenda: It's a slightly unusual way of doing it.
> Lucy: It was quite generally, I felt very awkward because you had the contract and they rang me, but at the same time I was / thinking
> Brenda: I don't think they perhaps understood how to do, how that wasn't really probably appropriate.
> Lucy: Mmm.
> Brenda: Because I knew you it was alright.
> Lucy: Yes.
> Brenda: But had I not known you, it might have been a bit odd.
> Lucy: If I got a contract and then I had someone ringing me up from another company saying 'Can I help you on this?' I'd be thinking 'No'.
> Brenda: Yes.
> Lucy: But it was alright because we know [each other].
> (Sustainable energy company employees[2], mid-Wales)

For Lucy and Brenda the way that the research group had brought the two companies together to work on the project was not the way such a partnership would normally develop in the commercial world and could have resulted in a complete failure, yet the research group did not to seem to be aware of their breach of normal business practices. Introducing a new partner into a project once it is underway with another would not normally be a successful way of developing bridging social capital

[2] Names have been changed to maintain anonymity

between academia and industry. However, because of the bonding social capital present between the two firms – Lucy and Brenda knew each other and recognised that they each had different but complementary expertise to contribute to the project – the academic partners' unorthodox method did not result in major problems.

Nevertheless, individuals within industry, the academic university and the commercial university, do manage to overcome these contradictions to produce knowledge. Perhaps the best way of understanding this state of affairs is by using Latour's (1987) idea of the translation of interests, the name he gives to the process in which scientists enrol other actors so that they participate in the construction of a scientific fact (e.g. germs cause wound infections) or techno-science object (e.g. the diesel engine). Specifically, he describes a reshuffling of goals and interests that occurs when the enrolled actors are steered into a progressive drift away from their original interests while still believing that they are still continuing along a straight line remaining true to their interests. In Latour (1987) this process occurs between science and industry when researchers are able to persuade their commercial backer that in order to fulfil the backer's goal of a new or improved product it is essential to gain knowledge in certain areas of basic research: his example is of the company that finds the only direct way of achieving a more efficient car is through the study of a single pore of an electrode, because this is the only way to study catalysis and catalysis must be understood to develop fuel cells, which are essential to a more efficient car. There are examples of this process occurring in the interactions in the present study. For instance, like the professor in the opening quote of this section, several academics noted that commercial work could lead to academically interesting work or have more academically interesting work fitted into it. So the owners of a small high quality food processing plant wanted a warning system that would alert them if something had gone wrong in the plant during the night so they did not have to get out of bed regularly to check physically that nothing had gone wrong. This resulted in a grant-funded piece of work performed by the professor's commercial centre that used standard software to produce a bespoke system which checked that the necessary temperatures and pressures for the process were being maintained and alerted workers if they went out of range. However, this work has also fed into the professor's academic research into the areas of model-based systems for diagnosis and diagnosis problems in chemical plants. Although the company probably did not originally see contribution to these research areas as the object of working with their academic partners, it has become a step to the goal of achieving a more efficient plant that requires less human supervision.

However, in the interactions under study, it is also clear that a translation of interests also occurs in the opposite direction, with the commercial world doing the enlisting of academic actors. This translation of interests occurs in the following manner. Behind the institutional norm of communism, which decrees that academics must share their knowledge, is the belief that scientific knowledge is (or should be) a public good. Science should seek to benefit humankind rather than being used for personal gain and for this reason it is funded by the public purse. While on the academic side, this norm manifests itself in publishing, on the industry side it results in the perception that university services are or should be free or very much reduced to taxpayers because universities are in receipt of taxpayers' money. (This opinion is encountered on a fairly regular basis by technology transfer staff, mainly from SMEs who are less familiar with contracting R&D out to other organisations). It seems difficult to reconcile the belief that scientific knowledge should be a public good with the goals of commercialisation, since the commercial use of knowledge generally leads to placing restrictions on who can access it. However, the belief that science should seek to benefit humankind rather than being used for personal gain, whilst remaining strong amongst both companies and academics, is often expressed by interviewees as a motivation for commercialisation even if this means the intellectual property rights will be held by a limited number of organisations. By assisting individual firms in this way the regional economy is strengthened, reducing regional economic disparities and ultimately benefiting the public good. Thus we see that entering the commercial world becomes a way increasing the public good. The academic university has been enlisted into the commercial world through a different interpretation of its norms. With these translations of interests operating in both directions, the university is able to overcome the contradiction in its commercial and academic goals to maintain its position between the two areas of activity, even if this occurs somewhat awkwardly.

For Latour (1987) the translation of interests is one of the processes through which scientific facts or techno-science objects are constructed, i.e. go from the status of one person's unconfirmed ideas about the world to a widely accepted truth about the world that is passed about and used unproblematically: a piece of techno-scientific knowledge. For him the idea of scientific knowledge simply being diffused from its initial place of discovery into the public domain ignores the multitude of people and objects that contribute to its existence. This idea has some important implications for the notion of knowledge transfer between universities and industry, and it is this issue of knowledge transfer that is explored next.

Knowledge transfer: construction, translation and transformation

As we have seen in Chapter 5, knowledge is transferred in university – industry interaction both in tacit and codified form. The cases where firms simply receive theses, license a technology or are taught skills, have had no technical input into the university's production of such knowledge, and the university does not adapt the knowledge for the recipient in any way, may be considered cases of pure knowledge transfer. However, these cases do not seem very common, and in fact it is difficult to identify any one of the studied interactions as a pure case of knowledge transfer. Although, most projects end with the handover of a written report or thesis, three additional processes are identifiable. These are: (i) the construction of knowledge by the interacting parties, (ii) the translation of academic knowledge into industrial knowledges, and (iii) the transformation of knowledge as it moves between different spaces.

Construction of knowledge

Knowledge transfer is a popular term for the processes involving the movement of scientific knowledge from universities to academia (see, for example, Breschi et al, 2005). It tends to be something of a catchall notion, sometimes referring to collaborative research projects, sometimes to consultancy activities and occasionally to the movement of knowledgeable employees between organisations (compare Schuetze, 2001; Siegel et al, 2003; Vaessen and van der Velde, 2005 and Clark, 2005). However, taking a more in-depth look at the idea of knowledge transfer we see that it is very much based on the linear model of innovation. The word 'transfer' refers to moving something or someone from one place to another, so the very term 'knowledge transfer' suggests that knowledge produced in universities is an object which is passed to firms (Malecki, 1991; Steinmuller, 1994; Lakomski, 2004). The notion of a joint project between a university and a firm becomes problematic when conceived in terms of knowledge transfer: input from the firm must be limited to specifying the research problem if the idea of knowledge being handed from one organisation is to be maintained. The firm may not take part in the activities of producing knowledge if transfer is to occur rather than knowledge creation or construction (Sharp, 1998; Bradley et al, 2004). Given that researchers have recognised innovation processes as loopy (Hayter, 1996) and involving 'functional overlap' (Rothwell, 1994) between its different stages, it is thus perhaps unsurprising that none of the interactions studied could be described as pure case of knowledge transfer. A typical response to the suggestion that the research group simply conducted the project and handed over the results came from an academic involved in work with the steel industry in Wales:

Interviewer: So you know you've done contracted or consultancy work, research for companies. Do they ever come back to you and say 'Well, we don't quite understand what you've done', or that sort of, and 'We need more help actually, you know, using this, these results that you've given us'? Or is that not really something that happens at all?

Senior Lecturer: Um, oh yes, I think that does happen, but not in quite such a almost clear cut way as you've implied there, because again, my view is that, you know, a good research project won't simply wait until the final report is written to report the findings. What it will be doing is reporting the findings as you go along and again if you do that on a regular enough basis then as, er, the, er, as the findings are reported that's when the company usually turns around and says 'Well, we don't quite understand how that fits in with what else we're doing' etc., etc. So the discussion tends to take place at that stage rather than a project being apparently completed and then somebody saying 'Oh well, what about such and such?'

(Senior Lecturer, male, south-Wales university)

This quote suggests that a dialogue between the inputs of academics and firm employees in these interactions, while different, is affecting how the project progressed and its results. We see a translation of interests here as a final outcome is built as the project evolves over time through dialogue to fit the aims of the company. Rather than knowledge simply being transferred, knowledge is *constructed* by the parties as they work together. These processes fit with Driver et al's (1994, page 5) description of those involved in knowledge construction as 'knowledge is not transmitted directly from one knower to another, but is actively built up by the learner'. They also note that 'scientific knowledge is both symbolic in nature and also socially negotiated. The objects of science are not the phenomena of nature but constructs that are advanced by the scientific community to interpret nature' (Driver et al, 1994, page 5). Once constructs have been accepted by the scientific community they become the accepted way of seeing the world. Thus the world contains entities such as molecules and magnetic fields and is organised by processes such as evolution. These entities and processes can be observed through certain measurement and experimentation procedures. Due to the increasing professionalisation and scientisation of management the same can be said about some types of industrial knowledge. For example, entities such as supply chains and futures, processes such as globalisation, and procedures such as market research and quality accreditation are all constructs that managers use to interpret the economy (Yanow, 2004). Because of their socially negotiated and symbolic nature these entities, processes and procedures are unlikely to be discovered by an individual outside of the scientific or management communities simply through observation. Thus, Driver et al (1994, page 7) suggest that '...knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared problems and tasks. Making meaning is thus a dialogic process involving persons-in-conversation…' It is this dialogic process that appears to characterise the collaborative projects described by the senior lecturer in the quote above. Occasionally the negotiation between the academics and company employees took a direct form. For example, one engineer from aerospace company AS2 explained that he might dispute the results of tests performed by the university on behalf of the firm:

> …if I disagree with something in the report I'll often, you know, well, I wouldn't say often, because it doesn't happen that often, if I disagree with something, or I think something is a mistake, I'll come and ask for clarification or even a report amendment. You know, if I come back and say 'You've said that this has happened' and I can prove beyond a doubt that it hadn't, then, you know, obviously the university isn't going to be of a mind to put a report out with an error in it, so they'll correct it.
>
> (Aerospace company manager, male, south-Wales)

In this case the employee in question had studied for his doctorate in the department that was carrying out the testing and was therefore knowledgeable about the scientific principles behind the tests being carried out. This background knowledge enabled him to engage directly with the testing processes and have direct input into the interpretation of the tests. Other firms engaged less with the actual nitty-gritty of the project. This lesser engagement was sometimes down to a lack of expertise on the side of the company although this was not always the case. For example, CE5 is a spin-out from the university with which they collaborate. The company founder is a former post-graduate student at the department that now provides the company with post-graduate students who work on projects proposed by the company founder. However, the academic supervising these projects describes a process quite unlike the direct negotiations regarding the results involved in the case of AS2:

> Well, we have meetings with the company every so often to talk through the project. …[Y]ou may be end up meeting at the beginning of the project to go through what CE5 hope to get out of it and you tell them what, you know, what things are reasonable for the student to do, and they'll have various meetings through the period of that eight or nine months that the project's running, just to talk about the progress and so on and just checking that the direction is still, you know, the direction you want to go in.
>
> (Reader, male, south-Wales university)

Nevertheless, the company is still involved in shaping the outcome of the project throughout its existence through the feedback that it gives to the researchers.

There is also an element of cultural assimilation. While the academics may be responsible for the actual mechanics of the discovery they must learn about the industrial context of their research problem, and likewise those in industry may have to extend their scientific knowledge. For both sides there may be a process of coming to see the world through the accepted constructs of their collaborator. A professor describes this process in the following way:

> Professor: Um, well, working with academics is much easier [than working with firms] because you know exactly what, where they're coming from. […] It's just you know what their goals are and you know what to ask them, but each company's got it's own agenda, so, you know, if you're talking to the media industry you have to understand that industry, which I don't, but I understand the automotive industry, you know, the manufacturing industry. It takes quite a while to get, to find out what really matters to them, you know.
>
> Interviewer: I suppose the only way you can do that is by working with them and looking for they want.
>
> Professor: That's right, and you don't know until you, I mean we're doing some work with X Magistrates Court doing something, and they're very pleased with it. They keep giving us more work and say it's wonderful, more work, you know, and we'd no idea they'd be like that. We thought they'd be very conservative and cautious. [Laughs]
>
> (Professor, male, mid-Wales university)

A particularly instructive example of the knowledge construction process is that of OE2 and their recent utilisation of a university patent. The licensing of university patents to companies is often mentioned in policy literature as a straightforward case of transferring knowledge; indeed, CBI's 2001 publication 'Partnerships for Research and Innovation: a Guide to Better Practice' does not even mention licensing university patents to existing firms as a type of partnership. Perhaps because patents take a codified form much of this literature seems to conceive of the university simply handing over the rights to use the knowledge contained within them once proof of concept has been achieved (Lambert, 2003; Wright et al, 2003; UNICO, 2004). OE2's case shows rather that the construction of totally new knowledge results from the licensing process, which involved both the firm and the university. OE2 were in the process of adapting one of their instruments to perform a different type of monitoring to that already provided by the company's products. The knowledge of how to perform this new monitoring process came from a Canadian university which had developed the technique in the laboratory and OE2 were looking to license this IP. The academics behind the idea were keen to find a partner who could turn the technique into working instrument which would automate the monitoring process. The process of developing this instrument was quite complex as it involved bringing together the electronics expertise of the company and the biochemistry expertise of the academics. First, the company had had to hire a biochemist to reproduce manually the laboratory results using slightly different measuring techniques that could then be automated, before designing a prototype instrument. This prototype instrument was then to be fine-tuned with the help of a researcher who was to visit from the licensing university. The company and the university foresaw the likelihood of their project producing further patents and therefore had drawn up a contract that allowed for the creation of shared intellectual property as the project progressed. This relationship exhibits, therefore, extensive construction of knowledge in terms of creating a joint knowledge held by the two organisations of biochemistry and electronics through discussion and working together. The knowledge is also embodied physically in a new instrument, which brings us to consider knowledge construction and different types of knowledge.

Knowledge construction and the distinction between tacit and codified knowledge

The notion of knowledge construction is used by Nonaka and Takeuchi (1995) in their account of organisational knowledge creation. Nonaka and Takeuchi (1995, page 58) define knowledge as 'justified true belief' in the manner of pre-1960's epistemology, ignoring Gettier's (1963) famous argument that it is possible to have a justified true belief without actually knowing something[3]. However, unlike traditional epistemology, they reject the notion of knowledge as 'absolute, static, and nonhuman' in nature (Nonaka and Takeuchi, 1995, page 58) instead considering knowledge as '*a dynamic human process of justifying personal belief toward the "truth"*' (Nonaka and Takeuchi, 1995, page 58, emphasis original), '*essentially related to human action*' (Nonaka and Takeuchi, 1995, page 59, emphasis original), which is also context-specific and relational. So knowledge can be described as a state of being, or perhaps more accurately, given its dynamic and active nature, a state of becoming. For Nonaka and Takeuchi (1995, page 61), knowledge is created and expanded 'through social interaction between tacit knowledge and explicit

[3] Gettier's (1963) argument runs along the following lines. Smith and Jones apply for the same job. The president of the company informs Smith that Jones will get the job. Smith counts the coins in Jones' pocket and finds ten of them. Smith thus believes that the man who will get the job has ten coins in his pocket. This belief is justified given the evidence, and is also true. However, it turns out that Smith is actually the one who has got the job, and unknown to him, he has ten coins in his pocket. So while Smith's belief is justified and true, we cannot say that Smith actually knows that the man who will get the job has ten coins in his pocket.

[codified] knowledge'. In this social interaction knowledge is converted from one type to another in one of four modes: socialisation (tacit to tacit), externalisation (tacit to explicit), combination (explicit to explicit) and internalisation (explicit to tacit). Following their work we might say that in the case of OE2 and their new instrument the knowledge produced by the project was both explicit (codified) – the knowledge physically embodied in their prototype and also written down in patent documents – and tacit: the know-how of the processes involved held by the company's biochemist and the researchers from the Canadian university.

Nonaka and Takeuchi (1995) are careful to distinguish between knowledge and information. They note that explicit or codified knowledge is knowledge that can be written down or formulated into procedures, while tacit knowledge is knowledge that cannot (see also Zook (2004)). Thus knowledge always belongs to people or groups of people, and codified documents can only lead to the transfer of knowledge if the person learning from them can create meanings from them. By themselves such objects are tools for constructing knowledge or expressions of knowledge, but they are not knowledge itself. This is a simple point but one that is sometimes ignored in some literature on knowledge transfer, where the transfer of papers, documents, plans or procedures is equated with knowledge transfer (see, for example, Johnson et al's (2000) critique of Cowan et al (2000)). The problem with this idea is that knowledge would remain unchanged as it passed between one community and another (Lakomski, 2004). However, meanings created by those people who acquire knowledge, either through interaction with various objects (books, journals, etc.) or with other people, do not necessarily need to be valid in the communities in which the knowledge originated. This can be seen in the processes of knowledge translation and knowledge transformation.

Translation of knowledge

As we saw in Chapter 5 technology transfer staff often saw their roles in terms of communicating academic expertise to the industrial world. Their presence was deemed necessary, not only because the academics producing the expertise were too busy with the process of production to communicate it but also because of the difficulties academics were perceived to have when communicating their expertise to non-experts. The perception that academics have problems communicating is somewhat ironic given that the success of their entire career is based on their ability to communicate their work through publications, seminars, conferences and teaching. However, academics in the different specialisms may form different knowledge communities with their own terminology and assumptions of basic knowledge that can make it very difficult for even an academic from another specialism to penetrate, let alone someone from outside academia (Gregory and Miller, 1998; Treise and Weigold, 2004). The language in which academic research is presented may need to be translated before it is accessible by people from outside the discipline in which it was generated (Treise and Weigold, 2004). While technology transfer staff see this process as one of their primary responsibilities they are usually involved in communicating expertise to firms in the early stages of a collaboration. Once a collaboration has reached the stage of the academic and industrial partners working together and knowledge is being constructed or co-produced, the need for translation can be underestimated. Though both partners may have an input into the results of an interaction, unsurprisingly, the division of labour is usually such that the academic partner does the actual practical production of the results and is responsible for codifying them. Such a translation process was performed by academics within the studied interactions, most of whom were very aware of the need to use different language when communicating with industrial partners. One lecturer explained that his industry-sponsored doctoral students had to produce two types of literature:

> [A]s well as the external publications they, the most interested audience is always going to be the industry itself so [the doctoral students] have to write quite a lot of technical briefs and technical notes to circulate, and again that's quite a good training for them because it gets them writing in two different styles. They have to write in a style which is acceptable to a scientific journal and they also have to write in a slightly more *Sunday Times* style which is accessible to production managers and things like that who, you know, couldn't give a hoot any about the minutiae…they'll appreciate concepts perhaps and understand perhaps what's going with on with that.
>
> (Lecturer, male, south-Wales university)

In several cases, highly-qualified research staff within the firm itself translated the technical knowledge received from its academic partner into language more recognisable to contract manufacturers, potential customers or students. So a steel company manager described how he disseminated the results of research commissioned by his company from universities in order to advertise the benefits of the novel product it manufactured using:

> …a big glossy pictorial handout, very basic handout for some people, um, more geared at sort of younger students and something more technical we can handout to engineers and designers.
>
> (Steel company manager, males, south-Wales)

One employee of a life sciences firm described a process whereby the knowledge obtained from academia is passed to a patent attorney to be translated into the technical language of patent applications:

> I mean we've got [our patents] through [i.e. granted] but you have to provide that key distinction and that generally is a scientific principle converted into patent-speak. I always call it patent-speak because we can provide our patent attorney with the technological description but his job and why we need him is that it needs to be converted into words … the patent examiner will comprehend and understand. It's a strange sort of legal, technical jargon and we couldn't do that for ourselves, you know. You need your specialist translator again….He

> has to translate the technological differences that we might describe into the right text to convince the examiner of those differences.
> (Life sciences company manager, male, north-Wales).

This type of narrative suggests that the translation process that allows knowledge to pass between the spaces of academia and industry is not merely the case of re-expressing some universal truth in different language. The meanings of the original and translated texts are not quite the same – in the case of the life sciences company, for instance, one conveys a description of a new feature of the world, and the other novel technical usefulness – although they allow communication between two different groups.

Here Quine's (1960, 1987) view on translation can be utilised. Quine (1987, page 9) claims that it is not the case that a sentence has a meaning and 'another sentence is its translation if it has the same meaning'. Translation is indeterminate: two translation manuals for another language could ascribe different translations for the same sentence, but if there was no behaviour from the native speakers of this language that indicated that one translation was better than the other, then there would be no fact of the matter. The thesis of the indeterminacy of translation means that there is no single unique meaning ascribable to a sentence; there are many acceptable translations. So meanings are not entities, though this is not to say words and sentences are not meaningful and significant. Whilst Quine's (1960, 1987) ideas are not accepted orthodoxy they can be usefully employed to explain why knowledge that passes between universities and companies displays the flexible, relational and context dependent nature that Nonaka and Takeuchi (1995) describe, rather than the absolute and static nature that the narratives of some academic and policy literature suggest. So long as the translations allow the different groups – patent examiners, companies, academics and so on – to communicate with each other, no one is better than the others.

Transformation of knowledge

Rather than being absolute, knowledge is often transformed as it comes to be perceived differently in different locations. We can think of the knowledge as losing some characteristics in the process of commodification and gaining others. This view is in keeping with the work of Osterlund and Carlile (2005, page 92) who suggest that:

> knowledge does not exist as well-defined bodies in the form of rules or abstract models with intrinsic features. A body of knowledge cannot be understood in and of itself, allowing it to be transferred unchanged from one context to another, without changes to its properties.

In some situations these changes are changes in the significance of certain facts about the world in different spaces of knowledge, i.e. which world views or discourses they fit into. This scenario can be compared to Kuhn's (1970) idea of the paradigm shift within mature sciences. The world is actually different in a different paradigm: it is not merely the old world seen differently. This process is akin to the gestalt switch; what is true has changed (Kuhn, 1970).

Vann and Bowker (2004) describe the transformation of academic knowledge during the commercialisation process in the following manner:

> [the] practical ambivalence of objects created as knowledge gives life to the political economy of academic research: it is difficult to survive in the ivory castle making knowledge that few recognise or are interested in, though it is possible to survive even if others use the object differently. Thus, to speak of the commercialisation of any knowledge is to speak of the mapping of a commercial logic onto an already complicated political economic process at work among interest formations. Commercialisation of knowledge follows the footpath of its many instrumentalisations.
>
> (Vann and Bowker, 2004, page 40)

Their example of the above process is the journey that the notion of practice has taken from Lave's (1988) use of it 'as an instrument of de-reifying, critical social theory crafted to problematise the prominence of normative models as formal educational assessment techniques' (Vann and Bowker, 2004, page 45) to its commercialisation as a tool for the management consultancy industry in the form of communities of practice (CoPs). In its original form, the study of practice reveals a reality that is obscured by normative models – learning ceases to be a process of internalising knowledge and becomes a creative process. A science of practice is therefore a science of the real. In its latter form practice is seen as a naturally occurring phenomenon, a 'real' – contrasted with the formalised abstractions of official work processes – which can be harnessed to create economic value for firms, i.e. is an asset. Thus practice ceases to be a de-reifying concept, although it is still posited as a science of the real. Moreover, because communities of practice emerge both in spite of and because of the hierarchical managerial system that develops formalised abstractions of official work processes, hierarchical relations of authority are seen to support practices of informal knowledge creation. Therefore, rather than problematising social relations of power:

> the CoP concept appears instead to be engaged in an intensification of the previously existent logic of organisation. Because in spite of the recognition of the multiplicity of knowledges and their values, formal organisational structures of authority, skill and valuation (meritocracy?) are not debunked.
>
> (Vann and Bowker, 2004, page 55)

The knowledge objects, as Vann and Bowker (2004) refer to the products of research, produced in the studied interactions are not knowledge about knowledge; rather they are knowledge about technical processes, knowledge about physical entities and their behaviour, knowledge about economic processes and knowledge about organisations. They are not originally posited to undermine common epistemological assumptions, nor are they part of a critical theory questioning social relations of authority. Nevertheless, they are often reinstrumentalised in their translation from academia to industry or vice versa. In academia the function of knowledge objects produced by the research process varies considerably. Some of these knowledge objects are designed only to have commercial use from their inception, such as the results of tests commissioned from university laboratories by two of the aerospace companies on faulty parts, but there are also knowledge objects that are created with a dual purpose. This is probably most clearly seen in the work produced from industrially supported student research projects where research results are the contribution to an academic body of knowledge and proof of the students' successful completion of their apprenticeship to become a researcher. In industry, however, results are (unsurprisingly) put to work in quite different ways: to solve a manufacturing problem, to improve an existing product or to demonstrate the feasibility of a new product. In academia, where the endless shaping and reshaping of ideas is its reason for existence, the knowledge objects that result from an interaction often continue to be reinstrumentalised, usually being taken up by researchers in different but related areas who use them for purposes not originally considered by their developers. Law (2002) calls such transformations 'homeomorphic': where an object is deformed while maintaining its continuity, i.e. does not break or rupture. In contrast, once solidified into an industrial process or product the knowledge object seems to lose its ability to metamorphose in the way it does in academia. One of the reasons for this, of course, is that companies often assert their intellectual property rights over such objects, or at least keep them out of the public domain so as not to advantage their competitors, so that the knowledge remains within the company. A number of firms in this study placed an embargo of up to five years on research results to prevent the knowledge leaving the company, while other vetted papers before publication to avoid commercially sensitive knowledge entering the public domain. Yet other companies, particularly those contracted to produce R&D, did not seek to keep secret the knowledge that they had obtained from an interaction with an academic partner. However, the knowledge tended to be applied within a restricted set of circumstances, such as a small number of related industries or clients. Due to the manner of application, it was not necessary to reinstrumentalise the knowledge once again when it is passed on. An example of this process of solidification is the experience of University Q which had established a jointly run testing facility with S3 using Objective 1 funding (see Chapter 5). For the academics involved, finding unexpected uses for the laboratory's core technology was one of the most exciting parts of the project. As one explained:

> ...some of the most interesting things are we identified that this kind of technology, which has been ... industrial, often associated with welding and joining and that sort of thing, hence S3's involvement in it, actually has very broad applications and it's spilling over into medicine. So we're establishing a medical special interest group to look at that area.
>
> (Head of School, male, south-Wales university)

On the other hand, such novel uses were notable for their absence in the account of the industrial partner and in this partner's advertising literature, which describes the technology's applications in the manufacturing and construction industries. The reinstrumentalisation of the technology from an engineering technique to a medical technique appeared to be easier to perform for the academics involved in the project than for the firm. Whilst the academics involved consciously sought out alternative applications for the technology, the firm was restricted by its specialisms in manufacturing and construction. For the academics, the technology was of prime importance, but for the firm the technology was simply a service that could be offered to their manufacturing and construction customers.

In other cases the boundaries of the knowledge object created by the interaction seem fluid. What constitutes the results of a project depends on the priorities of the partner. Thus certain characteristics of the results are dropped depending on the space in which the results are instrumentalised. This is the case with University D, which provided manufacturing advice to AS3, an aerospace SME based in mid-Wales and developed prototypes of new products for AS4, a large aerospace firm based further south. AS3 decided not to utilise the university's advice and AS4 made use of the university's services in their product development, but did not seem to employ them outside the initial, fairly narrow purpose, which was to test the effectiveness of a particular design. University D, on the other hand, used such experiences not only to publish on the technical aspects of the work, but also reinstrumentalised them as studies of product development management and related areas. In cases where the university had provided technical services such as testing and rapid prototyping, technical details could not be used for publication purposes because they were not considered original research, which made the non-technical results more valuable. The technology transfer specialist in charge of the department involved in this work explained:

> ...we publish on the whole range of product development, so we're publishing, for example, in very technical areas, the specific aspects of product development technology, we're publishing in areas such as product development management, the whole business about innovation, capture and management. So that, if you like, is more kind of generic product development work but ... a significant element of the work of our research team is the whole issue of product development in SMEs. How do they do it? What are the barriers they face and how do they overcome those barriers? Do they overcome those barriers? What happens if they don't? What management

> approaches do they take? What are the particular characteristics of product development? I know we publish an awful lot of them.
> (Senior Technology Transfer Officer, male, south-Wales university)

From such studies theoretical abstractions about SME product development had arisen, which, through publication, contributed to wider academic discourses regarding organisational behaviour. The experience of actually collaborating for the university was a result of the project and was characterised as such in academic terms. This was not the case for the firms involved with University D who were focussed on whatever the university's services produced for them. Publication of the results of interactions by the university appeared in a range of journals, not simply the engineering literature, but also in academic journals dedicated to technology transfer and management. Here the ability for knowledge to be reinstrumentalised in academia appears to depend not so much on the ability to apply an idea produced in one location in new locations but on utilising the 'residual' parts of a project that are considered redundant and irrelevant to the other partner.

That knowledge produced by the interactions can be differentially reinstrumentalised in the spaces of academia and industry thus has to do with the meanings attached to whatever is produced. The results of the interactions under study signify different truths depending on where they are located, although these results themselves have not changed. This occurs in the case of University D described above. For publication they have emphasised certain results – the difficulty of getting a new technology accepted by SMEs in comparison with larger companies – that appeared to be unimportant to AS4. For the academics the success of their interaction with AS4 signifies a cultural difference between SMEs and larger companies: SMEs' resistance to change as opposed to larger companies' open-mindedness. The success is part of a larger narrative about SMEs and how they behave. However, for AS4 the project results have a different meaning: they do not engage with the narrative constructed by the academic researchers. Rather the success of their relationship with the university is signifies the difference between the service offered by their academic partner and other universities that, in their experience, have worked to slower timescales. The knowledge produced is that of how a new product will look and behave rather than how the company itself looks and behaves, whereas, for the university, both aspects of knowledge are acknowledged. However, while a prototype may be considered novel and new in industrial terms, because it is the result of tried and tested methods, it is not new or novel in academic terms. Thus, for the university, the latter aspect of how the company looks and behaves is more important.

Here the notion of economies of meaning as proposed by Wenger (1998) seems relevant. An economy of meaning is a social configuration 'in which different meanings are produced in different locations and compete for the definition of certain events, actions, or artefacts' (Wenger, 1998, page 199). In an economy of meaning some meanings achieve special status, i.e. they have greater value than others. Meanings are socially negotiated in specific spaces and this negotiation involves bids for ownership of meaning. In order to contend for ownership of a meaning, an individual or group must produce 'a recognisably competent interpretation of it' (Wenger, 1998, page 201). In this case "ownership" indicates the extent to which 'we can make use of, affect, control, modify, or in general, assert as ours the meanings that we negotiate' (Wenger, 1998, page 200). While there may be local ownership of meanings which is valid in their site of production, such meanings may be less useful when the owner is in other locations. In this case he or she may appropriate meanings produced elsewhere in the economy of meaning. If this is not possible, for example, if the individual does not have access to knowledgeable people in different sites, he or she may become marginalised. Wenger's (1998) example is of claims processing employees at a large medical insurance company in the USA. It is their job to calculate the payouts claiming customers will receive. In his study of their working practices, Wenger (1998) found that claims processors had particular problems with a calculation they were required to make when a customer was covered by more than one health insurance plan known as coordination of benefits. Although the processors were able to calculate such claims correctly they were not provided with any explanation of the principles behind the calculation. Thus they were not able to judge whether their results were reasonable and nor were they able to explain to complaining customers how the disputed payment had been calculated. Wenger (1998) suggests that the worksheet the processors used to determine such claims is interpreted locally as a guide of computation and a reification of their position in the company that employs them. The meanings produced are those of non-participation and have local validity. Ownership of the meaning of the worksheet is located elsewhere in the economy of meaning within which the processors work; it belongs to the technical specialists employed by the company. The processors' inability to appropriate the ownership of meaning of the worksheet leads to their lack of confidence when calculating such claims and explaining the results to customers, because their local meaning has a lesser value in the economy of meaning than the technical specialists' meaning.

It can be argued that the academic and industrial partners in the above example are engaged in an economy of meaning. Within the academic world the university's interpretation of the results of their project with AS4 has greater currency and the same may be said for AS4 in the industrial world. When AS4 and their academic partners come into contact to produce prototypes it is the interpretations of newness and novelty held by the company that take precedence: the academics must align themselves with such meanings in order for the project to work. However, when the academics go on to use the results in the world of academia it is the meanings regarding the behaviour of different firms that take precedence. In this case the negotiation of meaning is quite successful. The local meanings co-exist without friction. The academics are able to understand and make use of the local meanings of newness and novelty produced by the company when working with them.

Another case in point is that of AS2, a medium to large aerospace company with a facility in south Wales. Here the company appropriates the meanings produced by their academic partner. AS2 employ a local university to perform testing on parts that they have manufactured which have broken or failed while in use. The university uses various instruments, including an electron scanning microscope, to examine the damage to such parts more closely. The company uses images and other results of such testing to determine whether parts have broken because of some error in their design or manufacture, or because they have been misused by the company's customer. Thus, judgments by the university about why the part failed become, in the company, judgements about correct usage of the part. For the company, the results of the testing signify the occurrence of abuse. They fit into wider understandings about how parts of aeroplanes should be treated if certain behaviour is wanted from them. However, the staff at the university laboratory do not see the complete piece of equipment, merely the part that went wrong. The explanations they produce have scientific meanings regarding the known behaviour of various materials when subjected to different stresses and forces. Such scientific meanings are appropriated the company and incorporated into their practices. On the other hand, the university staff do not seek to appropriate the meanings concerning the correct usage of aeroplane parts into their practices because these do not have a great deal of relevance to their work. They are happy to assume the existence of such meanings without seeking to own them. Here again we have a shared but distinct ownership of meaning.

However, where local meanings cannot co-exist, projects are likely to run into trouble. In the case of the project involving CE1, CE2 and University A, described earlier in this chapter, the companies' deemed the expectations of their academic partner to be unfocussed and unrealistic given the available time and money. Once the collaboration was underway, the firms also discovered that the research group would or could not provide them with the data required to complete the report to the firms' satisfaction. The firms concluded that further research needed to be carried out on the technology before it was able to undergo industrial application. From the perspective of the research group there was disappointment that the firms' original proposal followed a pre-existing procedure used by CE2 for previous projects, whereas the research group were eager to explore different avenues during the course of the research, rather than being tied to a strict timetable and preordained procedures. For the firms the collaboration was a finite problem solving exercise, but for the research group it was an evolving piece of academic research to be addressed creatively. These differences in the way the collaboration was perceived by the different parties appear to be due conflicting local meanings. The partners negotiated for ownership of the meaning of the project by trying to persuade the other side of the validity of their interpretation. The firms did appropriate some of the academic meanings of the project into their practices since they could see benefits to their businesses of publishing in the area of the project. However, they had limited success in persuading their academic partners of the necessity for a fairly rigid programme of work given the time and cost restrictions on the project. Shared ownership of meaning was not reached. Thus, despite the relationship being built on personal contacts, and one of the industrial partners being a former academic, trust did not grow between the two parties because they failed to meet each others expectations. A poor working relationship resulted as each side tried to translate the other side's objectives into its own and differences between the culture and working practices in the firms and in the university could not be over come. The relationship was further undermined by the academic partners' lack of response to the firms' queries and their consequent interpretation that the research group was not interested in the project. While the firms did manage to move into a new market as a result of the project, they did not learn as much from the university as they had hoped, feeling alienated from their academic partners.

In this example, a relationship between economies of meaning and the conversion of social capital also becomes clear. For CE1 and CE2 negotiation of shared meanings (or at least, compatible local meanings) was necessary for bonding social capital to be successfully converted into bridging social capital. When meanings of the collaboration became contested the bridging social capital between these companies (particularly CE1) and their academic partner was lost: neither side felt that they could draw on the link between them for resources not otherwise available to them. Tension between local meanings was also seen in the case of CE4 and its academic partner in which the two organisations were engaged on a joint project providing consultancy to local SMEs with the university as the lead partner. The relationship between CE4 and its partner was also initially based on personal contacts, but the university had not persuaded the firm that its motives for establishing the project were altruistic. Although this tension had not soured the relationship between the two organisations, the firm did not feel that it had gained a great deal from being involved with the project. Therefore, it is possible to argue that the development of bridging social capital in this case was limited. Similarly, contested meanings impede the conversion of bridging social capital into bonding social capital. Such is the case for OE1 (see Chapter 5). The interviewee from this firm felt that the chief products of work with a university, IPR, were not hard deliverables, but his counterpart at the university with which the firm was collaborating described such products, in this particular case a PhD project, as 'define outputs'. Since these local meanings cannot co-exist without friction it is not hard to see that developing the relationship into bonding social capital after their initial PhD project together would be difficult for the two organisations. They remain in separate epistemic groups which resist merging. On the other hand, in the case of AS2 and its academic partner the development of shared and compatible local meanings has helped the maintenance of bridging social capital initially based on bonding social and its eventual conversion back into bonding social capital. Again, a similar set of processes have taken place in the case of AS4 but in the opposite direction – successful negotiation of meanings has eased the conversion and maintenance of bridging social capital into bonding social capital. These relationships between economies of meaning and social capital are illustrated in figure 6.1.

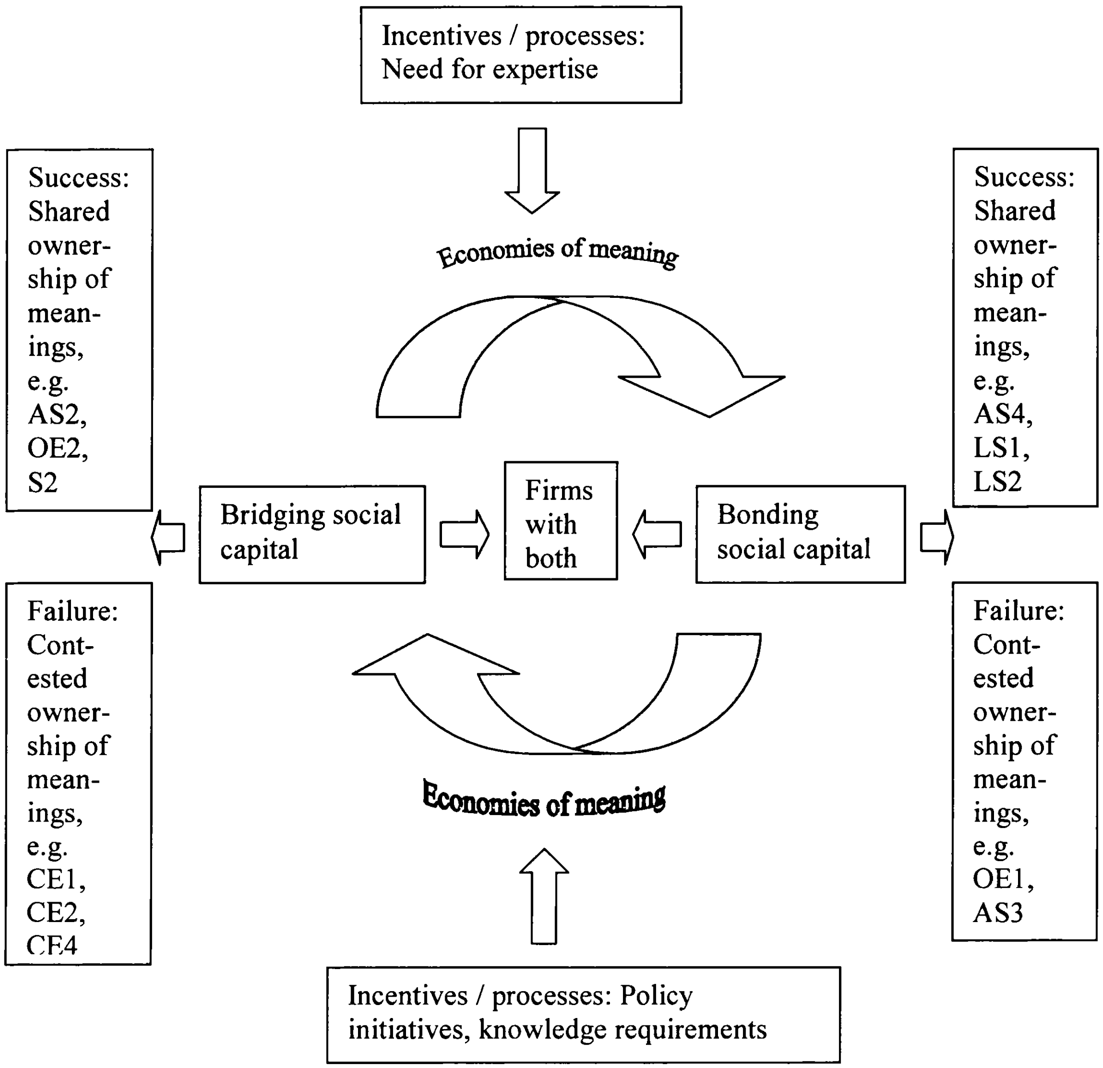

Figure 6.1: Economies of meaning and the conversion of social capital

Conclusions

This chapter highlights the need to examine knowledge flows between academia and industry in a nuanced manner. The different underlying principles governing the academic and commercial worlds are such that direct knowledge flows between the two is not a given. Specifically there is a conflict between the notion of knowledge as a public good as embedded in academic work practices and the notion of knowledge as a commodity embedded in commercial work practices. However, both parties are able to engage in a process of translating each others' interests in order to enrol each other onto their respective projects. This process creates knowledge flows, which may be conceived of the building of certain knowledge objects in different spaces of use.

Hence, when we speak of knowledge transfer activities we should not think of organisations as simply acquiring knowledge through a process of absorbing the results produced by academic – industry partnerships. Rather it is a case of constructing knowledge as each party influences and adds to the eventual outcome of an interaction. The notion of knowledge construction leads to a much more flexible and dynamic idea of knowledge and learning as far as collaboration is concerned. Gone are the unchanging and absolute chunks of knowledge implicit in the linear model of innovation that still appear in policy literature being acquired by companies as they would a new photocopier. Rather, as firms and academic institutions interact, some artefacts, sometimes a physical product (e.g. OE2's instrument) other times a concept (e.g. the hydrogen economy for CE1, CE2 and their academic partner), act as boundary objects – that is 'objects that serve to coordinate the perspectives of various constituencies for some purpose' (Wenger, 1998, page 106). Such boundary objects allow the creation of meanings that are useful both for the academic and the industrial partners in a collaboration, that is, knowledge.

The flexible and dynamic nature of knowledge is illustrated in the process of translation that occurs in the interactions under study. Such translation is necessary because, despite the involvement of the industrial and academic partners in constructing the knowledge during a project, the academic partner is usually responsible for codifying results, and they need to do so both in the language expected by the academic community and the somewhat different language understood by industry, customers and so forth. For each group there is a different translation, each, so long as it allows the groups to communicate with each other successfully, equally valid. Thus knowledge is transformed as it is translated for use by different groups. It continues to be transformed once it is put to work by these different groups – as it is reinstrumentalised certain aspects are dropped and others gained. Specifically, the significance of certain artefacts can be quite different depending on the worldview of the group interpreting them. This can be problematic when academic and industrial partners need to use artefacts in their work together and cannot negotiate sufficiently compatible meanings for these artefacts.

These detailed understandings of knowledge flows thus are helpful in explaining why apparently well matched partners can fail to work together successfully, and as such, could impact on attempts to promote interaction. Such attempts are addressed in the next chapter.

Chapter 7

University – industry interaction in a knowledge economy: a policy evaluation

This chapter examines the promotion of interaction between universities and firms as part of a regional development policy aimed at developing a knowledge economy. Universities are already important to the Welsh economy and arguably are of greater relative importance to the economy in Wales than they are in other regions of the UK (Higher Education Trade Unions in Wales, 2001). For towns such as Aberystwyth, Lampeter and Bangor they are the life blood of the local economy, accounting for a sizable proportion of the population and employment in their regions. Furthermore, the Welsh Assembly Government has identified an important role for universities in developing a knowledge economy. Strategy documents such as *Reaching Higher: Higher Education and the Learning Country - A Strategy for the Higher Education Sector in Wales* (2002b) suggest that exploitation of knowledge from Welsh universities can contribute to regional development by bringing in funding, encouraging Welsh firms to innovate and establishing new high-technology firms which will provide highly skilled and well paid jobs. Therefore a policy framework has been set out which not only seeks to develop the physical infrastructure to enable such activities but also builds social infrastructure between universities and firms by developing networks between academics and firms, forming academic spinout companies that retain links with their parent institutions and encouraging firms to approach universities (see Chapter 1). Yet, interviews with industrialists and academics reveal a sense of scepticism and mistrust regarding regional development activities aimed at developing a knowledge economy.

At the level of economic policy individuals in both universities and firms in Wales are sceptical as to the feasibility of developing a knowledge economy in the region. Of the interviewees involved in university – industry interactions, only three working in industry, one working in technology transfer and two academics expressed positive opinions about the goal of Wales becoming a knowledge economy. For those with negative opinions about the goal, at best the idea was seen as an uphill struggle, while at worst, terms such as 'knowledge economy' and 'learning region', if they have penetrated through to individuals in firms and universities at all, were seen as meaningless jargon.

On the level of policy implementation, the mistrust and scepticism towards policy aimed at creating a knowledge economy are rooted in the organisation of regional development funding distribution which combined with conflicting roles that the modern university has adopted lead to firms accusing universities of profiteering. This chapter therefore examines the organisational issues affecting the implementation of regional development policy promoting university – industry interaction and how these organisational issues can interact with the dual role of the university as public body and commercial enterprise giving rise to mistrust of universities in firms. It goes on to explore the roots of this mistrust in prevailing neo-liberal beliefs about the correct use of funding. These beliefs create unhelpful moral geographies of innovation and regeneration wherein the people of Wales are blamed for their economic predicament. The chapter concludes by looking at how negative conceptions of Wales help to keep individuals and organisations locked into certain patterns of behaviour and understanding which impede economic development.

Organisational issues: bureaucracy and fragmentation

Firms and universities are critical of the way in which funding schemes promoting university – industry interaction as an element of regional development were administered. It is felt that poor administration leads to money being wasted and reduces the likelihood of a successful knowledge economy being created. In particular, the amount of funding spent on administration, the short term funding and excessively complex regulations for university – industry collaboration initiatives are common criticisms. The case of firm CE4, a south Wales SME dedicated to developing sustainable energy technology and environmental consultancy, and their collaboration with a local university on a European funded project providing consultancy in disadvantaged parts of Cardiff illustrates this poor perception of the administration of regional development funding.

The academic partners of CE4 were the lead partner on the project and as such were responsible for application and administration procedures. During interview the academic partners of CE4 identified several areas where they believed that the official procedures for allocating regional development funding made inefficient use of the money available. Firstly, they felt that too much of the available EU funding went into administering the schemes that distributed it and, because of this, funding was not reaching the firms that it had been allocated to help. Too many government bodies were involved in distributing the money and the administrative procedures were too complex, thus eating into the funding. An example of this bureaucracy was the long and complicated application procedure that the university and their partner firm had had to go through to establish the project: it had been eighteen months from the initial application to the project actually beginn-

Table 7.1: Funding sources available to collaborating firms and universities, 2003 – 2005

Name of funding scheme	Funding body	Dates available	Organisations eligible	Type of interaction funded
EngD studentships	Research Councils	Ongoing	Universities	Collaborative engineering doctorate projects
Environmental Goods and Services Programme (EGS)	WDA (now WAG) / Objective 1	Ongoing	Sustainable energy SMEs in Objective 1 areas	Development of innovative products/processes
Graduate Opportunity Wales (GO Wales)	HEFCW / Objective 1	Ongoing	Firms	Student/graduate placements
HELP Wales	WAG, Objective 1	1998-2005	SMEs	Collaborative projects
Knowledge Transfer Partnership (KTP)	UK central government, WAG, Research Councils, EU European Social Fund	Ongoing	Firms	Collaborative projects of strategic importance to the company
LINK	DTI	Ongoing	Firms	Pre-competitive research
NESTA	National Lottery	Ongoing	Firms, individuals, voluntary bodies, universities	Development of innovative products/processes
PhD CASE studentship	Research Councils	Ongoing	Universities	Collaborative PhD projects
Small Business Research Scheme	Research Councils	Ongoing	SMEs	Collaborative research in specified areas
SMART Cymru	WAG, Objective 1	Ongoing	Firms	Development of innovative products/processes
Technology Exploitation Programme (TEP)	WDA (now WAG)	Ongoing	SMEs	Technology collaboration
Technology Programme for Collaborative Research & Development Projects	DTI	Ongoing from 2004	Firms	Collaborative research in specified areas
Wales Spinout Programme	Finance Wales (body sponsored by WAG and the EU)	Ongoing	Academic spinout start-ups	Establishing academic start-ups

(Source: fieldwork)

ing. Secondly, the short-term funding periods were wasteful. The technology transfer staff running the project with CE4 did not believe that the two year timeframe of their project was sufficient for a project to make a significant impact. No sooner was it established and publicised then it was over. Since funding was only available for short term projects a new project would then begin, offering similar services under a new name. This new project would then have to go through the new process of publicising itself and building up its clientele. In their opinion it would be more effective to fund longer projects. Thirdly, staff were also frustrated that the regulations dictating which companies were eligible for funding excluded many that could have benefited from university assistance (i.e. advice on energy-saving or more efficient manufacturing) or made the funding unattractive to companies by excluding its recipients from claiming additional funding in the future. Many companies were excluded because they fell just outside the Objective 2 area in which the project functioned, while others were excluded because they were owned by larger companies even though they operated independently. The technology transfer staff involved with CE4 felt that arranging links between firms in Objective 2 areas and firms in other parts of the UK could bring real benefits to the firms in Objective 2 areas, yet funding regulations did not allow such promotion of inter-regional collaboration. Eligible companies were wary of the project because they were worried that by taking up the offer of free consultancy they might make themselves ineligible for other, more significant Objective 2 assistance available in the future, since there is a cap on the amount of assistance a firm could only claim in a three year period. This issue concerning the amount of EU funded assistance a firm could receive was, in part, an issue of communication in that the technology transfer staff had been unable able to acquire the necessary information regarding implications for companies' future funding from either their university or the funding bodies and so could not explain these to prospective collaborating companies. In other words, the guidelines for claiming assistance are unclear and no help is available to those policy implementers trying to interpret them on the ground.

The long and convoluted administrative procedures that eat into available monies, short term funding and complicated regulations governing its use are all are symptoms of an overly complex structure governing the distribution of funds for university – industry collaboration which affects such activities across the UK. According to the Lambert Review 'the constant layering of new initiatives on top of old, often uncoordinated across government departments and agencies, creates an overly complicated regime' (Lambert, 2003, page 101). For example, a collaborative project between a university and a firm in Wales may have been funded by one of the schemes shown in table 7.1. Other schemes available include Technium, which provides high-technology start-ups with academic links as well as accommodation and business support services, Know-How Wales, which provides advice to firms looking for an academic partner, and a number of EU funded projects run by individual HEIs providing free or heavily subsidised services to SMEs. In addition, there are many networks and forums aimed at promoting dialogue between universities and industry in Wales such as the Aerospace Wales Forum and the Welsh Automotive Forum.

These initiatives are not necessarily duplicating each other since they all tend to serve slightly different types of collaboration, are aimed at different industries or are appropriate at different stages of the innovation process. Indeed to some extent diversity of collaborative activity and funding is good because different forms of collaborative activity are suited to different universities, disciplines and academics

(Lambert Review, 2003). However, the plethora of funding schemes, each with its own set of regulations and eligibility criteria, leads to confusion with HEIs (HEW and HEFCW, 2003). From the industrial perspective, interviewees from small firms found the array of schemes bewildering and the amount of work required to ascertain the most appropriate scheme for their needs excessive, especially as many firms do not fit neatly into one category.

This lack of coordination repeats itself within academia. Although most universities in Wales have some sort of commercial or industrial liaison office, many interactions and collaborations do not pass through this office and often the office is not even aware that they are taking place. This means that the staff working in these offices are not always aware of what sort of collaborative experience is available within their institutions and so are unable to respond to firms' by indicating a suitable partner in the university. One member of staff in a south Wales university explained that although she had attempted to compile a database of collaborations with firms currently being undertaken by academics in her institution she had been thwarted by the academics' fears that disclosing their industrial partners to another member of their organisation would contravene the Data Protection Act, although a recent demand by the vice chancellor that such information be made available had recently made the compilation of such a database more likely. The picture is one of a lack of coordination and fragmentation of effort where funding university – industry collaboration is concerned.

The Lambert Review (2003) attributes this state of affairs to a lack of trust in the abilities of universities to manage their finances:

> The government does not seem to have enough confidence in the way that universities run themselves to give them extra funding without strings attached. Some of this is justified – the sector has in the past suffered from poor management and a lack of strategic thinking. Yet

> if universities are to become creative and play their full part in regional and national economies, then ways must be found to give them more room to develop a strategic vision and take entrepreneurial risks.
>
> (Lambert, 2003, page 102)

It is important to note that that the fragmentation of funding initiatives also applies to schemes that fund firms rather than universities, at least in Wales. However, Lambert's (2003) diagnosis of the problem is shared by some interviewees from both universities and firms. These interviewees felt that the lack of flexibility in what they were able to do with the funding allocated to collaborative projects was the result of the over-cautious approach of the funding bodies.

A lack of trust in the capabilities of universities has resulted in excessive administration, short term funding and overly complex regulations. Yet there is a tendency within the policy literature to address these problems singly and in particular contexts. Thus WAG's (2002b) strategic plan for higher education in Wales, *Reaching Higher*, simply pledges increased funding for knowledge exploitation to overcome the issue of short term funding. On the issue of regulation the Lambert Review (2003) recognises that collaboration between universities and firms in different regions can have benefits for the universities' local economies and should not necessarily be excluded from public funding, but does not recognise the possible role of knowledge broker that a university might play in setting up collaboration between firms in different regions. In CM International's (2004) evaluation of the transfer of KEF from ELWa to the WDA notes that a lack of communication between funding bodies and universities has led to the universities mistrusting the funding bodies. This lack of communication is blamed on the transfer of responsibilities between the two bodies. In fact, lack of communication seems rather more widespread than this mention would suggest and another symptom of the overly complicated funding structure. Notwithstanding these instances of addressing individual symptoms rather than the underlying problem, HEW and HEFCW (2003) and the Lambert Review (2003) do put forward some recommendations in order to reduce fragmentation of university – industry collaboration funding initiatives. The Lambert Review (2003) recommends the allocation of third mission funding to universities for three year blocks on the basis of their third mission activity business plans whilst a system for allocating funds on a formulaic basis using metrics is developed as a means of providing more permanent funding. On the other hand, HEW and HEFCW (2003) suggest single funding stream to HEIs with which to carry out third mission activities.

A single funding stream allocated on a metrics basis might also help to resolve the fragmentation of effort with regards to university – industry collaboration that extends within the universities and prevents firms without previous links to academic staff from accessing expertise. The requirement to disclose third mission activities in order to receive funding would make a central record of collaborative activity in the university the norm. However, the rate of change is slow: in spite of recommendations for a single funding stream for third mission activities in HEIs made in 2003, significant change in the organisation of funding had not been achieved by 2007. Furthermore, a single funding stream available to universities for third mission activities does not necessarily address the problem of different funding sources for firms. Coordination between different funding streams to both universities and firms is required.

Change is desirable not only because it would mean that funds were distributed more efficiently but also because the current system exacerbates mistrust between universities and industry created by universities' boundary spanning existence as both a public body and a commercial enterprise. This process is examined in more detail below.

Public servant and commercial enterprise: the university's spilt personality

The Lambert Review (2003) suggests that it is a mistake to regard third mission activities, especially those involving SMEs, as an additional source of finance for universities. This report notes that such activities are unlikely to generate significant income and that their benefits accrue outside the university, saying:

> Third stream activities are not likely to generate large sources of funding for universities. For some activities, such as collaborating with SMEs, many of the benefits go to the outside world rather than to the university. There is a particularly strong case for continued support of these activities from third stream funding.
>
> (Lambert, 2003, page 45)

For Lambert (2003), the university provides a public service and in the long term it is not a viable commercial enterprise. However, the vision of the university as a commercial enterprise in all sectors, which pervades policy for Welsh HEIS, cannot accommodate this suggestion. Thus, for instance, the CETIC scheme must become self-supporting by the time its funding ends in order to continue. However, this means that the CETICs cannot fulfil their original remit, which was to assist Welsh SMEs, because the projects that such firms can afford are usually small and hence do not bring in enough money to make the centres financially viable without outside support.

Where universities did succeed in running projects aimed at encouraging university – SME interaction, some firms were wary of them. Such firms tended to feel that universities benefited more from grant-funded schemes promoting university – SME interaction than they did and that the universities' motives for interacting were suspect. The firms' suspicions that regional development funding used to promote university – industry interaction benefited the relatively well funded universities rather than the struggling firms which were supposedly the main beneficiaries were not totally unfounded as will be shown later. However, it would be a mistake to assume that universities had deliberately appropriated available funding for their own agendas. Rather, universities are favoured by the system for the assignment of funding which appears to assume that all organisations are equally able to compete for grants. Policy-makers have recognised that SMEs make up the majority of firms in Wales and that it is important to encourage innovative SMEs as part of the attempt to develop a home grown knowledge economy rather than relying on foreign direct investment in the form of large manufacturing facilities (House of Commons Welsh Affairs Committee, 2005, WAG, 2002a, WAG, 2003a and b). However, as we have seen, many funding schemes, especially those involving Objective 1 and 2 funds, had a complicated and lengthy application process and many SMEs do not have enough resources to dedicate to making such applications when there is no guarantee of any return. Universities, on the other hand, are sufficiently well staffed and well funded to be able to bear the costs of failed applications and to survive start-up times of over a year for successful projects. Therefore, it is universities that tended to be the recipients of funding for projects aimed at promoting interaction and collaboration with SMEs in Wales. Despite their success in obtaining funding, academics and technology transfer staff judged the start-up times to be inefficient. They accepted that funding bodies had to make (and be seen to make) fair and accountable decisions but also felt that it should be possible to do this over a shorter timescale.

Since universities are more likely to be able to access funding aimed promoting university – industry interaction, most projects that obtain funding involve the university going out to search for SMEs that could benefit from their expertise and persuading them to interact rather than firms identifying possible new or improved processes and products and finding appropriate academic expertise to help them. Furthermore, regulations governing which firms are eligible for assistance do not always apply to universities – small, struggling firms therefore find themselves excluded on grounds of size and location while the far larger universities, sometimes located in the same area as them, are not.

This situation might not arouse ill feeling amongst firms if it was not for the uneasy position that higher education institutions occupy as both public bodies and commercial enterprises. While many academics and technology transfer staff in universities genuinely see projects promoting interaction with firms as a means of assisting and contributing to the local economy, they are also additional sources of funding that allow the institutions to compete within academia. As the Lambert Review (2003) recognises, most universities operate on a narrow margin with many functioning on a deficit and this encourages them to chase funding. While to university staff these two motives appear as a happy case of killing two birds with one stone, the financial incentive for interaction makes firms suspicious of universities that reach out to them. On the other hand, not interacting with these universities would mean missing out on available funding altogether.

Returning to CE4, we see an example of how the grant distribution structure and the university's double role as the provider of a public service and commercial enterprise breeds scepticism and mistrust between collaborators. Thus an employee of CE4 raised concerns over which organisation actually benefited from the project. He felt that the motives of his academic partners for including his company in the project were unlikely to be altruistic and gave the following opinion of the justification for the collaboration:

> It wouldn't surprise me if the reason that the university brought us in was just to tick a box on a European funding form that a local SME needs to be in with the project just to make it, um, be able to receive the funding.
>
> (Environmental consultant, male, south-Wales)

The implication in this quote is that the university should only enter into partnership with an SME for the benefit of the SME and they were not doing this – the project was for their own benefit. On the other hand, this interviewee also realised that taking up the university's offer of partnership in the project could provide the firm with additional income and that the firm could not afford to have applied for the funding themselves and this had been the reason for collaborating in spite of doubts about the university's motives.

As it happened the project did not meet its targets for assisting SMEs and did not bring CE4 the projected additional income that had originally encouraged them to enter into partnership with the university. The interviewee reflected on the slow uptake of the project, this time expressing doubts about whether the those firms that it was targeted at really benefited from the assistance on offer:

> [A]lthough the first so many hours of consultancy is free to the company, when it's no longer free to the company it's really not cheap. So … who's benefiting from the funding? Is it the university or it the SME? So if the idea is to help the economy in that, you know, the less wealthy of, um, Wales then the funding ought to be passed on more to the SMEs and, you know, it may be that actually the benefits are going to the university than to those who are actually requiring and who it was originally aimed for. […] I guess the question to be asked is, um, was there a real need for the scheme? Was the concept for the project, um, initially put in because a need was seen for SMEs in the Objective 2 wards of Cardiff, or was it put in because it was a project which the university could do? […] We're an SME working on a project with the university and we are sitting thinking 'I'm not surprised other SMEs we're trying to target aren't showing much

> interest'. Because we can't see the really what the university is offering us that's good value for us.
>
> (Environmental consultant, male, south-Wales)

On the university side of the project, the company's doubts at first seem a little harsh. The technology staff believed from past experience that collaboration between universities and firm could be beneficial for both parties and that they could play a role in encouraging high-end technology in Wales that would help to improve the economy. They had selected their partner company because of the company's business contacts, area of expertise and because the two parties had collaborated before and these collaborations had been successful. However, they also admitted freely that one reason choosing to work in partnership with a company was:

> Kind of funding things, they're actually looking favourably on if you're actually with or in collaboration with a company.
>
> (Project engineer, male, south-Wales university)

Furthermore, the chief spur for establishing the project had been the awareness that European funding was available. However, market research before the project had estimated a greater number of firms which might benefit from the project than had been found in practice. They also recognised that firms targeted by the project were not benefiting as much as they should have from the funding and felt that these were the organisations which ought to have been benefiting. For these technology transfer staff, however, the benefits were not going primarily to the university rather than to the SMEs at which it was aimed; instead money was being wasted through the inefficient system of distributing regional development funding of which they were sceptical.

In this story and in similar ones told by other firms and their academic partners, the individuals engaged in interaction hold a series of normative beliefs regarding how regional development funding is to be used and who is to use it:

perceived violation of these beliefs brings about scepticism and mistrust. These normative beliefs are examined in the following section.

Moral geographies of innovation and regeneration

Specifically, it was felt that grant funding should be used to contribute to the development of the economy rather than simply to allow certain companies or individuals to survive in their chosen sphere of activity, i.e. funding should help form a 'correctly functioning market'[1], and make companies and universities less dependent on the state. While these beliefs concerning the 'correct' use of funds appear in firms' discussions regarding the true beneficiaries of schemes promoting university – SME interaction, they are seen most strikingly in the idea of grant dependency, which was considered a problem by both interviewees from industry and academia alike.

These interviewees expressed the opinion that dependency on grants when it came to undertaking new activities, whether it be collaborating with universities or starting a new company was a negative aspect of the Welsh economy. This dependency manifested itself in two ways. It was felt that some companies' and academics' activities were dictated by the grants that they could receive. For example, one interviewee described the early existence of the company that he worked for in the following way:

> I believe that the main reason that it started... in Swansea, was that Swansea is an Objective 1 area. So you try and have an Objective 1 address to make use of the funding that's available. The, er, it seemed the whole aim of the company, um, in it's first three years of its existence was 'Let's just try and get as much funding as possible', um, without really any clear direction or focus. So we were just scrabbling about like a lot of organisations do, um, just trying to exist by getting hold of, um, grants.

[1] Of the idea of the 'correctly functioning market' is in itself normative, deriving from neo-liberal discourse.

(Sustainable Energy Employee, male, south-Wales)

The above interviewee saw his company's behaviour 'fundamentally as wrong' because in his view 'you should have a direction and a focus and an aim'. Similarly, another sustainable energy company employee criticised the use that some academics had made of structural funding:

> [P]eople are going research for research's sake. Not because it needs to be done, but because they need to survive in academia. [Academics are] persuading people they need to do [research] when it's generally been done ten years ago in one particular instance....People in the Assembly think 'We don't know enough about certain issues, so therefore we need to do more research' and I'm saying 'Well, we do know about it. They've told you we don't because they need to survive'. But I was an academic so I know what it's like, but that's really not good, for anybody.
>
> (Sustainable Energy Employee, female, mid-Wales)

In these stories firms and individuals are not seeking to compete as their respective spheres – they are simply hoping to survive.

Additionally, it was felt that individuals and companies in Wales would not start up a new company or project to develop a new product or process unless a grant was available whereas in other regions they were prepared to take a risk and go it alone. In the words of one mid-Wales academic 'there's a strong grant culture in Wales, that [firms] now expect grants almost'. Thus interviewees from companies that had made use of funding schemes were happy to say that their firms were prepared to fund their collaborative activities themselves if external assistance was not available. Within a neo-liberal discourse it shows their independence from the state, although a different interpretation would be that they were taking up funds that could be used by more deserving cases.

These normative beliefs concerning the use of regional development funding create a moral geography of innovation and regeneration in Wales. A reliance on funding to keep afloat, innovate or create start-ups is attributed the poor character of

Welsh firms and individuals, who to blame because they are narrow-minded, resistant to change and unwilling to take risks. One interviewee goes even further. He explains why, although his firm relocated to Wales, it still uses suppliers located in the south of England:

> The companies aren't here, the manufacturing, small engineering companies that we are looking for, who can give us the service are not here. The ones that are here are looking for much larger quantities. Um, all of the machine people here cannot compete on price. For instance, I recently had a new product made in Surrey costing to our company just under £3 per part and somebody in south Wales in the Port Talbot area quoted me £49 for the same item. Now something is dreadfully, dreadfully wrong between somebody in Surrey quoting £3 and somebody quoting that sort of money, basically because they're not interested in taking on new things. [The companies here] worked for the coalmines, what the coalmines want and they've still got the same attitude to business: we'll make a one-off piece and a ten-off piece, but it'll cost you the same, and if you want 2500, it's going to cost you the same. [...] [U]nfortunately there's lacking what I call small start-up companies. [...] People that have been laid off and such from the larger big companies in operations don't seem to be able to get themselves off the ground, for some reason. Whereas in the Surrey area, where Farnborough, the aircraft industry has shut down, um, the RAF, a lot of the engineers have left the RAF, but picked up on their own machinery and are doing quite nicely with it. [...] [T]he labour in using on our parts because they're so small is quite intensive. No skill in it at all, I mean... It's too small for [the companies here], yes, and the quantities were too small.
>
> (Technical director of aerospace SME, male, south-Wales)

Essentially, the companies described here are still operating in a Fordist mode of mass production. Their reluctance to take on orders for new types of products reveals a lack of flexibility. Additionally, although they will make one-off pieces or small quantities they are reluctant to do this, as is shown by the fact that their customers are encouraged to order large quantities by charging a lower price per piece on large orders. Implicit in the above interviewee's account of the price difference between the Welsh suppliers and their Surrey counterparts is that laziness as well as narrow-mindedness is the cause of the south Welsh company's inability to adapt to a more flexible form of production – they do not want to take on the labour intensive work of making small batches of small parts – while the harder working, more adaptable companies in the south of England are willing to take on this type of work. This unfavourable comparison with the south of England, which is characterised as a region of enterprising high-technology firms, is not unusual.

A closer look, however, reveals a case of double standards. The south of England was perceived as an area with an economy that was stronger than that of Wales. The difficult economic circumstances in Wales were contrasted to those in the south of England, where it was felt that the economic conditions were conducive to success. For example, the south of England was seen by both firms and academics as a knowledge-based economy characterised by a cluster of high-technology firms along the M4 corridor and a pool of high quality, skilled graduates. This was a resource noted to be lacking in Wales with both firms and academia also finding it difficult to attract such graduates. The explanation given for this difficulty was that individuals working in the high-technology industry clusters in the south of England are unlikely to relocate to work in high-technology industry in Wales because difficult economic circumstances made it a less desirable place to work. It was felt that relocating to Wales was seen as a risky venture by such graduates because there were few choices for alternative employment if they disliked their new job or were made redundant, whilst returning to the south of England would be difficult due to the considerably higher house prices in this area compared to Wales. In this respect interviewees recognised that the disadvantageous economic circumstances impacted on the region's attractiveness as a place of work. Yet these same disadvantageous circumstances were not recognised as factors impacting on entrepreneurship and innovation, although similarly there are disincentives to starting a new business or investing in an innovation in the region. Specifically, individuals and companies are less likely to undertake entrepreneurial or innovative activities if they perceive few opportunities for alternative employment in the region if their ventures are unsuccessful and high house prices elsewhere make relocating difficult. In these circumstances grants and loans may help to overcome these disincentives.

Discourses of grant dependency also fail to recognise the lack of private equity and business service provision which makes the process of starting a new business or investing in innovation difficult in Wales and causes potential innovators and entrepreneurs to rely on grant funding (see Chapter 1). The story of one computer science spin-out firm narrated by an academic involved in its start-up and eventual sale reveals how financially vulnerable entrepreneurs can feel:

> So X [who] is the head of department now … set up a company […] and, um, er, last year we, er, sold the company to, um, a large American software vendor, who sells a lot of stuff like [our invention] to Ford. Oh, it's all owned by that company now, but there were a lot of people who put money into it. When it was set up as a company, the university put shares into it. And University Challenge Fund, which is a fund to promote spin-outs put quite a lot in, um, ourselves, all of the researchers who'd contributed to it put shares, well, bought shares, but we aren't going to make much money out of it because basically they negotiated a very tough deal.... I don't think we negotiated hard enough…. The university transferred, I mean the university owns the IP and pays us, the investigators, a percentage of the royalties but there's no royalties, just a handout when the shares were distributed. Um, but we also put loans in as well, to keep the company going, yes, so the, some people made a loss actually…. We're all scared here of going bankrupt if it doesn't work and if we've got to put our house into it….Er, you know, the person who set up the company did a lot of work on it and he was, while he was working here, a part time thing, and it's purely his risk…
>
> (Professor, mid-Wales university, Wales)

Sticking to tried and tested routes and avoiding risks are not inherent characteristics of the Welsh population, as policy aimed at substituting for a lack of private equity and business services recognises. Rather they are the result of existing in economically disadvantaged circumstances. One individual who played an active role in establishing the Technium programme of university-linked business incubators across Wales notes that, in fact, Welsh people have been successful at starting businesses and innovating. He explains the spur to creating the project in the following way:

> [A] group of us reflected on why so many Welsh people do well in the world of knowledge business but very rarely do it at home. Canada, America, Europe, England, of course. Very few examples of people doing it here and was there something missing? Did we not have some sort of infrastructure that would support that process?
>
> (Policy developer, male, south-Wales)

The Technium programme seeks to prove some of the infrastructure that tends to be unavailable to small firms in Wales: business support services, suitable accommodation, R&D support and incentives to grow.

Thus neo-liberal discourses serve to ascribe blame to those less successful regions for their predicament and masks the fact that all regions do not operate from a level playing field: arguably the south of England, appearing in the interviews for this project as a paradigmatic successful region, full of highly skilled and adaptable firms and individuals, has not had to adapt to deindustrialisation in the same way as region such as Wales, having had a concentration of legal and financial institutions for a significant period of time, rather than a concentration of producers of raw materials. The problem with this negative attitude is that it becomes a self-fulfilling prophecy, locking Welsh organisations into certain ways of acting and preventing change.

Lock-in and negative thinking

The effects of negative thinking can be seen in two areas. Firstly, there is the problem of skills shortages, which has been touched on briefly above. Secondly, there is a lack of confidence in the ability and innovativeness of the Welsh people which leads people to believe that a knowledge economy is something that must be imported from economically successful regions.

As we have seen, companies complained of difficulties in recruiting skilled graduates. This is not necessarily because Wales does not produce such individuals, but because they do not stay within her borders. Several interviewees, both academics and those in industry, suggested that people with the most successful careers (in industry, at least) leave Wales and this idea was repeated in policy documents such as *A Winning Wales* (WAG, 2002a) and *Polisi Gwyddoniaeth ar gyfer Cymru 2006* (WAG, 2006). A vicious circle occurs wherein people with higher level qualifications are attracted to areas outside Wales where there are more suitable jobs meaning that when industry seeks to recruit for such positions in Wales there is no pool of appropriately qualified workers. Without this pool the type of industry employing workers with higher level qualifications is unlikely to expand. Thus the notion that it is necessary to leave Wales in order to succeed career-wise is an example of an ingrained idea that eventually becomes self-fulfilling, impeding change. The image of Wales as a place with few opportunities for those with higher-level qualifications encourages the highly educated to leave and, as we have seen, discourages them from coming. However, it is important to remember that skills shortages are not something unique to Wales. Focussing on the sphere of university – industry interaction, we see that although Welsh universities experience a lack of appropriately experienced technology transfer staff and staff to manage academic spin-out companies this is something they share with universities in the rest of the UK (Lambert, 2003). Furthermore, there is a way to overcome the problem. Some firms in the steel and life sciences sectors have attempted to overcome skills shortages by sponsoring students at local universities through appropriate qualifications with the aim of recruiting them when they have qualified.

Within the universities, many academics and technology transfer staff who are interested in promoting the development high-technology industry in Wales still think in terms of attracting foreign firms (i.e. non-Welsh firms), although policy recognises the need to develop home-grown industry as well as seeking foreign direct investment (e.g. WAG, 2002a). One interviewee, a technology transfer employee at a South Welsh university, went as far as to state 'I mean, the only way that high-end technology is going to come here [i.e. Wales] is from elsewhere, isn't it?'. The idea that Wales must import industry and strategies from successful core regions runs deep. Encouraging firms producing arms and other military equipment to locate or remain in Wales, as put forth in the House of Commons Welsh Affairs Committee (2005) is an example of this tendency. For universities collaboration with the defence industry remains seductive because of the significant funding it brings in. However, research shows that in terms of promoting a knowledge economy military R&D does not contribute significantly to greater innovativeness and thence to economic competitiveness because innovations made in this context are usually too specialised and expensive to be of use in other sectors (Leslie, 1993).

A reliance on importing strategies means that it is hard to break free from ingrained but inefficient ways of thinking. As we have seen linear model of innovation is still alive and well in UK policy: this model is inscribed into the RAE. This determines the distribution of funds though the university funding system, which in turn, according to some academics, drives universities to traditional research outputs in the form of publications rather than IP or collaboration with industry. It is perhaps not a surprise then that the linear model of innovation makes its appearance in a purely Welsh context as well. It is implicit in the design of the Technium network – manufacturing is not usually present in these incubators with the exception of the Sony Technium.

Of course, the very idea of creating a knowledge economy is an imported strategy, and because of this there seems to be a rather shallow understanding of what innovation means. It is often felt that innovation must appear in certain forms. Firstly, funding schemes could be rather limited in their view of an innovation. They tended to see innovation as improved (physical) products, rather than new applications of knowledge. The directors of a company that worked closely with a local university to commercialise its GIS and remote sensing research described their experiences. Their work had a number of applications, including the visualisation of proposed wind farms – a hot topic in Wales – but they found it tended to be judged on one aspect:

Interviewee 1: [T]here's problems with, um, software development grants. It's often seen as, software development, it's not seen as innovation, which is very strange.
Interviewer: Is that something to do with the fact that, um, it changes very quickly or that it's not sort of something that's generally gets patented or…?
Director 1: Possibly, I think it's just that probably the people in charge of money don't really understand.
Interviewer: Yes, what it is.
Director 1: What is it, yes.
Interviewer: And what you can do with it.
Director 1: Yes.
Interviewer: Ah right, I see.
Director 1: It's always quite interesting trying to explain what we do. They always say 'You make maps then? Aren't there enough maps about already?' which is normally the case, I mean we, maps is just one by-product.
Interviewer: Yes, exactly. There's more to it than just maps.
Director 1: Yes. Not that they can see it. Puts you off applying a bit. […]
Director 2: Um, certainly the main experience we've had, we're in something of a pocket, or least in Wales, with the knowledge economy, people have been getting funding

> for research and development work. They considered, um, things like software as not being innovative. [...] [T]o me things like that are, if it's funding for R&D, certainly in the public sector is geared about producing a plastic widget or the latest steel part for something and, it's not about, um, it's not really feasible for the knowledge economy.
>
> (Company directors of environmental monitoring company, male, mid-Wales)

Firms that were innovative but did not fit into the perceived notion of an innovative firm also found it difficult to find assistance. AS3 is an aerospace company run by a husband and wife team who act as technical director and non-technical director, which subcontracts its manufacturing and has no ambitions to grow any bigger. Neither of the couple had higher-level qualifications in areas of technology relevant to the company: the technical director had not had a college or university education, while the non-technical director had been a teacher. Nevertheless, the company was active in producing new and improved products. Somewhat to their surprise they had found themselves supplying organisations such as NASA:

> [W]e know that Rolls Royce are supplying some of our stuff into NASA because NASA, we had a e-mail from NASA and we thought it was somebody winding us up and we nearly didn't open it, but it was a good job that we did because it actually was from NASA.
>
> (Technical director of aerospace company, male, south-Wales)

However, because of its small size the company tends to be ineligible for help from the WDA or university-run schemes. Furthermore, when they had approached universities for help in developing new products these institutions were not interested, partly because AS3 foresaw that were likely to only invest relatively small amounts of money in the collaboration, but also because the firm had a rather unconventional approach to product development, with no budget for developing the new product, no documented specifications for it and no idea of how many of they might eventually produce. Indeed as the technical director explained it, the whole process seemed a rather low-technology, trial and error affair. Here is his description of a development that had saved Rolls Royce 30 hours engine build time:

Interviewer:	The ideas for your new products generally come from...
Technical director:	Within me.
Interviewer:	Within you, and where does that come? Is that from your...
Technical Director:	General knowledge from what we do, and what Rolls Royce are looking for, and I went through an electrical training as well. ...[O]ne of the things that Rolls Royce wanted recently was to be able to terminate, um, tiny tubes, um, stainless steel tubes. [...] They were terminating in a nut ... and they wanted a quicker way of doing it.... I took on this project and I suddenly realised that you could hold a stainless pipe in the same way as a piece of cable is held onto a machine. On the back of a machine, a piece of cable feeds into the machine that feeds the electricity into it. It's fed through like a small rubber and the rubber holds the cable in position so when you pull it don't pull out. Well, that actually worked on a stainless steel pipe. [...] I actually approached a rubber manufacturer and said 'What should I use?' [The manufacturer said] 'I don't know, but what we can do is send you some rubber and you can play with it' and so they sent me some short lengths of rubber. I cut it, drilled it, tried it and now much to the amazement of I think nearly everybody including myself, this particular product will hold a stainless steel pipe in to 3000 PSI by just tightening the nut once and it's absolutely amazing, and that is where [Rolls Royce have] saved so much time, because they can push this stainless steel into the nut, through the rubber and down to the bottom, tighten the nut, finished.

(Technical director of aerospace company, male, south-Wales)

However, in spite of appearances of being a low-technology development process, there were some technical aspects, such as the very high voltages used to start aircraft engines, that the technical director felt required academic assistance.

Underestimation of the abilities of very small firms had led both funding bodies and universities to overlook the genuine novelty of ideas emerging from this firm.

Gender inequalities and the knowledge economy

Perhaps because they underestimate the abilities of small firms, some academics show a certain amount of arrogance towards SMEs. They tend to talk in rather dismissive terms about small companies with one lecturer going as far as to describe large multi-national firms as 'proper industry', thereby relegating all SMEs to second class status. Such attitudes are encouraged by the RAE which rewards academics for being recognised as authorities in their field and attracting the most funding – which usually entails working with the largest companies – and in turn legitimises a culture of competitiveness and egotism. According to Knights and Richards (2003) this culture is produced by social pressures upon men to live up to the image of certain masculine ideals. They suggest that:

> Masculine subjects feel 'driven' for no discernible reason other than a demand to 'perform' in relation to what it means, and how it feels, to subscribe to an ideal of competence.
>
> (Knights and Richards, 2003, page 227)

Conquest, competition and control are used as strategies to resolve masculine insecurities about the self which are exacerbated by the competitive culture within academia. Of course, this strategy is self-defeating 'because it reinforces precisely the conditions of that insecurity – that is, the unceasing necessity to display a competent self on each and every academic discursive occasion' (Knights and Richards, 2003, page 227) and in fact strengthens the culture that it seeks to overcome. The RAE, therefore, represents an institutionalisation of 'masculine norms and practises and the instrumental rationality…that informs and reinforces their reproduction' (Knights and Richards, 2003, page 237).

The lack of women in academia, particularly in science and engineering, has been attributed to the institutionalisation of masculine norms and practices (Benschop and Brouns, 2003; Heward et al, 1997; Knights and Richards, 2003; Krefting, 2003). In universities throughout Europe and the USA, fewer women than men are employed in academia, and the women that are employed tend to be overrepresented in part-time and temporary positions. Moreover, women are paid less, slower to be promoted and less likely to be awarded research grants than men with equal qualifications and experience (Benschop and Brouns, 2003; Finch, 2003; Heward et al, 1997; Krefting, 2003; Knights and Richards, 2003). In this respect, Welsh universities are no different from other European universities. There was only one woman among the permanent academic staff taking part in the collaborations studied for this project, and the Higher Education Trade Unions in Wales' (2001) document *Contribution of Higher Education to the Welsh Economy* suggests that this result is not an anomaly in Welsh academia. This report notes that there are more male full time and permanent staff employed in academia in Wales than female, and that women are more likely to have part-time and fixed-term contracts with an average pay gap of more than £5000. The worst offenders in the academic year 1997/98 were the University of Wales College of Medicine (now part of Cardiff University), the University of Wales Lampeter, Cardiff University, the University of Wales Aberystwyth, the University of Wales Swansea and the University of Wales Bangor, i.e. the oldest and most traditional research active universities.

Benschop and Brouns (2003) suggest that a move from what they term 'the Olympus Model' of the sciences to 'the Agora Model' will encourage greater gender equality in academia. The Olympus Model:

> situates the scientists, in their unselfish and disinterested quest for truth, at the top of Olympus, far distanced from everyday down-to-

> earth worries. In this model, science is described as an autonomous social institution, which produces superior knowledge: only science delivers true and objective knowledge. [...] Science is primarily aimed at other scientists. The interaction with a wider audience, with other loci of knowledge production and transmission is almost reduced to zero in the context of valuing the scientific quality. These results and products of scientific activity do not count...
>
> (Benschop and Brouns, 2003, pages 207-208)

On the other hand, in the Agora Model:

> science becomes a societal practice, tightly bounded with other societal practices...In this model there is a strong interaction between the production of knowledge, transmission and translation of knowledge. Science is one of the loci of the market place of exchange, firmly rooted in and interacting with what is commonly known as 'the knowledge society' [...] In that case, scientific quality can no longer only be related to esoteric, academic values and the recognition of peers through publications in international scientific journals, but should also be related to other values (for instance, use to various parties or emancipatory potential) surrounding knowledge... In fact, this image of the sciences strongly reflects the actual of female scientists and the younger generations in the academy...
>
> (Benschop and Brouns, 2003, page 208)

Therefore, Benschops and Brouns (2003, page 209) expect that 'gender will be done differently' if universities become part of the knowledge society, with a reduction in gender inequalities within academia. Benschops and Brouns' (2003) notion of the Agora Model of science bears strong similarities to Gibbons et al's (1994) idea of Mode 2 knowledge production (see Chapter 2 and Chapter 4). However, as argued previously, there is little evidence to support Gibbons et al's (1994) claim that universities are moving towards a radically new form of knowledge production, at least within the Welsh context. Indeed, the embedded masculine culture within Welsh universities appears to be inhibiting institutional involvement with efforts to develop a knowledge economy or knowledge society in Wales by discouraging involvement with SMEs which make up a large part of the Welsh economy. In additional, it impedes cooperation between institutions.

The culture of control, competition and pursuit of prestige (which often entail conquest of others) is not limited to individuals. On an institutional level, competition between Welsh universities for is quite often seen with institutions perceiving each other as rivals for funding or at least the prestige that contributes to gaining funding. As one academic put it:

> Inter-university collaboration, my experience of it in the past has been it can be a little fraught. You can get conflict between the institutions where they'd be vying for position, jockeying for position...
> (Head of School, male, south-Wales university)

This situation arises despite the fact that literature such as the HEFCW consultation proposals for future third mission funding arrangements in Wales (HEFCW, 2004) and the *Joint HEW-HEFCW Working Group on Third Mission Final Report* (HEW and HEFCW, 2003) promotes co-operation and collaboration between universities as necessary for successful regional development. Although research collaboration between academics is a frequent occurrence where joining forces can have mutually beneficial outcomes for those involved there is a sense that collaboration does not always come naturally outside of these arrangements: essentially the RAE constructs universities as competitors for limited public funds towards their research activities and this spills over into third mission activities which contribute to RAE rankings by feeding into research activities or providing prestige factors. There are some successful instances of inter-university collaboration on third mission activities – for example, some of the CETICs are spread across more than one university – which show that it is possible to collaborate on one project whilst also competing with partners for funding for other activities. However, one technology transfer officer suggested that collaborating with institutions outside Wales was easier, because these were funded by different bodies to Welsh institutions and therefore are not competitors for money from the same sources.

Conclusion

In this chapter therefore we have seen how an over complex structure for distributing funding for university – industry interaction leads to confusion and inefficiency. Moreover, it interacts with the dual role of the university as public body and commercial enterprise to breed mistrust of universities in firms. Whilst the use of Objective 1, Objective 2 and WAG funding to encourage universities and industries to work together has certainly enabled more collaborations than would have otherwise taken place, it is not always clear whether these collaborations are always answering an identified need for university expertise in Welsh firms. The benefits of these funding schemes are not always going to the firms at which they are targeted and it is possible that some benefit universities more than firms. Short timescales and narrow eligibility criteria further reduce the effectiveness of funding schemes.

The mistrust shown by firms to the universities has its origins in the violation of certain beliefs about the 'correct' use of funding which are influenced by prevailing neo-liberal discourses. These beliefs can be seen particularly clearly in the ideas of grant dependency and create unhelpful moral geographies of innovation and regeneration wherein the people of Wales are blamed for their economic predicament. Negative conceptions of Wales help to keep individuals and organisations locked into certain patterns of behaviour and understanding which helps keep the economy from changing. Policy implementation exacerbates these problems by favouring universities in funding application procedures and taking a narrow view of what constitutes innovation. Additionally, the RAE institutionalises masculine norms and practices that impede universities' integration into the knowledge economy.

In spite of the negative picture painted in this chapter there were some positive signs that policy aimed at developing a knowledge economy in Wales was having some effect, even if was patchy and slow in occurring. Thus, Cardiff in particular was seen as vibrant and with a buzz[2], but smaller locations such as Wrexham and Aberystwyth were also seen to be doing well. According to one academic Aberystwyth is a hive of activity:

> Um, there's been a big change in the last ten years though, definitely. I mean we've got a Technium down there; the science park is full. We've got incubator units, there's [the university's Commercial and Consultancy Services department], [the university are] building the Visualisation Building which has got incubators and commercialisation for, I mean, it would have been silly to do that ten years ago, I think. There were three spin-out companies from this department over the last few years and there are there a lot of others. I mean it's much more active than it has been, and it I do, I mean, Aberystwyth has grown as well, there's lots of building work. The population's increased. I do think the lifestyle and all that is very attractive to people.
>
> (Professor, male, mid-Wales university)

However, the areas of Cardiff, Aberystwyth and Wrexham have traditionally had higher levels of human, cultural and economic capital than other parts of Wales. Wrexham is one of the largest towns in the industrial north-east and its location close to the English border means that it has closer links to the more populous and wealthy West Midlands region. Cardiff is the capital of Wales whilst Aberystwyth, as home of the National Library of Wales, Wales' first university, Plaid Cymru and the Urdd, has long been seen as a seat of learning and political activity. The knowledge economy appears less obvious in areas such Llanelli or Bangor which have not traditionally been endowed with the same levels of human, cultural or economic

[2] One interviewee (a geographer by training) even described Cardiff as a global city although perhaps his point of view had been influenced by living in the rather smaller and more remote location of Aberystwyth for several years.

capital. Therefore, care needs to be taken that current policy on the knowledge economy does not further entrench inequalities within the Welsh regions.

In the light of the discussion and conclusions above a series of policy recommendations can be made:

- More research is needed on the need for and best use of Welsh university expertise in firms in Wales.
- The plethora of funding schemes for university – industry collaboration that replicate each other but for small differences needs to be simplified. A 'joined-up' strategy between different funding bodies is needed in this area. Whilst a single funding stream to universities for third mission activities may help universities through the funding maze, it will not necessarily help industry find suitable financial support. Simplification of funding distribution is needed on the industry-side as well.
- Recognition of communication problems and improvement of communication channels between funding bodies and universities is necessary.
- Universities need greater freedom to use third mission funding as they see fit.
- It needs to be recognised that third mission activities with firms, particularly SMEs, are unlikely to bring in funding and are more likely to be an additional demand on universities' resources and therefore require funding accordingly. This should involve longer term funding.
- Application procedures for funding for university – industry collaboration need to be simplified and start-up times reduced, enabling smaller firms to apply and making such funding schemes more appropriate to industrial timescales.

- Loosening eligibility criteria for funding could enable a larger number of deserving firms to be assisted. Additionally it could encourage further interregional interaction which has been shown to be important for regional learning (Rees, 2005a,b).
- Discourses of grant dependency which blame those in economically disadvantaged areas for their own predicament are not helpful for engendering change in the Welsh economy. Encouraging greater understanding of the dynamics of uneven development in academia and industry is necessary.
- Further attempts are needed to overcome discourses of failure which characterise much thinking about the Welsh economy. Potential solutions to problems such as the sponsoring of local young people at university to overcome skills shortages need to be promoted. Additionally, wider conceptualisations of what constitutes 'innovation' need to be promoted among policy implementers.
- Institutionalised masculine discourses within universities can impede their engagement with regional development activities. Bringing the hidden assumptions behind these discourses into the open can help to promote change as discussions arising from the publication of a report acknowledging problems of gender inequalities at the Massachusetts Institute of Technology (MIT) have shown (Krefting, 2003). Therefore further research into this area is recommended.

Chapter 8

Conclusions

The history of scientific practices and spaces impacts upon both the formation and nature of relationships between universities and industry. Conflicts between the internal and external constructions of science, the social and spatial division of labour between the university and industry and the linear model of innovation all interact to form the complex socio-cultural context in which university–industry interaction occurs in the present day. It is this context that determines the contributions of universities to regional innovative capacity. In much of the literature there has been a narrow conception of such contributions with a tendency to focus on knowledge spillovers.

With this evolutionary perspective in mind, this thesis has sought to provide a more detailed understanding of knowledge flows between universities and firms in peripheral regions, using Wales as an example, focussing on the different types of knowledge flows, how knowledge flows occur and conditions that encourage such flows. Using five industrial sectors selected on the grounds of their past, present or potential significance to the Welsh economy – aerospace, life sciences, opto-electronics, steel and sustainable energy – it has investigated four central issues. These are the presence of university – industry interaction in Wales and the spatial division of scientific labour between academic and industry, the formation and maintenance of links between industry and universities, the ways in which knowledge changes as it passes into different spaces and the implications of university–industry interaction for regional economic development in the Welsh context. Key findings on these issues are presented below.

Interactions between universities and firms from selected industries: the Welsh experience

The potential for interaction in the selected industries is mixed. The number of firms in each of these industries is small. In the sustainable energy sector, the number of small, young firms located in rural areas with few HEIs close by with which to interact suggests a particularly low potential although this is not borne out in practice. In the aerospace, sustainable energy and steel industries, firms interacted with universities at all stages of their innovation processes. However, no life sciences firms made use of university expertise for problem solving and no opto-electronics firms made use of university testing services. Most engagement between firms and academia occurred within schools and departments in the physical, natural, biological and computer sciences. Firms made surprisingly little use of funding schemes aimed at encouraging interaction, possibly because these schemes are deemed to have complex and lengthy application procedures and have very strict criteria for eligibility.

Sponsoring university research is the most popular form of substantial collaboration undertaken by firms followed by testing services. It is a relatively cheap way of obtaining knowledge and expertise from universities. There are many benefits to collaboration that show basic similarities between the spaces of industry and academia. These include research income for HEIs and funding for firms or production of trained researchers for HEIs and recruitment of skilled staff for firms. However, firms and academics also cite a number of impediments to collaboration which reflect the different working practices between firms and universities and the continued fragmentation of the innovation system. Particularly important impediments in this respect were the marginalisation of industrial work in academia as lacking prestige and disagreements over whether projects should be conducted according to academic or industrial mores.

The establishment of centres within universities specifically dedicated to interacting with firms and employing staff solely on such projects points to the development of a further division in scientific labour in universities between staff conducting traditional academic basic research and staff conducting applied research in conjunction with industry. However, these centres still draw on the expertise of academic researchers and therefore do not always avoid the problems associated with combining academically prestigious research with the demands of industry. The centres' market driven model also means they often do not reach the smaller Welsh firms at which they are aimed, since they can only become financially self-supporting by providing services to larger firms which can afford to fund larger projects. Due to the lack of medium to large firms that undertake R&D in Wales the larger firms with which these centres work are often outside Wales. In addition, centres with a focus on short term commercial contracts may be less likely to lead to the development of new products and processes than long term, more traditional academic projects, although these centres can still contribute incrementally to the innovation process. Short term commercial contracts often produce little original IP.

Little evidence was found in the Welsh context to support Gibbons et al's (1994) suggestion that the traditional division of labour between universities, industry and other organisations is breaking down and being replaced by a radically different way of performing science involving a search for knowledge for application, an absence of disciplinary boundaries, a heterogeneous set of practitioners (academics, industrialists, consultants and government researchers), a transient and heterarchical structure, and a socially accountable and reflexive method of quality control. Rather, the findings from this projects support Whitley's (2000) suggestion that Gibbons et al (1994) severely oversimplify changes in the way scientific labour is divided occurring at the present time. Gibbons et al (1994) suggest that we are moving to a new mode of knowledge production (Mode 2 knowledge production) which blurs the previously distinct boundaries between production of basic research in universities and applied research outside universities. However, although the interactions studied in the current research involved heterogeneous sets of collaborators coming together for transient projects in the manner of Mode 2 knowledge production, the hierarchical structures of university research remain in place, as senior academics manage the research activities of post-doctoral researchers and post-graduate students with additional management input from their industrial collaborators. Publication in refereed journals and peer review in the form of the RAE remain the chief form of quality control for the academic collaborators. Moreover, while problems may be brought to the university by firms, in many cases they must be deemed academically interesting for interaction to occur. Although useful to industry, the research undertaken in collaborations would still be of interest to the scientific community even if it did not have the applications that it possesses. In other words, there is still an element of pursuing knowledge for its own sake for the academics involved in collaborations. Whitley (2000) argues that there are considerable differences in the institutional governance of research and education across the Global North which also varies over time. He suggests that academic interest in use-oriented research and human-made objects is not a new phenomenon and that disciplinary boundaries within academia have never been completely rigid. Indeed, a variety of practitioners have been involved in science throughout its history. In keeping with Whitley's (2000) ideas, academic interviewees in this project have noticed a movement in university and funding council policy towards encouraging research involving non-academic partners, which usually tends to be more applied research. However, they do not see this movement as involving radical change in the way they produce scientific knowledge, since old institutional arrangements such as peer review, publication and academic hierarchy remain in place. Their experiences support Whitley's (2000) suggestion that, for political and economic reasons, there has been an increase in the amount of explanatory instrumental research being carried out within the academic science community in parts of the Global North. Explanatory instrumental research is one of four ways of performing research that have existed since science began – theory-directed explanatory research involves no consideration of use of the phenomena explored but concentrates on explanation, instrumental research involves no consideration of reasons for the phenomena explored but concentrates on their use, explanatory instrumental research involves consideration of use of and reasons for the phenomena explored, and classificatory research involves the systematic exploration of phenomena without consideration of their use or general explanation of their behaviour. All these forms of research are still undertaken within academia with many academic interviewees translating explanatory instrumental research into theory-directed explanatory research type publications.

Non-interacting firms describe barriers to interaction that are similar to the impediments described by interacting firms and academics. The most common reason for non-interaction is the perception that working with a university is not necessary or relevant for R&D. It is possible that social ties between industry personnel and academics are a reason why some firms see university research as relevant to their business and some do not.

Forging links between academia and industry: the role of social capital, trust and communication

The utilisation of social ties by universities and firms to instigate interaction highlights the importance of cross-field connections between the different spaces of knowledge in enabling interaction. Social ties between personnel in firms and universities based on personal and close professional links can be thought of as bonding social capital belonging to these individuals and their organisations, while links formed between these organisations purely for the purposes of interacting may be thought of as bridging social capital. The relations that make up bonding and bridging social capital are fluid: one may develop into another. While some researchers have sharply distinguished between these different types of social capital, characterising bonding social capital as ties between homogenous groups or strong, dense ties and bridging social capital as ties between diverse groups or weak, loose ties (O'Brien et al 2005; Tura and Haarmakorpi 2005), in practice it is hard to make such definite distinctions. Groups are rarely completely homogenous or heterogeneous, and ties may strength or weaken over time, thus allowing interchange between bonding and bridging social capital.

Within the selected industries personal links play a prominent role in forging relationships between universities and industry in Wales. Overlapping spaces where connections between academics and industry personnel occur are particularly important for the development of bridging social capital. The use of links formed through professional activities, such as attending conferences or participating on advisory panels, to establish interaction suggests a process of converting bridging social capital into bonding social capital. In such cases, a period of trust building is usual. Conversely, the use of longstanding personal links such as former colleagues and friends to establish interaction suggests a process in which bonding social capital is converted into bridging social capital. As a research group become members of a network of familiar contacts to be approached by a firm when the need arises, or vice versa, this bridging social capital is then converted back to bonding social capital.

Communication between universities and firms is important in these processes of building bonding and bridging social capital. This is because strategic searching for academic expertise does not seem to be of prime concern to firms. Even when collaborating with academics from outside of Wales, links seem to usually involve academics who are very well known in their field and so are known to firms through word-of-mouth. Therefore, proximity does appear to have some effect on the tendency of universities and firms in Wales to interact because academics and industry employees are more likely to know people in nearby firms or HEIs through personal or professional networks. Official 'third mission' divisions within universities with a *raison d'être* to bridge the gap between the spaces of industry and academia, such as industrial liaison offices and commercial research centres, are not always involved in communicating their university's expertise to companies. Rather than using industrial liaison or commercialisation offices to find specific expertise, firms often use such offices to reach as someone they already know, or specific expertise of which they are already aware. The industrial liaison or commercialisation office then acts only to formalise collaborations by drawing up contracts between the firm and university. This usage of such offices may be a sign of the immaturity of the knowledge-based economy in this region. On the university side commercialisation efforts by Welsh universities are fragmented and may not be particularly flexible. In addition, industrial liaison or commercialisation offices tend to be small. On the industry side firms do not systemically search for academic expertise, partly because pressure to remain competitive means any tasks perceived as non-essential are avoided and strategic R&D planning often seems to be regarded as non-essential. In this type of environment, it is easy to see how utilisation of both bonding social to create bridging social capital and bridging social capital to create bonding social capital can be useful to firms and universities seeking to interact.

Knowledge flows between academia and industry: transfer, construction, translation and transformation

As shown by the discussion of impediments to interaction above, the different underlying principles that govern the academic and commercial worlds are such that direct knowledge flows between the two is not a given. In particular, there is a conflict between the academic characterisation of knowledge as a public good and the characterisation of knowledge as a commodity which informs commercial work practices. In order to overcome this conflict both parties engage in a process of translating each others' interests in order to enrol each other onto their respective projects. The outcome of this process is the creation of knowledge flows. These knowledge flows can be seen as a process of building different knowledge objects in different spaces of use.

Consequently, when discussing knowledge transfer activities organisations should not be thought of as simply gaining knowledge through a process of absorbing the results produced by academic – industry partnerships. Instead it is better to think of knowledge being constructed as each partner influences and adds to the final product of the interaction. Knowledge construction is a notion that enables the creation of a much more flexible and dynamic model of knowledge and learning than still appears in some policy and academic literature influenced by the linear model of innovation. Knowledge does not consist of unchanging and absolute artefacts which can be obtained firms in the same way as a new piece of machinery. Instead, some artefacts, such as a physical product or a concept, serve to coordinate the perspectives of academic and industrial actors during interaction, i.e. they act as boundary objects. These boundary objects enable academic and industrial partners to create meanings that are useful to them. It is these meanings that constitute knowledge.

Knowledge has a flexible and dynamic nature which is demonstrated by the process of translation that occurs in the interactions in this study. Although industrial and academic partners are involved in constructing the knowledge during a project, translation is necessary because it is the academic partner who is usually responsible for codifying results. It is necessary to codify results in at least two forms. These are the language expected by the academic community and the language of industry. Results may also have to be expressed in forms suitable for patent examiners, students, customers and a number of other interested groups. There is a different translation for each group and each translation is equally valid so long as it allows the groups to communicate with each other successfully.

In addition, knowledge is transformed as it is translated for use by different groups. Once it is put to work by these different groups its transformation continues. As knowledge is reinstrumentalised certain aspects are dropped and others are gained. In particular, certain artefacts can have different significance depending on the interpretation of the group using them. These differing interpretations can cause problems when academic and industrial partners need to use artefacts in their work together and cannot negotiate sufficiently compatible meanings for these artefacts. These detailed understandings of knowledge flows thus are helpful in explaining why apparently well matched partners can fail to work together successfully, and as such, could impact on attempts to promote interaction.

University – industry interaction in a knowledge economy: policy and practice

Universities have been given an important role in developing a knowledge economy for Wales in Welsh policy. The exploitation of knowledge from Welsh universities is seen as contributing to regional development by bringing in funding, encouraging Welsh firms to innovate and establishing new high-technology firms which will provide highly skilled and well paid jobs. A policy framework has been developed to build both the physical infrastructure to enable such activities and the social infrastructure between universities and firms. This framework involves encouraging the development of networks between academics and firms, the creation of academic spinout companies that retain links with their parent institutions and the promotion of interaction to firms and universities. A number of schemes are in operation to fund these objectives. Some positive signs that policy aimed at developing a knowledge economy in Wales is having some effect are evident, with increased economic vibrancy perceived in some of the main urban centres in Wales. However, change is patchy and slow in occurring. An over complex structure for distributing funding for university – industry interaction has led to confusion and inefficiency. This structure also interacts with the dual role of the university as public body and commercial enterprise and thereby encourages firms to mistrust universities. The use of Objective 1, Objective 2 and WAG funding to encourage universities and industries to work together has enabled greater engagement than would otherwise have been likely. Even so, there is uncertainty as to whether these collaborations always answer an identifiable need for university expertise in Welsh firms. There are two central problems here. Firstly, the benefits of funding schemes do not always go to the firms at which they are targeted. Secondly, there is some evidence that some schemes benefit universities more than firms. Effectiveness of funding schemes is further reduced by short timescales and narrow eligibility criteria.

It appears that some firms are mistrustful of universities and their motivation for interacting. This mistrust originates in the universities' infringement of certain beliefs about the 'correct' use of funding which are rooted prevailing neo-liberal discourses. Universities are perceived to be using available funding for their own benefit rather than for assisting firms to become more competitive. Such beliefs create notions of grant dependency, in turning leading to unhelpful moral geographies of innovation and regeneration in which blame is ascribed to the people of Wales for their economic predicament. Negative pictures of Wales and Welsh ability lock individuals and organisations into patterns of behaviour and understanding. In turn these behaviours and understandings keep the economy from changing. By favouring universities in funding application procedures and taking a narrow view of what constitutes innovation, policy implementation intensifies these problems. In addition, universities' integration into the knowledge economy is impeded by the institutionalised masculine norms and practices found in academic structures, particularly the RAE.

The above conclusions lead to a number policy recommendations. Whilst pertaining to the Welsh case, these recommendations are likely to be applicable to similar regions in Europe and further afield. In summary these are:

- More research should be performed on the need for and best use of Welsh university expertise in firms in Wales.
- Funding schemes for university – industry collaboration should be simplified and a 'joined-up' strategy between different funding bodies in this area should be implemented.
- Efforts should be made to identify and rectify communication problems between funding bodies and universities.
- Universities should be provided with greater freedom to use third mission funding as they see fit.
- Longer term funding for university – industry interaction should be made available.
- Application procedures for funding for university – industry collaboration should be simplified and start-up times reduced.
- Eligibility for funding schemes should be made looser and should not preclude interregional collaboration.
- Encouraging greater understanding of the dynamics of uneven development in academia and industry is necessary to overcome unhelpful discourses of grant dependency.
- Further attempts are needed to overcome discourses of failure which characterise much thinking about the Welsh economy. Potential solutions to problems should be promoted. Additionally, wider conceptualisations of what constitutes 'innovation' need to be promoted among policy implementers.
- Institutionalised masculine discourses within universities can impede their engagement with regional development activities. Bringing the hidden

assumptions behind these discourses into the open can help to promote change. Therefore further research into this area is recommended.

Future research

Universities are highly complex organisations undertaking a great variety of different activities. Therefore, it is not possible to capture the diversity of their contributions to and interactions with the regional economy in one project. This study has sought to understand knowledge flows between academic science and industry in one small area only – direct interaction between academics and firms for the purposes of research and development. Other types of knowledge flow remain untouched. Given universities' joint role as researchers and educators, an obvious area for future research in addition to the areas recommended above, would be the role of universities in disadvantaged regions in building and retaining the skilled workforce needed for a knowledge economy though education and training. In the case of regional development, the importance of universities is captured best by the old Welsh proverb: 'Gorau arf, arf dysg'.[1]

[1] The best tool is learning.

Appendix:
Questionnaire and follow-up questionnaire

University – industry collaboration in Wales
(supported by the University of Wales Swansea)

Note: Your responses to this questionnaire will be kept strictly confidential.

Section A: Corporate Background

1) What is the main product or service provided by this firm? (Or facility, if the firm has several facilities)

Main product / service:

Other products / services (if any):

2) What is your job title?

3) How old is the firm? (Or facility, if the firm has several facilities)

   a) Less than 3 years old □
   b) 3-5 □
   c) 6-10 years □
   d) 11-20 years □
   e) Over 20 years □

4) Where is the firm located? (Or facility, if the firm has several facilities)

Nearest village / town / city:

5) Is the firm a subsidiary of a larger firm?
   a) Yes □ If yes, which one ....
   b) No □

6) How many people are employed at this facility?

   a) Less than 10 □
   b) 10-25 □
   c) 26-50 □
   d) 51-100 □
   e) 101-250 □
   f) 251-500 □
   g) 501 – 1000 □
   h) Over 1000 □

7) How many R&D staff are employed at this facility?

   a) None □
   b) Less than 10 □
   c) 11-20 □
   d) 21-50 □
   e) 51-100 □
   f) Over 100 □

8) Is the firm a spin-off from a university or other higher education institution?
   a) Yes □
   b) No □

Section B: Interaction with universities / colleges

1) Has the firm had any interaction with universities or colleges outside Wales within the last five years?

   a. Yes □
   b. No □

2) Has the firm ever had any interaction with Welsh universities or colleges?
   a. Yes □
   b. No □

3) Has the firm had any interaction with Welsh universities or colleges within the last five years?
   a. Yes □ Please go to Section C
   b. No □ Please go to Section D

Section C: Interaction with Welsh universities / colleges

1) Which Welsh universities / colleges has the firm interacted with in the last five years? (Click as many as are applicable)

   These institutions will NOT be contacted

   a. Cardiff University □
   b. Coleg Sir Gâr □
   c. North-East Wales Institute (NEWI) □
   d. Royal Welsh College of Music and Drama □
   e. Swansea Institute of Higher Education □
   f. Trinity College Carmarthen □
   g. University of Glamorgan □

h. University of Wales Aberystwyth □
i. University of Wales Bangor □
j. University of Wales College of Medicine □
k. University of Wales Institute, Cardiff (UWIC) □
l. University of Wales Lampeter □
m. University of Wales Newport □
n. University of Wales Swansea □
o. Other (please state) □ ....

2) Which departments / schools in these universities / colleges has the firm interacted with in the last five years?

These departments / schools will NOT be contacted

Department / School of ...

3) What type of interaction has the firm undertaken with the above departments / schools in these universities / colleges in the last five years? (Click as many as are applicable)

a. Consultancy to university □
b. Consultancy by university □
c. Student placements □
d. Formal joint venture, e.g. company □
e. Teaching Company Scheme / Knowledge Transfer Partnership □
f. Sponsoring research student, e.g. CASE award studentship □
g. Corporate sponsored chair □
h. Collaborative research project □
i. Use of university equipment / services, e.g. for testing □
j. Use of university library / computing facilities □
k. Attending seminars organised by the university □
l. Other (please state) ....

4) For that Welsh university / college with which the firm has most recently interacted when did the relationship begin?

2005 □
2004 □
2003 □
2002 □
2001 □
2000 □
1999 □
1998 □
1997 □
1996 □
1995 □
Before 1995 □

5) When did it finish?
   a. Still ongoing □
   b. 2005 □
   c. 2004 □
   d. 2003 □
   e. 2002 □
   f. 2001 □
   g) 2000 □

6) Are links with this institution likely to continue in the future?

   a. Yes □
   b. No □
   c. Don't know □

7) Was the firm's most recent interaction with a Welsh university / college funded by an outside agency?

   a. Yes □ Please go to question 8)
   b. No □ Please go to question 9)

8) Which outside agency funded the firm's most recent interaction with a Welsh university / college? (Please click all agencies that provided funding)

   a. Agri-Business Programme □
   b. Cymru Prosper Wales □
   c. Environmental Goods and Services Consultancy □
   d. European Union R&D Funding □
   e. Finance Wales □
   f. HELP Wales □
   g. Knowledge Transfer Partnership / Teaching Company Scheme □
   h. LINK □
   i. National Endowment for Science, Technology and the Arts (NESTA) □
   j. Research council (AHRC/ BBSRC/ EPSRC/ ESRC/ MRC/ NERC/ PPARC e.g. CASE award) □
   k. SMART Cymru □
   l. Technology Exploitation Programme (TEP) □
   m. Wales Spin-out Programme □
   n. WDA □
   o. Other (please state) □ ....

9) What was the primary motivation for the firm choosing to interact with an external organisation? (Please click as many as are applicable)

   a. The firm had a problem that could not be solved in-house □
   b. The firm equired a design that could not be produced in-house □
   c. The firm required product development that could not be done in-house □

d. Saved the firm time □
e. Prestige of working with another organisation □
f. The firm required independent testing / evaluation □
g. The firm was ordered to interact by headquarters □
h. Funding was available for collaboration □
i. Other (please state) □ ……………………..

10) Why did the firm choose to interact with a university / college *rather than a firm*? (Please click as many as are applicable)

a. The firm required specific research expertise □
b. Cost □
c. Funding was available to work with university / college □
d. Do not trust other firms □
e. Do not know of any appropriate firms □
f. Appropriate firms too far away □
g. Prestige of working with a university □
h. Other (please state) □ …………………

11) Why did the firm choose to work with the university college it did in its most recent interaction? (For each consideration, please rate its importance from 1 (very important) to 5 (not important at all))

a. The university is nearby □
b. Perceived expertise / knowledge of university □
c. Known expertise / knowledge of university □
d. University has specific expertise in key technology / market □
e. Reputation of the university □
f. Prestige □
g. Funding opportunities / constraints □
h. Students / graduates / researchers from the university work(ed) in the firm □
i. Personal contacts with the university □
j. Other (please state) □ …………………..

12) How was the link with the university established for this interaction? (Please click as many as are applicable)

a. Employee of firm is a former student of the university □
b. Personal contact in the university □
c. Professional contact in the university □
d. Membership of a network / forum □
e. Contacted by / met member of industrial liaison staff from university □
f. Firm enquiry to the university □
g. Other (please state) □ …………………..

13) What is / will be the main outputs / outcomes of your firm's most recent interaction? (Please click as many as are applicable)

a. No product but relevant knowledge / research expertise □
b. New or revised product / process now in production □
c. Prototype of product / process not yet in production □
d. Nothing □
e. Other (please state) □ ....

14) Have there been any difficulties arising during the firm's most recent interaction? (Please click as many as are applicable)

a. No □
b. University and firm timescales do not match □
c. Timetable / scheduling difficulties, e.g. finding mutually convenient times to meet □
d. Project was taken in a different direction by the university to that required by the firm □
e. Project was taken in a different direction by the firm to that required by the university □
f. Project was never completed □
g. Poor working relationship, e.g. non-cooperation, no response to e-mails etc. □
h. Dispute over IP ownership □
i. Dispute over the use of IP □
j. Outcome of project was a market failure □
k. University did not know what it wanted out the project □
l. Firm did not know what it wanted out the project □
m. University did not deliver necessary information for the firm to undertake the project properly □
n. Firm could not give university necessary information (e.g. because of IP issues) □
o. Lack of funding □
p. Other (please state) □

15) How would you rate the success of this interaction? (Please indicate by placing a mark on the line below)

Highly successful
Disastrous

---

16) If there is anything you would like to add about your experiences of university-industry interaction and what you have learnt from them, please do so below:

Section D is for firms with no interaction with Welsh universities / colleges only

<u>Section D: No interaction with Welsh universities / colleges</u>

1) Why has the firm not undertaken interaction with a Welsh university / college? (Please click as many as applicable)

a. Funding issues □
b. R&D is done in-house □
c. R&D is done outside Wales □
d. Expertise needed is not available in Welsh universities / colleges □
e. IP issues □
f. Potential conflict of interests □
g. Do not know where to go to begin interaction □
h. Have enquired about interaction but academics were not interested □
i. Do not need R&D □
j. Other (please state) □ ……………………….

Thank you for your participation in this research programme.

University – industry collaboration in Wales
(supported by the University of Wales Swansea)

Note: Your responses to this questionnaire will be kept strictly confidential.

Section A: Corporate Background

1) What is the main product or service provided by this firm? (Or facility, if the firm has several facilities)

Main product / service:

Other products / services (if any):

2) What is your job title?

3) How old is the firm? (Or facility, if the firm has several facilities)

   a) Less than 3 years old □
   b) 3-5 □
   c) 6-10 years □
   d) 11-20 years □
   e) Over 20 years □

4) Where is the firm located? (Or facility, if the firm has several facilities)

Nearest village / town / city:

5) Is the firm a subsidiary of a larger firm?
   a) Yes □ If yes, which one ....
   b) No □

6) How many people are employed at this facility?

   a) Less than 10 □
   b) 10-25 □
   c) 26-50 □
   d) 51-100 □
   e) 101-250 □
   f) 251-500 □
   g) 501 – 1000 □
   h) Over 1000 □

7) How many R&D staff are employed at this facility?

   a) None □
   b) Less than 10 □
   c) 11-20 □
   d) 21-50 □
   e) 51-100 □
   f) Over 100 □

8) Is the firm a spin-off from a university or other higher education institution?
   a) Yes □
   b) No □

Section B: No interaction with Welsh universities / colleges

1) Why has the firm not undertaken interaction with a Welsh university / college? (Please tick as many as applicable)

   a. Funding issues □
   b. R&D is done in-house □
   c. R&D is done outside Wales □
   d. Expertise needed is not available in Welsh universities / colleges □
   e. IP issues □
   f. Potential conflict of interests □
   g. Do not know where to go to begin interaction □
   h. Have enquired about interaction but academics were not interested □
   i. Do not need R&D □
   j. Other (please state) □ ....

Thank you for your participation in this research programme.

Please return this questionnaire by May 23rd, 2006 to:

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Swansea SA2 8PP

Yr Adran Ddaearyddiaeth
Ysgol yr Amgylchedd a Chymdeithas
Prifysgol Cymru Abertawe
Parc Singleton
Abertawe SA2 8PP

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