

History Matters

Path dependence and innovation in British city-regions

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Andrew Chadwick and Ron Martin



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Foreword

Innovation is a hot topic in economic development circles around the world. Buoyed by the success of Silicon Valley, Hsinchu region, or Helsinki, innovation is seen by leading regions as the key to staying ahead; in those that lag, as an opportunity to catch up. The result has been a plethora of ambitious innovation strategies. Unfortunately, the common thread has often been under-delivery.

This failure to deliver has been blamed on many things: lack of institutions, lack of ambition, and lack of skilled policymakers. However, what has been less straightforward to understand is the extent to which such change was ever possible. In this research project, we have worked with leading researchers from Oxford Brookes and Cambridge Universities to use advanced economic techniques to uncover the extent to which 'history matters'.

The results contain important lessons for national and regional economic policymakers. Developing new 'pathways' for economic development depends considerably on a region's innovation system. However, individual policy interventions are likely to have little impact on economic development if they do not take into account previous economic structures and their legacy. Perhaps most importantly, policymakers must be patient and allow major interventions time to bear fruit.

This work feeds into a wider body of work that deals with the spatial aspects of innovation policy. Its insights underpin many of the practical programmes we have underway at NESTA and it forms the backdrop to our work with the nations, cities and regions that make up the UK. As with all of our work, we welcome your comments and your views.

Jonathan Kestenbaum

CEO, NESTA

July, 2008

NESTA is the National Endowment for Science, Technology and the Arts.

Our aim is to transform the UK's capacity for innovation. We invest in early-stage companies, inform innovation policy and encourage a culture that helps innovation to flourish.

Executive summary

History matters: A city-region's past determines what is possible while the present controls what possibilities are explored

Local economies' capacity to absorb new knowledge, grow and regenerate is developed over time. Industrial growth, decline and renewal results from historic combinations of knowledge assets and innovation. In turn, the sectoral and structural pathways followed by cities and regions determine their long-term success or failure.

The 'lagging' cities in our study – where economic development trails the national average (Middlesbrough, Newport, Norwich, Swansea and Wakefield) – are all characterised by weaknesses derived from their specific industrial histories. Conversely, 'leading' cities such as Aldershot, Cambridge, Northampton, Oxford, Reading and Warrington are all characterised by their lack of industrial heritage.

City-regional economies are interactive systems composed of four main strands

- 1. Sectoral development pathways.** The economic, social and institutional histories of city economies that have brought them to where they are in the present. Sometimes these can be traced back for decades if not centuries.
- 2. Knowledge assets.** These assets – which include universities and expenditure on research and development – have become increasingly significant as the role of

knowledge in contemporary economic performance has increased.

- 3. Local innovation systems.** The dynamic use of knowledge to create new products and services. Here the local innovation system plays a critical role in combining local and external knowledge to inject varying degrees of novelty into local economic activities.
- 4. New path creation.** More radical innovations arising from the local innovation system sometimes generate new development pathways – when cities branch into new industrial or economic sectors.

New ideas and new development pathways appear more often in cities without long industrial histories

We investigated five different possibilities for the creation of new development pathways.

- 1. Indigenous (local).** These included the actions of 'individual stars' such as those who formed Cambridge Consultants in 1960 and the contemporary Vice Chancellor of Swansea University who inspired the Technium Programme launched in 2001. We expected to find that new firm creation played a vital role in the creation of new pathways. But new firm formation declined nationally through the 1990s and was often lowest in some of the more innovative cities. We also found that the direct role of local universities as institutions (as opposed to a few star individuals emanating from them) in new path creation appeared to be

limited. There were few university spinout companies in Swansea. Even in Cambridge the numbers of university spinouts did not pick up much before 2000. The main role of universities has been to provide a supply of highly qualified personnel.

2. **Heterogeneity and diversity.** We analysed whether diversity or specialisation contributed most to innovation and found that sectoral diversity has been declining both nationally and in most of our sample of cities since at least 1981. We concluded from this that simple diversity is not necessarily a significant generator of radical innovations nor is it sufficient therefore to create new economic pathways. As a result, we argue that *specialised diversity* (or *clustered diversity*) is a more likely cause of radical innovations and new pathways of development than diversity *per se*.
3. **Transplantation of a new industry from elsewhere.** Our major example is the electronics industry in Swansea. At the height of production, 50 per cent of televisions and 75 per cent of video cassette recorders (VCRs) produced in Europe were made in South Wales. But both these markets have now disappeared with cheaper production elsewhere and new technologies (decisions made by the overseas headquarters of the Welsh branch plants). While the transplantation of new industries from elsewhere can establish new sectoral pathways, our evidence suggests that focusing on foreign direct investment (FDI) can prove a risky development strategy without some degree of local autonomy and embedding in local supply chains and networks.
4. **Diversification into technologically related industries.** There was some evidence for this in Cambridge. Starting from developments in information technology some 40 years ago, the high-tech economy has developed in four successive waves.
5. **Upgrading existing industries.** We were not able to discover significant examples of where existing industries were 'upgraded'.

Once started, new pathways tend to continue through a growth phase followed by a loss of momentum and decay unless their dynamism is renewed

We analysed five possible sources of path dependence – where firms' development is strongly influenced by their historic legacy and contemporary circumstances:

1. **Serendipity (chance).** Despite frequent recourse to this concept in the path dependence literature, we have no evidence from our empirical analyses of sectoral development being determined significantly by chance.
2. **Increasing returns (the more profits that can be made from the selling of a particular product or service, the more producers are inclined to produce of the same).** This leads to firms and consumers to being locked-into repetitive patterns of production and consumption and hence limiting the opportunity for new products and services to make it to the market. These are difficult to measure for entire city-regional economies. We assume that GVA per capita is an indicator of increasing returns.
3. **Technological lock-in.** This is where cities are tied to existing technologies, and can either be a good or a bad thing. In Swansea, for example, there have been two waves of both growth and decline as a result of technological lock-in. In both cases, the local economy remained locked-in to technologies that were overtaken either by the discovery and exploitation of alternative sources of natural resources or by the invention of replacement technologies and their production elsewhere.
4. **Institutional inertia (governmental, organisational or cultural systems that lag behind economic change).** The development of city-regional economies is not just the result of purely economic factors but also of simultaneous technological, socio-cultural and institutional developments. This was illustrated in our case studies of Cambridge and Swansea. Many of our private sector respondents in the two cities were critical of the slow pace of change in local institutions such as the local land-use planning system, and in Swansea of the grant dependency culture and an expectation of 'jobs for life'.

5. Strong local social networks. By this we mean the relative strength of local social history and networks that form an important part of the norms and values within which local economic activities are conducted. These can be either a good or bad thing. Strong local social networks can encourage conformity and consequent path dependence. Successful innovative British* cities like Cambridge, Oxford, Warrington and Reading tend to have high levels of out-of-region and international social networks and are not limited to their regional networks.

Knowledge assets drive the ability to develop new industrial pathways

The main differences between leading and lagging cities in our sample were their historically developed knowledge assets – such as universities and R&D infrastructure and the dynamism of their local innovation systems.

Among the lagging cities in our sample:

- The development of knowledge-intensive sectors has been slower than elsewhere.
- This has had a knock-on effect on the quality of human capital with lower proportions of both knowledge-intensive occupations and those specifically engaged in R&D or university research.
- The combination of a few large private sector employers with a large public sector has not fostered a culture of enterprise.
- There exists a lack of local investment and thin venture capital markets. The commercialisation of new ideas also appears limited by the low proportions of knowledge-intensive business services in most of the least innovative city economies.

Leading cities have generally benefited from the cumulative development of their local absorptive capacity and innovation systems:

- They tended to have more people working in knowledge-intensive occupations (KIOs).
- They had more employment in R&D and university research than other cities.
- This was then reflected in higher rates of the generation of new knowledge in the form of patent applications.

- They were better able to commercialise these new ideas as a result of higher levels of knowledge-intensive business services (KIBS) in those cities.

Implications for policy

It is necessary to think large-scale and long-term using an evolutionary economics approach to understanding change and innovation

This should be reflected in setting realistic expectations, in policy analysis and in the evaluation of specific initiatives.

In leading areas like Cambridge there was widespread scepticism among the private sector firms about the relevance or efficacy of public policy on innovation

Few firms could name any policy that had made a positive and measurable difference to their innovation activities. Their development was largely based on the identification of market opportunities and organising to meet those demands. They were more concerned however with policies related to issues falling under Local Authorities jurisdiction, such as planning.

While public policies targeted specifically at local innovation had little apparent impact, several firms noted significant effects arising from the consequences of other kinds of policy

We recorded some criticism of local land use planning as being too slow, bureaucratic and unimaginative in developing transport and communications infrastructure. It was also held to place too many restrictions on the physical development of the new knowledge-based economy.

On the other hand, the large-scale town expansion schemes in both Northampton and Warrington proved to be very successful at generating innovation and creating new industrial pathways. While the promotion of innovation in itself was not one of their original objectives, much of what they have achieved has been based on the creation of an innovative set of institutional and cultural phenomena that positively encourage new economic growth and innovation (even if by accident).

* The data in this report refer mainly to Great Britain, but references to the United Kingdom are made where appropriate.

Large-scale and multi-purpose initiatives combined with policies that tolerate certain levels of redundancy have higher chances of success

Northampton and Warrington's successful town expansion plans were based on a broad set of objectives none of which were specifically targeted on innovation. The universities of Cambridge and Oxford are also large scale institutions with multiple objectives out of which innovations sometimes emerge. Successful policy needs to be able to tolerate such redundancy, and the seemingly indirect link between interventions and eventual outcomes.

In lagging cities like Swansea, firms recognised the significance of the large-scale EU cohesion funds

Few of the firms we interviewed in Swansea would have existed at all without the European Union structural funds obtained due to the area's Objective 1 and transition fund status. Some are likely to die when the transition funds run out in 2013.

Strong local social networks and ties can be a barrier to developing new relationships with outside players that are important in innovation

In Swansea, the strong local social networks embedded in generations of working in large industries with expectations of jobs for life effectively limited the search for new ideas from outside Wales. Government support for international visits, building links with new markets and establishing distributors appeared to be more effective than its efforts to encourage local Welsh business networks.

The need for international knowledge networks is paramount

Innovation is increasingly based on internationally distributed systems. Some of the firms in Cambridge said that their global networks were more important to them than any local ones. In geographical terms this world of innovation is both spiky (in that it has a small number of significant hubs) and connected. British cities that aspire to join this world class innovation club must be internationally connected and develop specialised niches.

Encouraging and enabling innovation is a long-term goal

In all our most innovative sample cities, the development of their current successes took around 30 to 40 years. Public policies that had played a role in the early years were not been

based on forecasts of what emerged several decades later. Public policies for innovation should therefore be broadly enabling, allowing for policies to adapt and change over the long-term. They should provide opportunities for radical and systemic innovations to evolve and emerge in ways that cannot be foreseen today.

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Contents

History Matters

Path dependence and innovation in British city-regions

Part 1: Introduction	10
1.1 History matters	10
1.2 Thinking about the development of cities: path dependent evolution	12
1.3 The application of long-term historic analysis to understanding the development of city-regional economies	15
1.4 Outline of the study	18
<hr/>	
Part 2: Path dependence and innovation across 12 British cities	20
2.1 The bases of path dependence and new path creation	20
2.2 Selection of leading and lagging city-regions	23
2.3 Path dependent development in old and new industrial areas is diverging	23
2.4 Absorptive capacity in the form of knowledge assets is one of the bases of divergence between city-regional economies	25
2.5 Local innovation systems are the dynamic generators of novelty, change and growth in their local economies	30
2.6 New pathways are created by interactions between absorptive capacity and innovation	31
2.7 Conclusions	33
<hr/>	
Part 3: Cambridge and Swansea: contrasting path dependent economies	36
3.1 A Tale of Two Cities	36
3.2 Path dependent development	36
3.3 Absorptive capacity: firms need sources of new external knowledge	45
3.4 Local innovation systems: the creation, adoption and commercialisation of new knowledge	53
3.5 Concluding remarks	59
<hr/>	
Part 4: Why do cities differ in innovative performance? Conclusions and some lessons for policy	62
4.1 Introduction	62
4.2 Knowledge, absorptive capacity and local innovation systems	62
4.3 Positive and negative path dependence: the cases of Cambridge and Swansea	64
4.4 Policy lessons	66
<hr/>	
Appendix 1: Maps	69
Appendix 2: Secondary data indicators	80
Appendix 3: References	91

Part 1: Introduction

1.1 History matters

A number of authors have shown that capitalist economies evolve through long cycles of recession, recovery, growth and decline (Kondratieff 1935; Schumpeter 1939; Mensch 1979), and that these cycles develop differently in different places (Marshall 1987; Hall and Preston 1988). Such insights led attention initially to focus on whole regions such as Silicon Valley in California, Baden-Württemberg in Germany and Emilia-Romagna in Italy. It later became apparent that functional city-regions were the main geographic concentrations of economic activities. This placed them in the front line of globalisation where they had to remain competitive to survive and thrive.

As they became increasingly exposed to international competition, some cities adapted much better than others. Thus while some persisted with their traditional industries until they were overtaken by foreign competition or technological change, others seemed better able to re-invent their old industrial activities or create new ones. We are mainly concerned with the reasons underlying such long-term divergence in the fortunes of British cities.

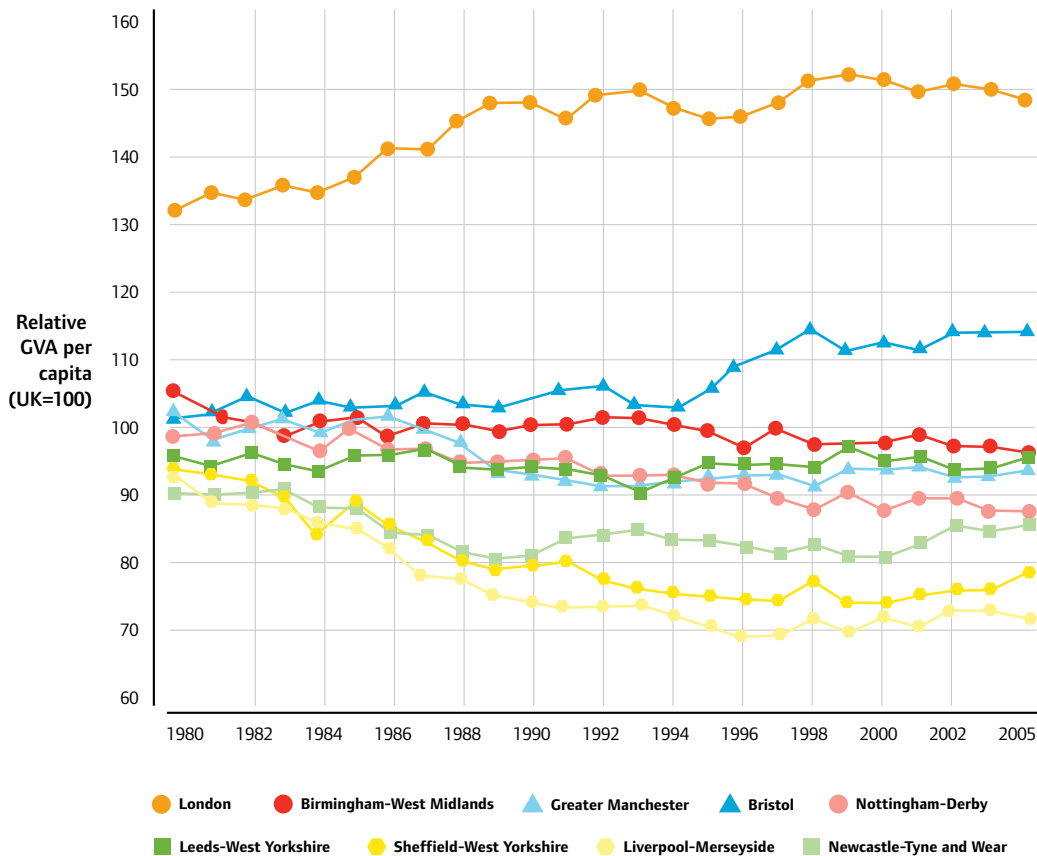
We argue that an evolutionary economics approach is key to understanding such long-term economic change. There are four strands within a local interactive system which, for the purposes of clarity, we examine sequentially. The first strand includes the sectoral development pathways – the key industries – that developed in different cities over decades and centuries. They represent the economic, social and institutional histories of city economies that have brought them to where they are today. They determine

what is immediately possible in a given city's economy. This is partly because they determine much of the second strand of analysis which includes the knowledge assets or absorptive capacity of the local economy. These assets – including higher education and R&D – have become increasingly significant as the role of knowledge in contemporary economic performance has increased. The third strand of analysis is concerned with the dynamic use of knowledge to create new products and services. Here the local innovation system plays a critical role in combining local and external knowledge to inject varying degrees of novelty into local economic activities. This system plays a key role in selecting from the historically determined range of possible pathways those that develop in the future. The more radical innovations arising from this system sometimes generate new development pathways, where new types of industry or economic sector are involved. This new path creation is the fourth strand of our analysis.

The interactions between such pathways, their knowledge assets and their local innovation system determine the long-term success or failure of their economic sectors. They therefore decide the nature of the sectoral and structural pathways followed in particular city-regional economies. In our study, cities like Leeds, Middlesbrough, Newport, Norwich, Swansea and Wakefield have experienced decline in many of their industries inherited from the Industrial Revolution. By contrast Aldershot, Cambridge, Oxford, Northampton, Reading and Warrington, relatively unencumbered by their industrial heritages by the early 1980s, have prospered.

We adopt an evolutionary economics approach to understand such long-term developments

Figure 1: Relative growth trajectories of the English core city-regions, 1980-2005 (UK=100)



and the dynamics of distinctive local innovation systems along with their differing abilities to absorb and use new knowledge within particular city-regions.

The importance of taking a long-term (historic or dynamic) view of the development pathways is illustrated by Figure 1. This shows the relative growth in GDP per capita for the English core city-regions from 1980 to 2005. The picture is one of increasing divergence in relative and absolute prosperity, with London and the Bristol city-region pulling ahead of the rest of the group. There are also few major shifts in relative position, suggesting that the pattern of growth across these city-regions tends to reproduce itself over time.

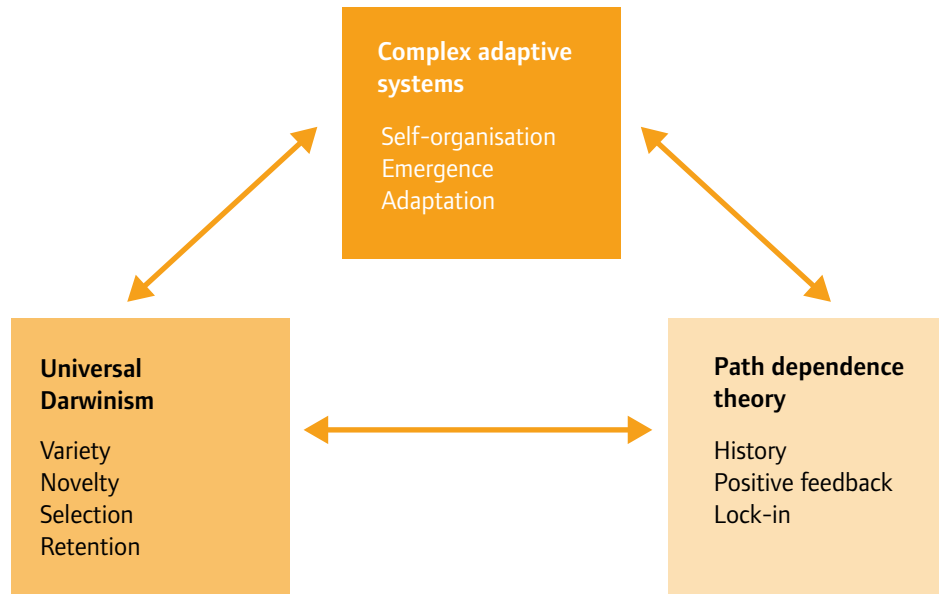
We argue that a key underlying reason for such differential economic growth is the aggregate ability of the different city-region economies to generate or adopt new economically valuable knowledge. This requires continual indigenous innovation combined with the ability to absorb and adopt new knowledge from elsewhere.

There are three main evolutionary approaches to analysing economic change and innovation.

These are: the Darwinian-inspired biological analogy and the notion of the co-evolution of institutions with economic change; complex adaptive systems theory; and path dependence theory. These are illustrated schematically in Figure 2.

Within these three theoretical approaches, evolutionary economists have addressed issues where mainstream economics offers little theoretical explanation. Their big themes include economic growth and decline, technological change, industry life cycle studies and the importance of institutions in influencing economic change (Essletzbichler and Rigby 2006). Research in these areas includes economic growth (Nelson and Winter 1982, Nelson 1995, Verspagen 2001), technological change (Arthur 1987, 1988, David 1985, Dosi 1982, Dosi et al. 1988, Pavitt 1984, 1999), industrial evolution (Abernathy and Utterback 1978, Klepper and Graddy 1990, Klepper 2001), and the importance of institutions and regimes (Hodgson 1988, Nelson 2001, Veblen 2001). This body of work is now substantial enough for Witt (2003) to have produced a collection of classic articles in evolutionary theory, for Hodgson (1993)

Figure 2: Three perspectives on economic evolution



to have provided a history of evolutionary theorising, and for a new evolutionary microeconomics to have emerged (Potts, 2000).

In this study of the innovative development of British cities, we draw on all three perspectives, but especially on the path dependence approach, in order to address directly the following questions:

- Why has the economic performance of British regions and cities been diverging over the long-term?
- What are the relationships between this divergence and differences in the ability to generate new economically valuable knowledge?

1.2 Thinking about the development of cities: path dependent evolution

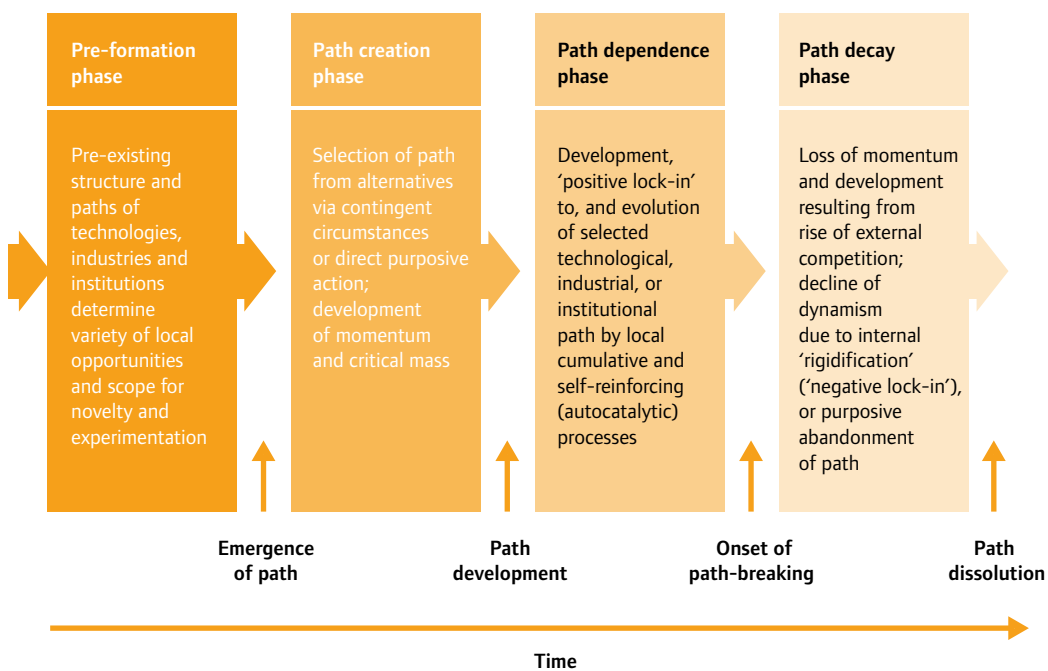
From an evolutionary perspective, these empirical observations lead us to ask, given similar evolutionary principles in different economies: how does their historical development lead them to such divergent outcomes? The answer for many evolutionary economists is that once a particular pattern of socio-economic development is established, it can become cumulative and entrenched or 'path dependent' (Martin 2003, p. 27).

Martin and Sunley (2006, p. 402) define path dependence as "a probabilistic and contingent process (in which) at each moment in historical time the suite of possible future evolutionary trajectories (paths) of a technology, institution, firm or industry is conditioned by (is contingent on) both the past and the current states of the system in question". Put another way, economies inherit the legacy of their past development, and this partly shapes the possibilities for the future.

A four-phase model of the path dependent evolution of an industrial sector in an urban or regional economy can be hypothesised: a pre-formation stage; a path creation phase, a path lock-in phase, and a path dissolution phase (see Figure 3).

New industrial paths do not emerge in a vacuum, but always in the context of existing structures and paths of technology, and institutional arrangements. These existing structures and paths together constitute the 'pre-formation phase'. At this phase, several different alternative new technologies or industries may co-exist. Which particular technology, product or industry emerges – or is 'selected' – may simply be a chance or contingent event, for example where conditions happen to favour one alternative over another, or where it has a slight 'first-mover' advantage; but it could also be the result of deliberate and purposive (and competitive) behaviour by

Figure 3: Path dependence and the development of a new technological/industrial sector in the urban economy



economic agents or institutions (such as a local university research laboratory).

This development then begins to attract other actors or acquires market influence; a critical mass around this activity begins to build up and a development path is formed (Path-Creation Phase). Once this critical mass achieves a certain size or momentum, the path gets 'locked-in', and a third phase of cumulative and self-reinforcing (catalytic) development along this path ensues (Path Dependent).

Loss of momentum and development can result for several reasons. It can arise because of the emergence of external competition, radical innovation or new technology elsewhere. It can arise because of the onset of an internal slowdown in the innovative dynamism of the sector concerned. Loss of momentum can also be the direct result of the movement of key firms and actors to other locations. As a consequence, the path will break down and dissolve.

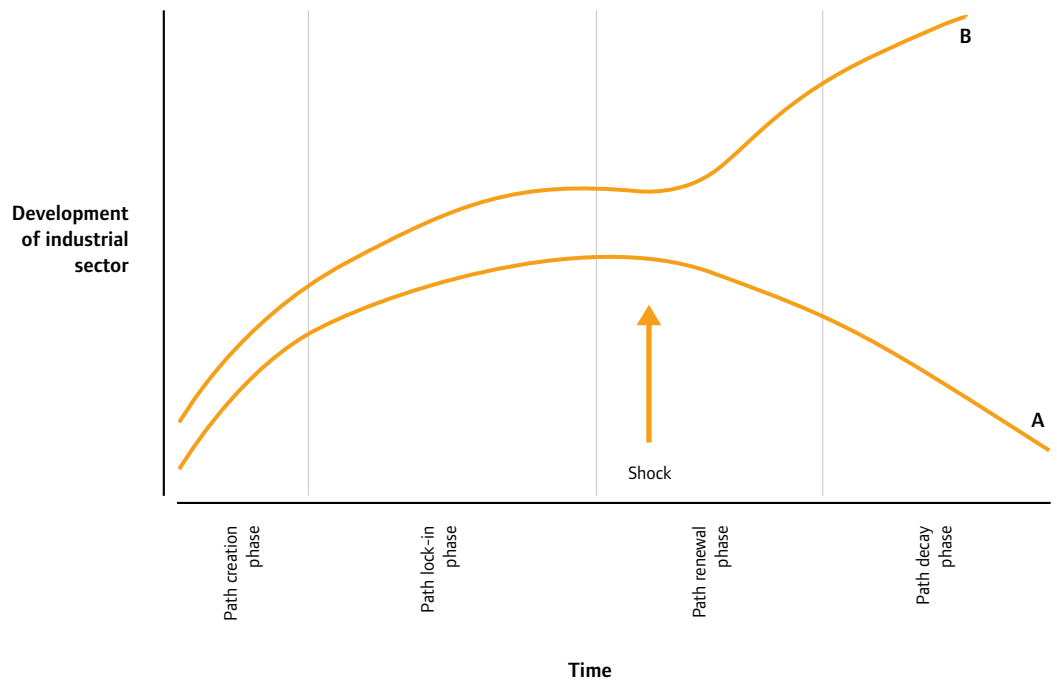
On the other hand, if firms adapt and adjust to such processes by engaging in a renewed phase of intensive innovation and development, the path may then not dissolve but be given a further phase of growth. So while many industrial technological paths do follow a 'rise, lock-in, and decline' life cycle, others seem able to 'reinvent' themselves successfully.

These two contrasting possibilities are shown schematically in Figure 4. Of course, both types of path can co-exist in an urban economy.

Some research shows that where strong local networks exist the interactions and learning between partners can constrain possible future paths of development; hence the process becomes path dependent (Lambooy 2004, p. 648). There is also some evidence that strong local networks can induce a 'lemming effect' – where participants simply follow the lead of others – as in the Ruhr (Grabher 1993) and Swiss mechanical watch making (Maillat 1996; Glasmeier 2000). The lesson here is that local networks need to be open to their national and the international economy in order to prevent them from becoming too parochial and inbred in their search for commercially valuable new knowledge.

While the evolution of many economic entities through history is path dependent, new pathways do also start from time to time. Thus we need both a theory of path dependence and one of path creation. While we do not as yet have a fully articulated and generally accepted theory of path dependence and how it is created (Martin and Sunley 2006, p. 408), our argument above suggests that we should be investigating the roles of human decision-making in conditions of uncertainty and the structure and extent of knowledge networks in seeking such an explanation.

Figure 4: Two alternative path dependence trajectories



Trajectory A corresponds to the basic path dependence model. Trajectory B refers to a situation where path decay is avoided and the existing path is renewed and extended.

For now, however, the lack of a generally accepted theory of path dependence means that there are different conceptualisations of the term and also of the possible causes of the establishment of new pathways. Martin (2003, p. 29) has identified at least five different sources of path dependence. These are:

1. Dependence on initial external chance events.
2. Technological lock-in (Paul David).
3. Increasing returns (Brian Arthur).
4. Institutional hysteresis (Douglas North, Mark Setterfield).
5. Social embeddedness.

A critical issue in explanations of path dependence is why and how new pathways get started. In much of the path dependency literature the emergence of novelty and new pathways is said to be accidental. Although new developments such as the discovery of penicillin or the inspiration for Silicon Valley were partly chance events, reliance on random chance is not generally a good enough explanation for the creation of new pathways.

It offers little explanation, since after the initial chance the rest is merely descriptive history.

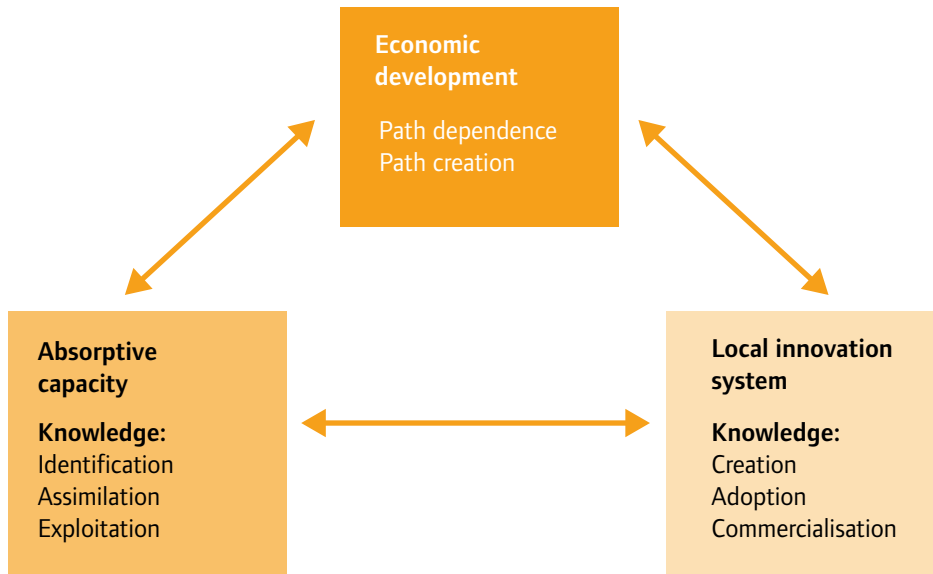
Martin and Sunley (2006) suggest five possible reasons for the start of new pathways in particular (urban and regional) economies. These are:

1. Indigenous creation.
2. Heterogeneity and diversity.
3. Diversification into technologically related industries.
4. Upgrading of existing industries.
5. Transplantation from elsewhere (Martin and Sunley 2006, p. 420).

The first four of these meet the criteria of evolutionary systems while, strictly speaking, the transplantation of innovation and novelty from elsewhere does not.

Most work, particularly by economic geographers has focused on the first of these path creation mechanisms – indigenous creation. Here the organisation of the production and transfer of new knowledge is the key element in the establishment of new

Figure 5: Path dependence, local innovation systems and absorptive capacity



pathways. Patel and Pavitt (1997) argue that the main innovation actors – firms – develop most of their new technologies in-house by modifying processes alongside contributions from other firms and the science base. Most of the time firms build and improve upon their existing technological base. Patel and Pavitt call this technological accumulation.

Branching out of existing industries into new but technologically related activities can also create new pathways. Some firms, for example 3M, are well known for pursuing such a strategy. Over the years it has developed its basic adhesive technology from producing sand paper and Post-It™ notes to plasma screens. The British motor sport industry has also developed close to areas with generic skills in the mass production car industries, particularly Birmingham, Coventry and Oxford (Pinch and Henry, 1999).

New pathways can also be created by upgrading existing industries. In this scenario, existing industries are revitalised and enhanced by the infusion of new technologies or the introduction of new products and services. This evolution is not easy. Some of the few remaining furniture manufacturers in High Wycombe have achieved such change by adding the organisation of the furnishing of entire office blocks to their manufacturing activities. Generally, however, firms can do only a few things well at any one time; their learning

capabilities are equally constrained (Nelson 1995, p. 79).

1.3 The application of long-term historic analysis to understanding the development of city-regional economies

The analysis of the long-term development of city-region economies requires an analysis of three interrelated phenomena. These are the structural evolution of the economy, including the decline or maintenance of old sectors and the creation of new ones; the capacity to identify, assimilate and exploit new knowledge; and the indigenous creation, adoption and commercialisation of new knowledge. Each of these phenomena has its own conceptual and measurement problems. The overall structure of the analysis is illustrated in Figure 5.

Economic development

Unless development takes place in previously underdeveloped localities, such as North West England before the Industrial Revolution or Santa Clara County before the ICT revolution, then their economic pathways are highly dependent on their previous economic histories. The structural characteristics of previous eras determine many of the possible directions of future development, making many local economic changes path dependent.

In the long-run, city-regional economies do not follow the same paths forever. Those that do not create new pathways tend to stagnate and eventually decline. The creation of new paths of technological and industrial development is critical to the continued survival and growth of urban economies. Much of this, along with the continual change and adaptation in existing pathways, is dependent on new knowledge and its commercial success in national and world markets. Thus innovation drives both path development and new path creation.

Absorptive capacity

Underlying the ability to create new knowledge in the form of innovation is the need to be able to recognise, understand and use relevant knowledge. These attributes have come to be known collectively as absorptive capacity. This concept as applied to individual firms was introduced by Cohen and Levinthal (1989). They define it as the “ability to utilize externally held knowledge through three sequential processes: (1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning, (2) assimilating valuable new knowledge through transformative learning, and (3) using and assimilating knowledge to create new knowledge and commercial outputs through exploitative learning”. An outcome of absorptive capacity is innovation.

Firms that develop strong in-house knowledge bases have greater absorptive capacity and more incentives to search for external knowledge, as they know that they will be able to use it profitably. Such firms are also likely to be sought out by similar firms with strong in-house knowledge bases. All other things being equal, this means that such firms are probably better at developing groundbreaking ideas and of collectively using them to develop pathways of economic development.

According to Lane et al. (2006), absorptive capacity:

1. builds on prior investments in absorptive capacities;
2. tends to develop cumulatively and is therefore itself path dependent; and
3. depends on the organisation’s ability to share knowledge and communicate internally.

Innovation

Joseph Schumpeter, the founding father of evolutionary analyses of innovation, defined the activity as the “carrying out of new combinations such as a new good, a new method of production, a new market, a new source of supply, a new industrial organisation” (Schumpeter 1961). These constituted what he called the process of “creative destruction” (Schumpeter 1942). Although his analysis has inspired much of the subsequent work on technological innovation, Schumpeter himself was at pains to point out that innovation did not need to be technological. So, for example, he regarded the setting up of new production functions, new forms of organisation and the opening up of new markets as innovations. Despite his insight, much subsequent work has focused on the contribution of technological product and process innovation to economic change. This is partly because it is a key economic driver and partly because it has proved easier to measure than other forms of innovation that also play important parts.

Much of Schumpeter’s analysis is echoed in the more recent definition of innovation contained in The Oslo Manual Guidelines for Collecting and Interpreting Innovation Data, where innovation is defined as “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations” (OECD 2005, p. 46).

Innovation in the form of the creation, adoption, and commercialisation of new economically valuable knowledge within urban economies is based on complex relationships between the nature and types of economic variety present in those economies and the capacity of the local innovation systems to combine this endogenous knowledge with that drawn from other sources and locations across the international economy.

The degree of economic variety – the range of economic sectors in a city – represents another important indicator of the changing stock of knowledge in an urban economy over time. The pathways and sectoral change that emerge in city-regional economies determine the level and extent of economic variety present in those economies at any given moment. This variety determines the knowledge available for later innovations. With city economies as a whole, we are primarily concerned with aggregate variety as expressed in agglomeration economies – economies of scale and

networking opportunities – that are external to individual firms in any individual local innovation system. The varieties of knowledge combined with the aggregate ability to acquire, transform and exploit that knowledge are the basis of its local innovation system. The nature of local, territorial innovation systems has been laid out by, among others, Marshall (1932), Camagni (1991), Storper and Scott (1992), Lundvall (1992) Braczyk et al. (1998), de la Mothe and Paquet (1998), Florida (1998) and Simmie (2001). They form a crucial part of the open architecture of city economies.

The main function of local innovation systems is to generate new (practical) knowledge and to commercialise it. The generation of novelty by recombining indigenous knowledge with external new knowledge provides a local economy with its evolutionary momentum. The interaction between this momentum and the external environment determines the extent to which the economy is subject to positive or negative lock-in and the rate of new path creation. In lagging city economies existing varieties of knowledge tend to decay with time, and the economy becomes locked-in to increasingly outdated activities. In leading cities where a local innovation system is constantly creating and importing new knowledge, the economy can either be positively locked-in to leading edge sectors or creating new ones.

A supposed advantage of all forms of agglomeration economies is the link between geographical proximity and knowledge spillover. Geographical proximity should facilitate intense sharing of ideas. At the same time the concentration of knowledge within cities also makes them hubs in the wider national and international distribution of knowledge (Simmie, 2003). Their internal and external connections also contribute to the relative intensity of knowledge transfers.

Networking is crucial to the creation and adoption of new forms of knowledge. Potts (2000) argues that knowledge is a structure of connections, and the various instances of knowledge – such as technology, routines, habits, competences and the like – are instances of specific connections. From this perspective innovation-based economic evolution is about the emergence and evolution of multiple connections, most significantly in the form of knowledge networks. Much work in this area has not distinguished between different kinds of networks.

But there are at least two kinds of networks fulfilling significantly different functions. Business networks facilitate the co-ordination of decisions made by individuals, departments, firms or cities. Knowledge networks enable the transmission of data, information, and knowledge by using or making connections with various degrees of intensity (Lambooy 2004, p. 643). Giuliana (2006, p. 5) defines the latter as “the network that links firms through the transfer of knowledge for the solution of complex technical problems”. They are especially significant for the transfer, exchange and diffusion of tacit informal knowledge, because of their ability to build trust and understanding. These are referred to as ‘relational capital’.

This has spatial implications. Thus, for example, it is to be expected that different places will have different strengths and this will affect the extent to which they are connected to each other. Geographical proximity is not a necessary condition for tacit knowledge transfer. Dense social networks rather than particular regions may be effective vehicles for the creation and diffusion of knowledge (Rallet and Torre 1999, Breschi and Lissoni 2002, Boschma 2006, p.16). Indeed it is becoming clear that knowledge creation and innovation is an internationally distributed activity with different elements located in different places, with local, regional, national and international connections (DTI/ONS, 2005).

The geography of this international system is spiky and connected. It is spiky in the sense that the highest rates of innovation are concentrated in a few city-regions around the globe including:

- USA – Silicon Valley, Seattle, Austin, Raleigh, Boston.
- Europe – Stockholm, Munich, Helsinki, and also Israel.
- India – Bangalore.
- Far East – Beijing, Singapore, Seoul, Shanghai, Taiwan, Tokyo (Miles and Daniels 2007, p.15).

It is connected in the sense that these cities are also major hubs in international knowledge networks. Local innovation systems link to such cities so that, as far as possible, local businesses know the latest thinking and the local system has the capacity to absorb and combine both internal and external knowledge

into new practical and commercial forms of novelty.

1.4 Outline of the study

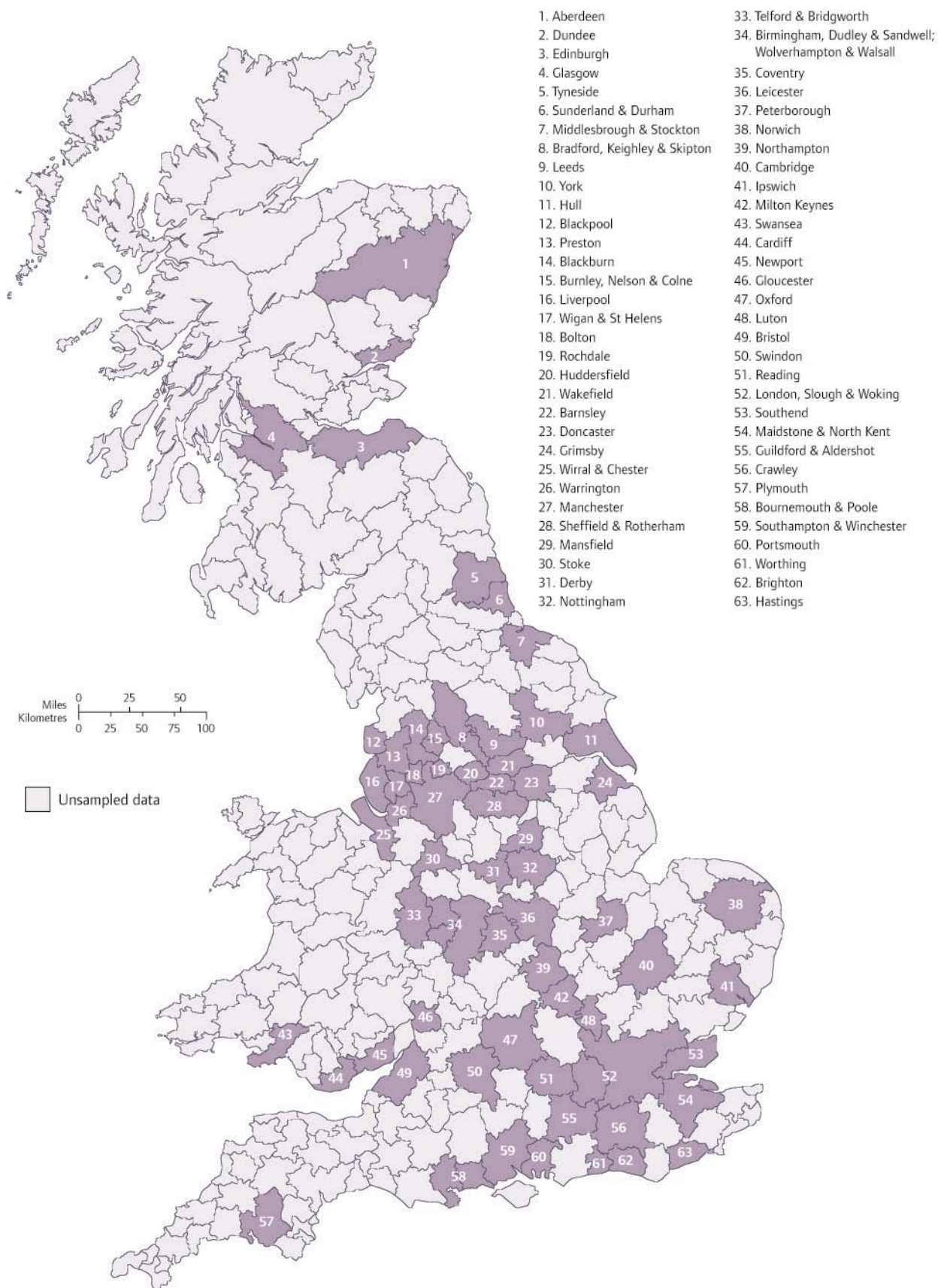
In order to investigate these arguments empirically we used a sample frame of all 63 city-regions in Great Britain with core populations of 125,000 or more. These are shown in Map 1. We analysed their recent innovative performance on the basis of the results of the Fourth Community Innovation Survey (CIS4) covering the period 2002-2004. We contrasted cities based on this data and selected a sample of six of the most innovative and six of the least innovative cities in Great Britain for detailed analysis. We then collected long-term secondary data for these 12 cities to illustrate the relationships between their sectoral development pathways and the absorptive capacities and innovation underlying and driving them. We selected two of the most contrasting cities, Cambridge and Swansea, for more detailed historical analysis.

Our task is to explain the long-run divergence of city-regional economies in Britain. Our approach is to adopt an analysis based on the theoretical concepts of evolutionary path dependence. We argue that this is appropriate because it focuses on the dynamics underlying the long-run structural changes in spatial economies.

We argue that local innovation systems are the key driving mechanism underlying change in spatial economies because they are the primary source of new commercially valuable knowledge. Indeed, their main functions are the creation, adoption and commercialisation of such knowledge. It has also become, along with land, capital and labour, a key factor of modern economic production.

Underlying the ability to innovate is the collective absorptive capacity of the firms, institutions and organisations located in a particular city. This provides the asset base for the identification, assimilation and exploitation of new knowledge. This capacity is itself path dependent on the distinctive structures and pathways that emerge in specific urban economies.

Map 1: Travel-to-Work Areas with core populations > 125,000 in 2001



Source: Travel-to-Work Areas 1998. National Statistics.

Part 2: Path dependence and innovation across 12 British cities

2.1 The bases of path dependence and new path creation

Our basic argument is that the sectoral pathways that develop over time within city-regional economies collectively determine the relative capacities of those spatial economies to absorb new knowledge from their external environments because they determine to a large extent:

- the occupations that emerge in different sectors;

- the types of knowledge assets and infrastructures that emerge as a result of both private and collective investments in accessing and exploiting new knowledge; and
- the individual and collective capacities to interact with external sources of knowledge and to exploit them in combination with local knowledge assets.

These interactive relationships are illustrated in Figure 6.

Figure 6: Path dependent development, absorptive capacity and local innovation systems

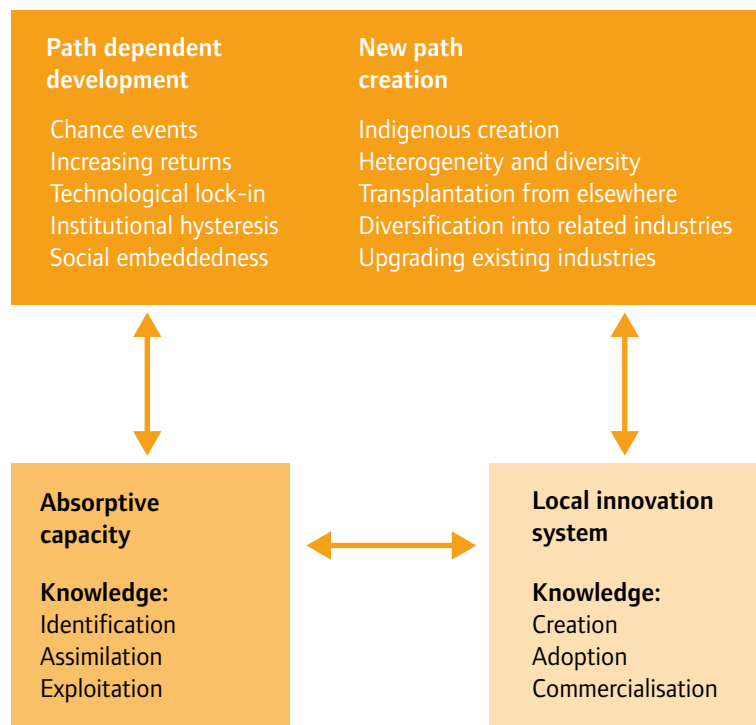
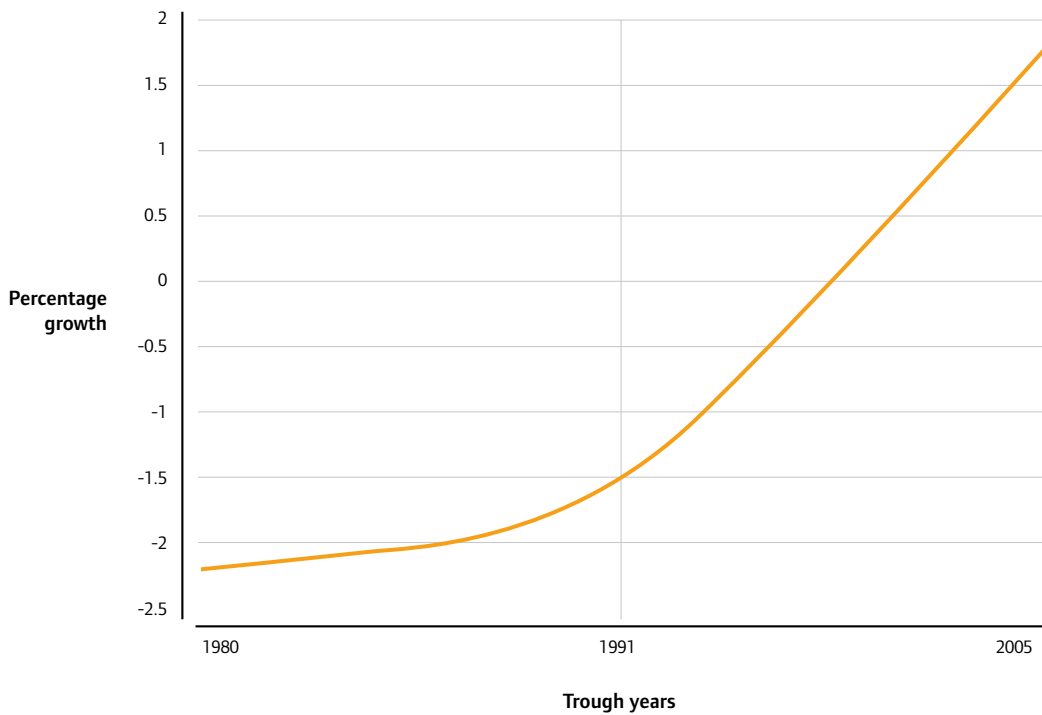


Figure 7: Smoothed trough to trough growth in UK GDP 1980-2005 (at constant 2003 prices)



Not all the potential sources of path dependent development or new path creation can be investigated using existing secondary sources of data. As a result, in this chapter we focus on the limited set of data sources that are available on a reasonably consistent geographic and definitional basis from the early 1980s. We would have preferred to have been able to use longer time series but in most cases these are just not available in a consistent or electronic form.

A further difficulty in tracking and interpreting long-run urban economic change is that many other factors are also changing at the same time. There are therefore issues to be dealt with surrounding the interpretation of what is significant in the urban context. One such issue is that cities are where changes in the national economy are played out. Thus there are complex interactions between what happens in individual cities and what happens in the national economy as a whole. In the analysis of the long-run development of city economies, it is also important to expose the underlying trends rather than focusing on the annual ups and downs of economic change. One way of dealing with these problems is to examine the smoothed changes taking place between the main trough years of the national economic cycle. For the practical time frame of this study

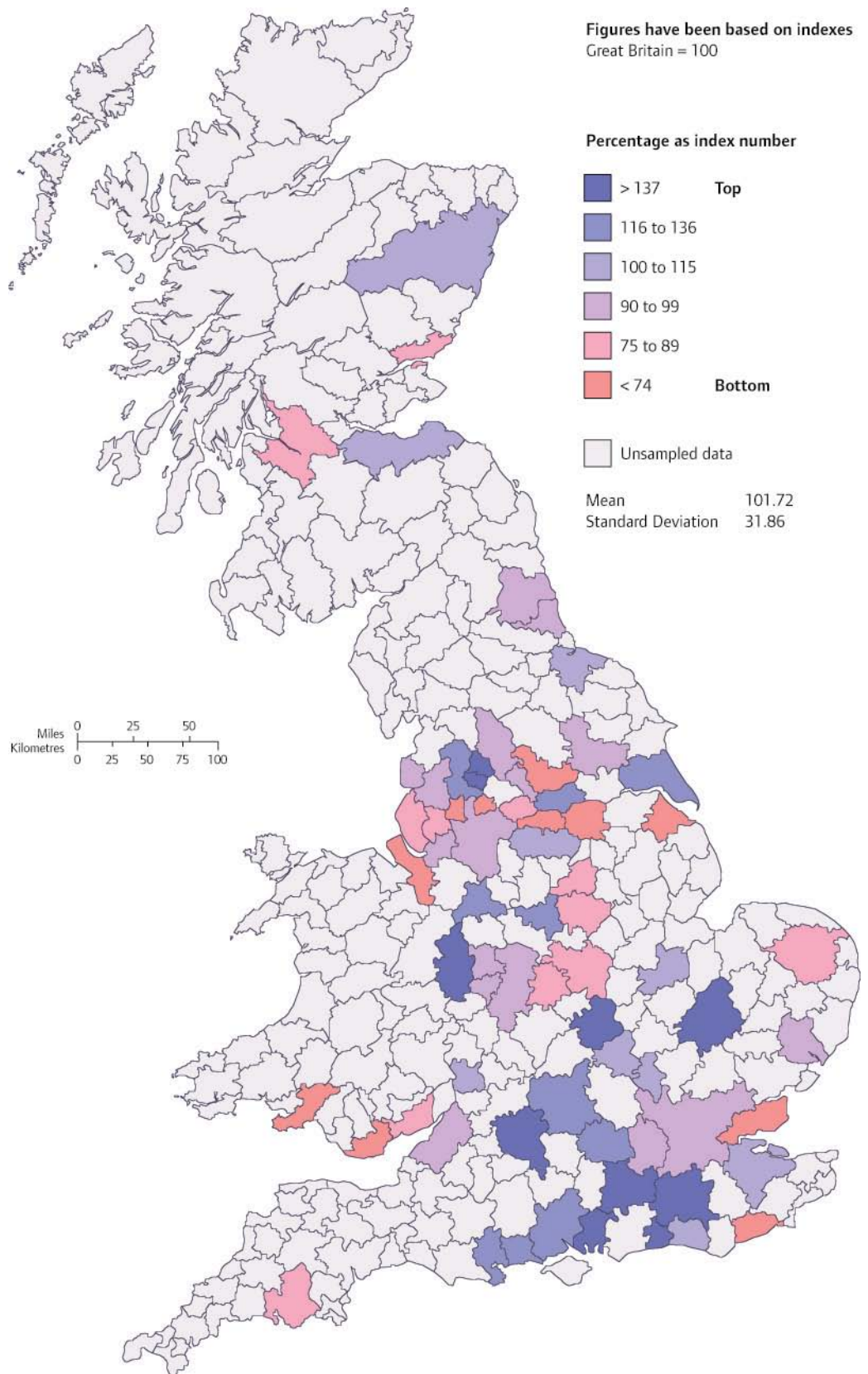
these years were 1980, 1991 and 2005. Figure 8 shows the smoothed growth trends between these key years.

Following Figure 7 we should expect that, if city economies both compose and reflect the national economy, the 'normal' trajectory of their economic development between 1980 and 2005 would have followed an upward trend. Cities and sectors that did not grow relative to this overall trend could therefore be considered to have experienced relative decline while those that grew faster than this trend could be considered to have experienced relative growth.

In this chapter, we select 12 contrasting cities from among all those 63 in Great Britain with core populations greater than 125,000. We use their respective Travel-to-Work Areas (TTWAs) as our main unit of spatial analysis. In subsequent sections we use what secondary time series data are available to analyse:

- their development pathways;
- their collective absorptive capacities;
- their local innovation systems; and
- the creation of new pathways.

Map 2: Introduction of novel products in GB cities CIS4, 2002-2004



Source: Travel-to-Work Areas 1998. National Statistics.

2.2 Selection of leading and lagging city-regions

In order to select particular cities to illustrate the nature of path dependent development and the respective roles of their collective absorptive capacities and local innovation systems in their development, we first analysed the innovation outcomes shown in the results of CIS4 for all 63 British cities with core populations greater than 125,000. Figure 10 shows the introduction of novel products between 2002 and 2004 and the wide variation in innovation outcomes between British cities. The highest rates of such innovation were located mainly in Southern England particularly around the Greater South East (GSE). The lowest rates were disproportionately concentrated in cities located around peripheral coastal areas in England and Wales and also in middle and Northern England.

In order to illustrate the historical trajectories that have led to such results we selected a sample of 12 cities for further more detailed analyses using existing data sets (mainly time series). Six were selected from the top deciles of performers on the six different measures of innovation outcome provided by CIS4. A further six were selected from the corresponding bottom deciles. Table 1 shows the results of this selection exercise.

2.3 Path dependent development in old and new industrial areas is diverging

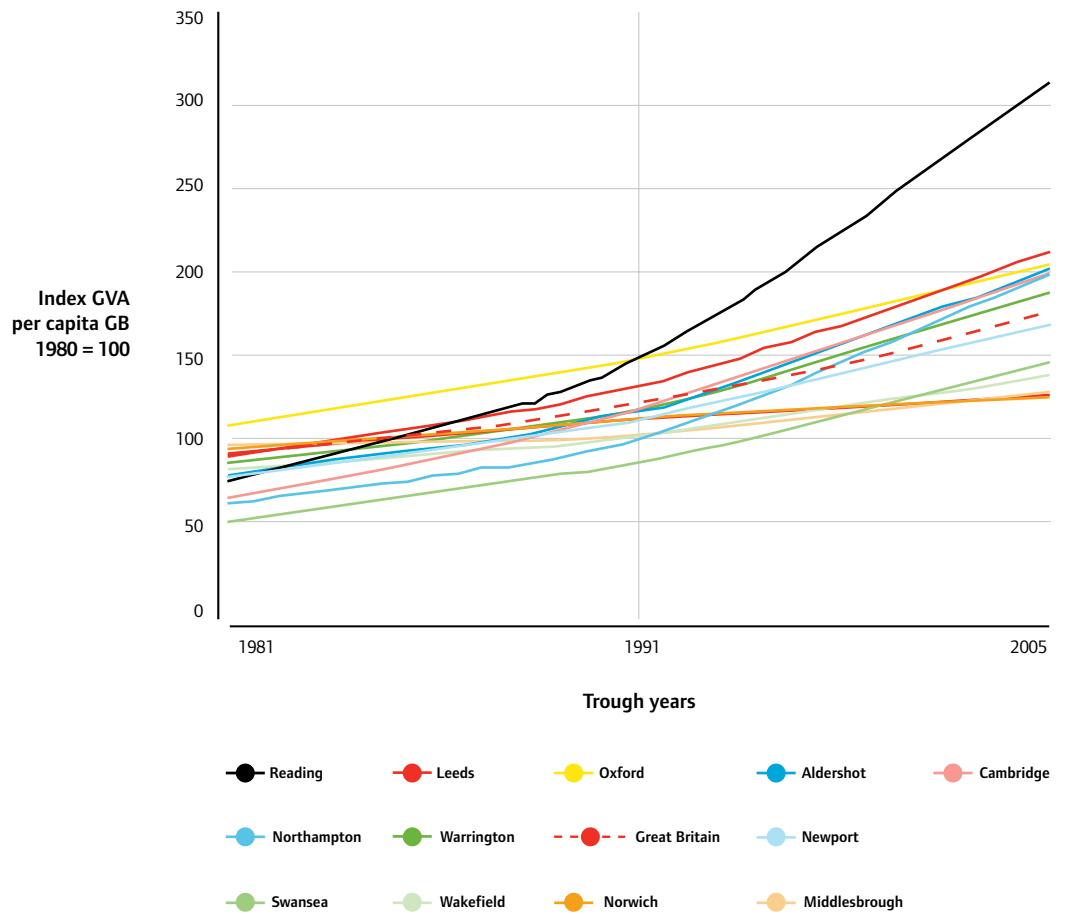
From our selection of cities, we can see the long-term nature of the pathways followed to arrive at their positions in the early 21st century. Thus, all the cities in the lowest deciles except Norwich had experienced rapid

Table 1: Best and worst performing cities on CIS4 innovation measures

Innovation measure	Cities in top decile (best first)	Cities in bottom decile (worst first)
Percentage of firms introducing novel products	Cambridge (35 per cent) Aldershot (27 per cent) Northampton (25 per cent) Portsmouth (23 per cent)	Swansea (6 per cent) Leeds (10 per cent) Birkenhead (11 per cent) Cardiff (11 per cent)
Percentage of firms introducing novel processes	Northampton (11 per cent) Wakefield (11 per cent) Cambridge (10 per cent) Bournemouth (9 per cent)	Newport (2 per cent) Southend (3 per cent) Mansfield (3 per cent) Leeds (3 per cent)
Percentage of firms introducing new or improved products	Cambridge (45 per cent) Northampton (42 per cent) Aldershot (38 per cent) Milton Keynes (38 per cent)	Swansea (18 per cent) Norwich (20 per cent) Southend (22 per cent) Cardiff (24 per cent)
Percentage of firms introducing new or improved processes	Oxford (32 per cent) Northampton (29 per cent) Southampton (27 per cent) Bournemouth (26 per cent)	Leeds (13 per cent) Norwich (15 per cent) Stoke (16 per cent) Swansea (16 per cent)
Percentage of firms implementing major changes to organisational structure	Reading (34 per cent) Milton Keynes (31 per cent) Portsmouth (31 per cent) Oxford (31 per cent)	Wakefield (13 per cent) Preston (16 per cent) Newport (16 per cent) Southend (17 per cent)
Percentage of firms implementing changes in marketing concepts or strategies	Warrington (32 per cent) Reading (31 per cent) Birkenhead (31 per cent) Crawley (31 per cent)	Wakefield (13 per cent) Middlesbrough (15 per cent) Swansea (16 per cent) Norwich (16 per cent)

Source: Analysis of CIS4 dataset at city level, for GB cities with a population above 125,000 and a sample size of at least 75 firms in CIS4. Cities highlighted in bold are those included in the final selection of 12 cities.

Figure 8: Selected cities best fit NUTS 3 area GVA per capita 1981-2005



growth in the 19th century. This was primarily driven by industries such as copper and coal mining and the manufacture of steel, ships and textiles. By the start of the 20th century they were still leading centres for the export of these goods into world markets. This industrial heritage continued more or less successfully into the 1950s.

In contrast those in the highest deciles had remained largely unaffected by the Industrial Revolution and were primarily university cities, small manufacturing towns or rural centres in 1900. This only began to change between the two World Wars with, for example, the introduction of the motor car industry in Oxford.

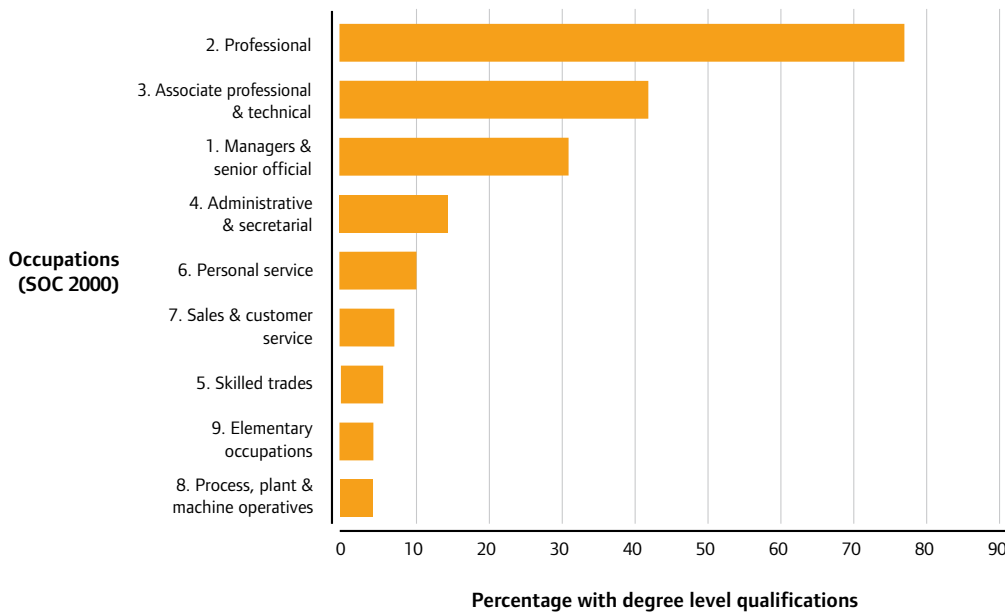
Change occurred during the late 1950s and 1960s as improvements in transport and communication facilitated the growing internationalisation of the world economy. Now the products of the Industrial Revolution that had sustained the local economies of Leeds, Middlesbrough, Newport and Swansea could

be supplied more competitively by the newly developing and industrialising economies of Asia and South America. This also marked the beginning of the declining competitiveness of many of the UK's manufacturing industries.

During this period our sample cities that were not tied to previous industrial pathways were developing more modern sectors such as electronics, motor cars, computers and software together with financial services. Others like Northampton and Warrington were designated as the locations for major town expansion or new town status. This also provided possibilities for new economic pathways to be created in those localities untrammelled by past and declining industrial sectors.

So by 1981 many of their relative fortunes had been or were soon to be reversed from what they had been even as late as the 1950s. Figure 9 shows the relative changes taking place in GVA per capita between 1981 and 2005 using 1981 as index 100. During this period Middlesbrough, a once successful

Figure 9: Knowledge-intensive occupations 2001



city, started above the British average but declined below it, while Newport, Swansea and Wakefield all fell below the British average over the entire period. Although Norwich was not much affected by the Industrial Revolution, it continued a long-term relative decline from being the third city in England during the agricultural era to have the lowest GVA per capita of any of our cities by 2005.

By contrast, Leeds appears to have been our most successful city at shaking off its old industrial heritage and creating new pathways in financial services. Along with Oxford it was our only city consistently to out-perform the British average over the 24-year period. The remaining top decile cities all started below the average in 1981 but had overtaken it – quite spectacularly in Reading – by 2005. Aldershot, Cambridge, Northampton and Warrington also all accelerated past the average GVA per capita during the period. As a result, the relative prosperity of our cities aside from Leeds and Norwich has been reversed over the last quarter of a century.

Not surprisingly these findings also show that there was some net divergence in overall economic performance between those economies that accelerated faster than the British average and those that declined below it. Two extreme cases of divergence are illustrated by Reading and Middlesbrough. While the latter's GVA per capita was above average in 1981 and the former's was below,

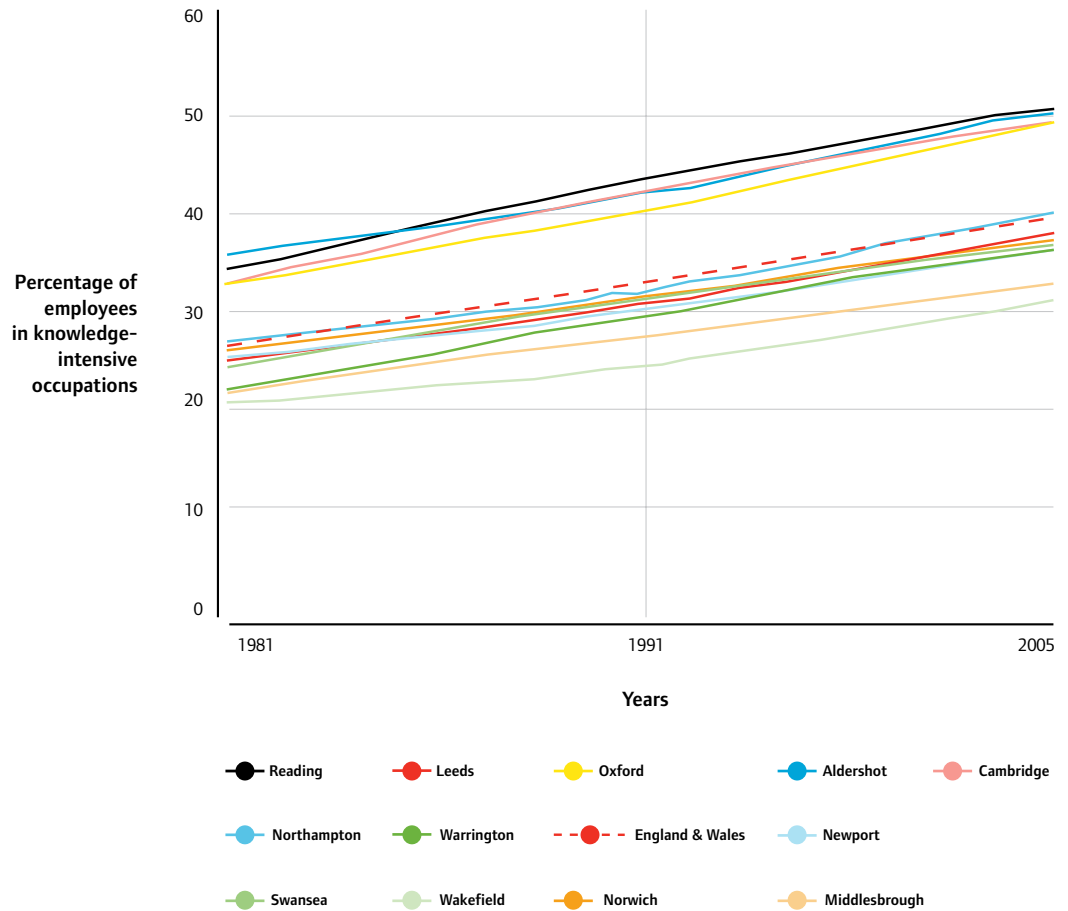
by 2005 the reverse was the case. Reading was among the leading performers and Middlesbrough among the laggards.

2.4 Absorptive capacity in the form of knowledge assets is one of the bases of divergence between city-regional economies

Absorptive capacity may be defined as “a firm’s ability to identify, assimilate and exploit knowledge from external sources” (Cohen and Levinthal 1990). In city economies, the concept refers to the ‘collective capacity’ of the firms, organisations or institutions in the locality to absorb knowledge from external sources. These sources may be found either within the same city-regional economy or anywhere else in the national or the international economy. The key limiting factor in any particular city’s ability to absorb new knowledge is the current collective capacity in the locality. Much of this reflects the cumulative historical development trajectories of local firms, research centres and universities. Between them they will have determined the types of occupations available and therefore the quality and kinds of expertise and knowledge developed in the locality.

We analyse first the internal knowledge assets of our sample of cities. These include their knowledge-intensive occupational structures and the amounts of human capital devoted to

Figure 10: Change in knowledge-intensive occupations in selected cities 1981–2005



R&D and higher education. We then examine how effective the urban economies are at identifying and assimilating knowledge from sources external to the city itself.

Figure 10 shows the concentrations of graduates by occupation as identified in the 2001 Census. It may be seen that those with the highest proportions of graduates are professional, associate professional and technical, and managers and senior officials. We therefore define these, for the purposes of this study, as knowledge-intensive occupations (KIOs).

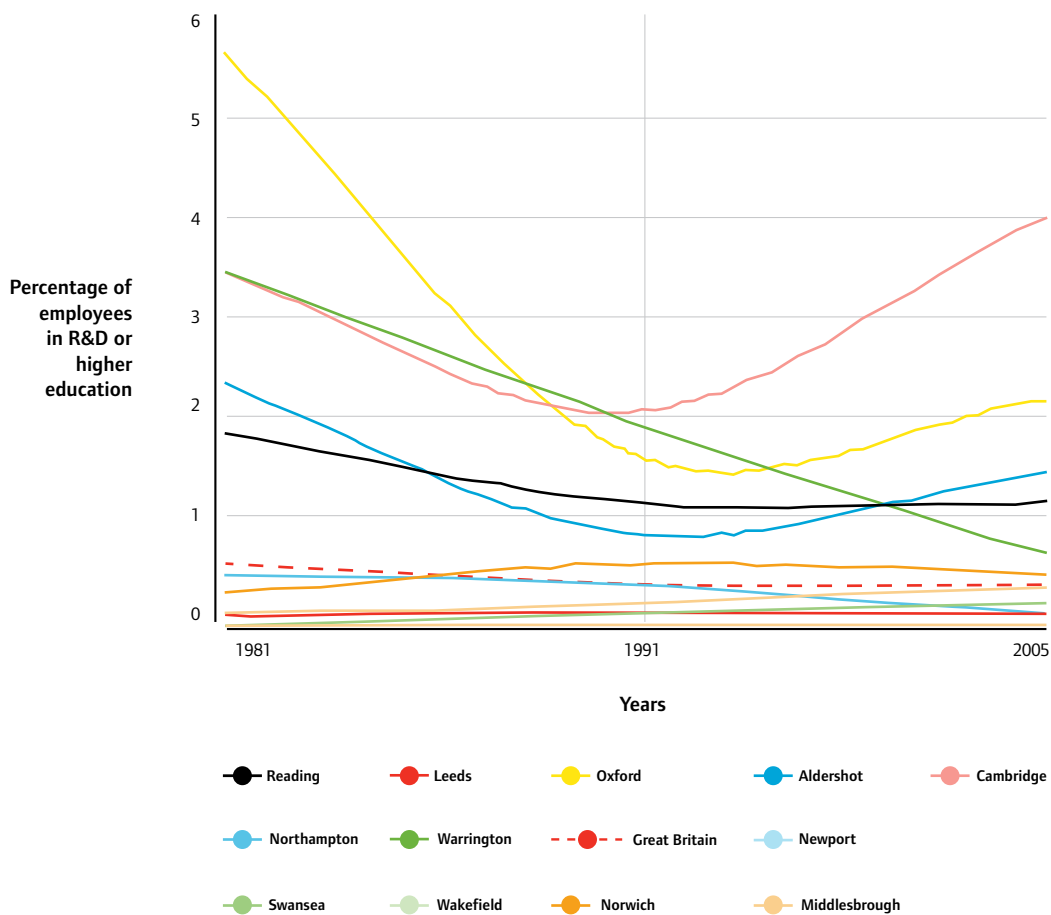
Figure 11 shows the changes taking place in the proportions of workplace-based employees in KIOs for our selected cities reflecting the sectoral development pathways followed in those city-regions between 1981 and 2005 relative to the British average. So we can see that Reading, Aldershot, Cambridge and Oxford all started and continued with higher than average proportions of KIO employees. The growth of KIOs in Northampton kept pace with

that average. By contrast, the proportions of KIOs in Leeds, Norwich, Warrington, Swansea, Newport, Middlesbrough and Wakefield were all below the average for the whole period. The gap between the top ranking city, Reading, and the bottom city, Wakefield, increased from 13.2 per cent to 20.1 per cent. In 2005 just over half the entire workforce in Reading worked in KIOs while in Wakefield the figure was less than a third.

Another key asset in a city's capacity to identify and assimilate knowledge is the amount of R&D and higher education (HE)/research being conducted in the region. We have grouped these two activities together partly because there have been some reclassifications from R&D to HE that make R&D data on their own inconsistent over time, and partly because of the significance of university research in generating new knowledge.

Figure 11 suggests some fairly dramatic changes in the R&D capacity of our sample of cities. In Cambridge, Oxford, Aldershot and

Figure 11: Change in proportions of employees classified to R&D and higher education in selected cities 1981-2005



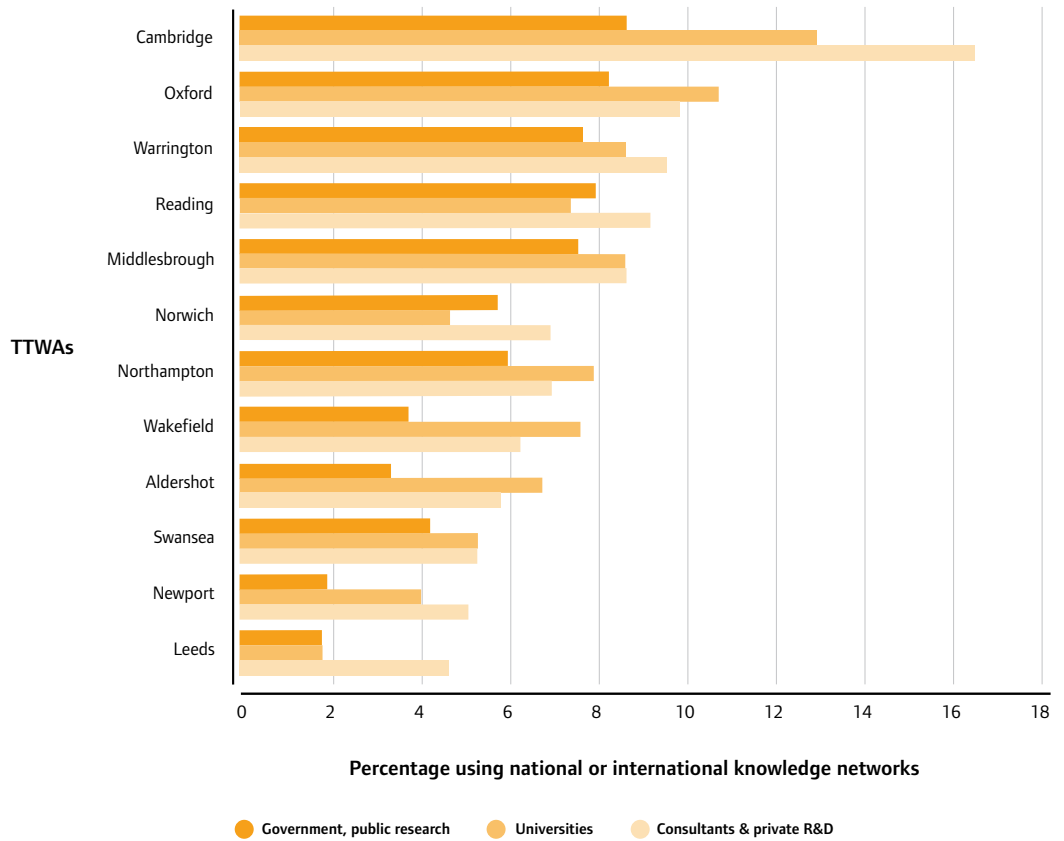
Reading this declined during the 1980s and recovered during the 1990s. At the same time capacity in Warrington declined steadily over the entire period although it remained just above the British average in 2005. Newport and Wakefield failed to register any research or higher education employees over the 24 years. The difference between these two city-regions at the bottom of the ranking in 2005 with no employees in R&D, and Cambridge at the top with 4 per cent employees in R&D, was considerable. They represent a major difference between the relative capacity of these city-regional economies to identify and assimilate new knowledge. It is also of some concern that only Cambridge among the top ranked economies has a higher proportion of R&D employees in 2005 than it had in 1981. This is one indicator of the structural changes taking place in the local economies.

One might expect R&D or other knowledge assets to affect the output of local high-tech manufacturing. But the evidence suggests no such correlation. Where there has been a

decline in the proportion of R&D employees this has indeed often been the case. So, cities with significant R&D employment in 1981 that subsequently declined – as in Reading and Warrington – saw a relative decline in employment in their high-tech manufacturing sectors including computers, electronic components and scientific instruments. (Aldershot saw a decline in computers and electronic components). But output also fell in Cambridge, the only city to experience an overall relative increase in R&D and HE employees; yet in Oxford, the resurgence of R&D during the 1990s was marked by similar growth or resurgence in all of its main high-tech manufacturing sectors. It is difficult to explain from available secondary data these differences between the two university cities.

An equally complex relationship exists between knowledge workers and output in those cities with consistently below average proportions of R&D employees. In most cases this deficit was reflected in declines in high-tech manufacturing: this was generally the case in

Figure 12: Knowledge partners located nationally or internationally in selected cities CIS4 2002-2004



Note: Locations of external knowledge partners include: UK partners only; overseas partners only; both UK & overseas partners

Norwich, Middlesbrough, Swansea, Leeds and Northampton. But both Newport and Wakefield bucked this trend with combinations of low proportions of R&D employees combined with local growth in their high-tech manufacturing sectors. Again, with the information to hand, it is difficult to explain this apparent paradox.

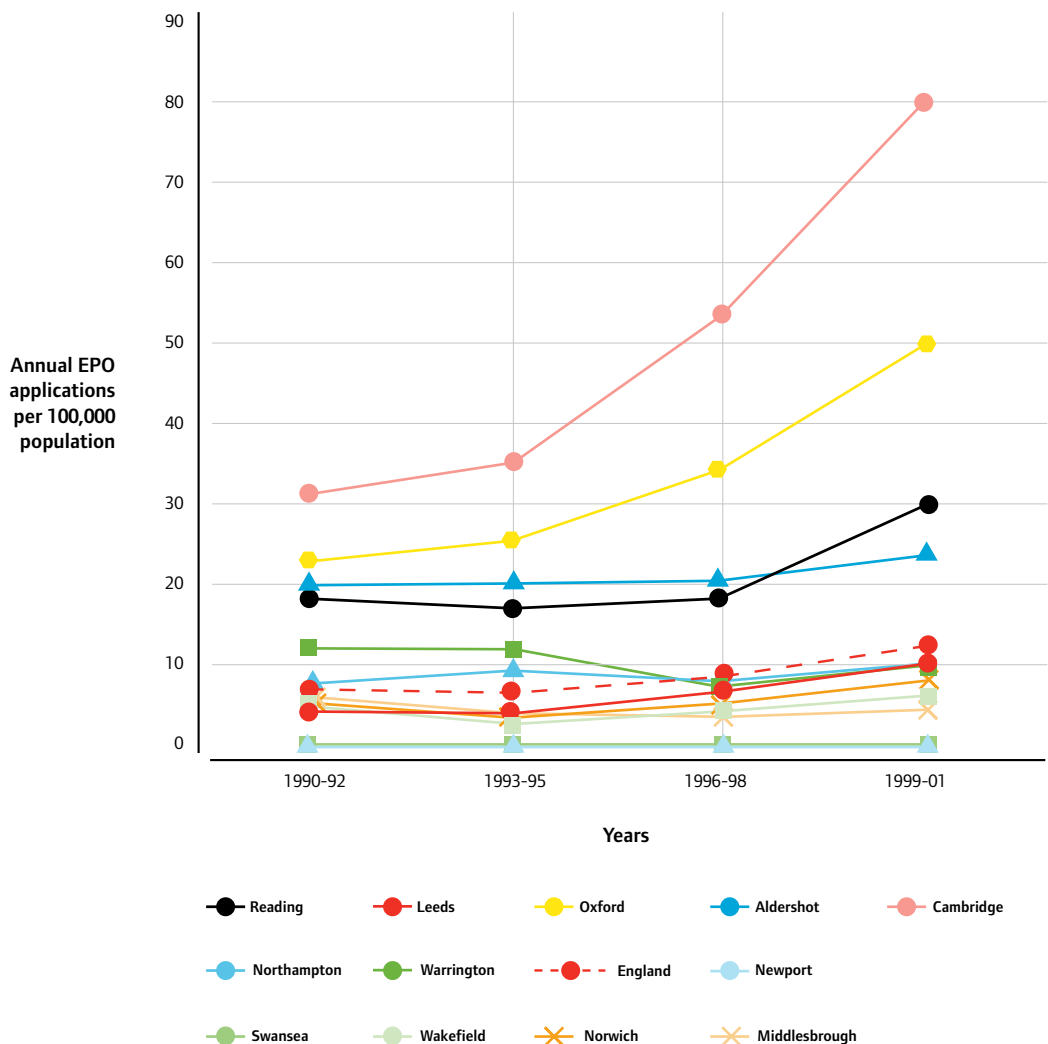
Internal knowledge assets are, however, only half the story as far as a city’s absorptive capacity is concerned. Equally significant is their ability to access knowledge through networks within the national or international economy. Indeed, given that much specialised knowledge appears to be located in a handful of urban areas around the globe, links to these centres are essential in order to appreciate where the contemporary frontiers of knowledge are in any given specialisation.

In Figure 12 we analyse a snapshot of results from CIS4. In this case the analysis shows the extent to which the firms in our sample cities had been collaborating with universities and other knowledge partners elsewhere within

the UK or abroad. The greatest use of external consultants was made by firms in Cambridge, Oxford, Reading and Middlesbrough. Firms in the same cities also partnered with universities located elsewhere as did those in Northampton, Wakefield and Aldershot. Firms in Swansea, Newport and Leeds had the fewest external links with both consultants and universities. Norwich firms were also among the lowest users of external universities.

Thus there is some evidence here to support the proposition that firms in cities with the highest internal absorptive capacity tend to be most able to identify and assimilate knowledge from external sources. Conversely, around half of our cities with the lowest levels of internal absorptive capacities are also among those with the fewest interactions with external knowledge partners. There is some degree of overlap between these two categories: Middlesbrough has a higher proportion of external partners than might be expected and Aldershot a lower proportion.

Figure 13: Change in annual patent applications to EPO per 100,000 population 1990-2001



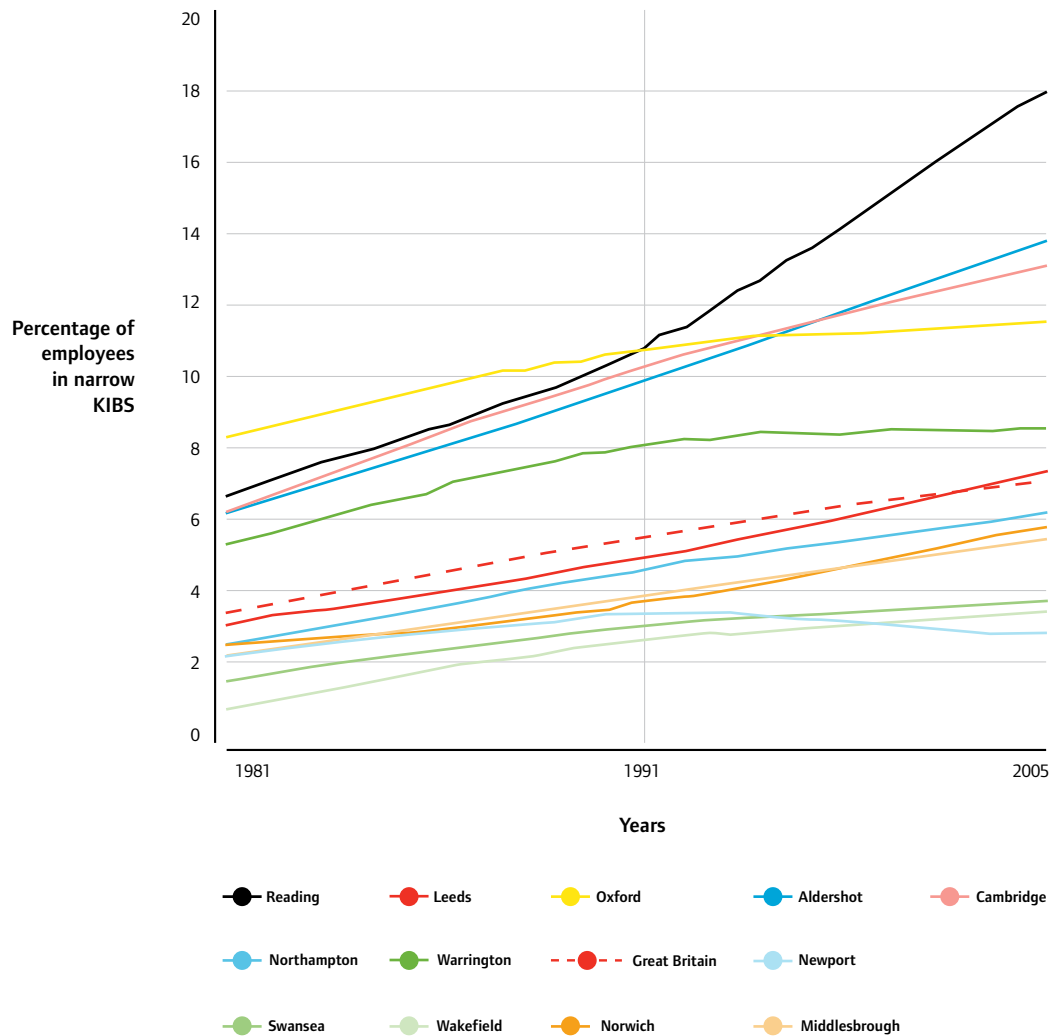
From this analysis we argue that the collective absorptive capacities of our sample of cities are both path dependent and cumulative. They are path dependent in the sense that the historical development of their particular sectoral mix has determined their occupational profile. Old industrial cities have mostly not developed the knowledge-intensive infrastructure needed to compete in the contemporary international economy. Equally, those cities that did not develop such sectors during the 19th century have more recently developed new knowledge-intensive sectors generating knowledge-intensive occupations and the kinds of skills that are needed in competitive post-industrial economies.

These basic differences tend to have a cumulative impact. Sectoral and occupational differences influence the scale of R&D

conducted in specific cities. They also provide the bases for external interaction. Thus Newport, Swansea and Wakefield consistently appear in the bottom half of all the tables in this section, and have not been gaining on the national average. Meanwhile, Oxford and Cambridge always appear in the top half with Aldershot and Reading not far behind.

This raises the fundamental questions of “why are these long-term trajectories so persistent?” and “what are the possibilities for changing them?” Part of the answer lies in the nature and characteristics of the city’s local innovation systems and the degree to which they can upgrade existing sectoral pathways and create new ones. In pursuit of answers we provide a brief analysis of some key aspects of the local innovation systems of our sample cities.

Figure 14: Change in proportions of employees in narrow KIBS in selected cities 1981–2005



Note: Narrow KIBS includes the following SICs:

72: Computing and related activities

73: Research and development

742 + 743: Architectural & engineering design activities and related technical consultancy; technical testing & analysis

744: Advertising

7411 + 7412: Legal services; accounting, auditing & tax consultancy

7413 + 7414 + 7415: Other KIBS ***

2.5 Local innovation systems are the dynamic generators of novelty, change and growth in their local economies

We define a local innovation system (LIS) as “a functionally localised collection of organisations, institutions and processes that create or adopt valuable new economic knowledge and commercialise it”. The generation or adoption of novelty by combining varieties of indigenous with externally sourced knowledge provides a local economy with its evolutionary momentum. A

LIS requires the combination of indigenous knowledge capacities – and knowledge interaction or collaboration – with the ability to identify and interact or collaborate with external sources of knowledge to commercialise and export new knowledge.

A local innovation system should inject new knowledge and ideas into the existing sectors of a local economy and provide the basis for the emergence of new sub-sectors or pathways. Such injections may lead to revived or new economic practices by:

- Taking advantage of chance events leading to the opening of locational windows of opportunity.
- Improving the productivity of existing businesses.
- Breaking out of technological lock-in.
- Creating new institutions.
- The introduction of new social structures.

The available data only allow us to investigate a few of these characteristics. One way to analyse local new knowledge creation is to look at patent data. Although this casts light mainly on high-tech manufacturing industries, it does provide an indicator of new knowledge creation in this area.

Figure 13 shows the changes taking place in the annual rates of patent applications to the European Patenting Office (EPO) during the 1990s. This analysis mirrors that shown in Table 2. All the cities that appeared in the top deciles for innovation outcomes in CIS4 in Table 2 also produced more patent applications than the average for England during the 1990s. Conversely all those in Table 2 that appeared in the lowest deciles produced fewer patent applications than the English average. While patent applications are an important element of an LIS in their own right, there is no necessary correlation between the generation of new ideas and their application in products in the same city.

The adoption of external new knowledge is also an important source of innovation in any city-regional economy. Every year the UK spends some £21 billion on creating new knowledge through the science system in universities, research institutes and companies. But this represents only 3.5 per cent of the total creation of such new knowledge among OECD countries (AIM 2008). This re-emphasises the importance of cities developing capacity to identify, access and assimilate external new knowledge. In many cases the capacity to adopt new knowledge from elsewhere is likely to be at least as significant as its indigenous creation.

An important indicator of a city's capacity to commercialise locally or internationally generated new ideas is the presence of knowledge-intensive business services (KIBS). These provide highly specialised contributions to firms' whole range of commercial activities

including computing, R&D, technical services, advertising, market research, legal, accounting and tax services.

Figure 14 shows the relative growth in narrowly defined KIBS for our sample cities. The proportion of employees in KIBS has increased most rapidly above the British average in Reading, with significant increases in Aldershot, Cambridge, Oxford and Warrington. But the rates of increase in the remaining cities except Leeds have not kept pace with the average. The lowest rates are to be found in Swansea, Wakefield and in Newport (where the proportions of KIBS actually fell between 1981 and 2005).

KIBS face a problem faced by other aspects of a local innovation system. With limited numbers of innovative firms, demand for specialised services may be too low to provide a sufficient market for the development of specialised KIBS. But without access to local KIBS potentially innovative firms may find it difficult to acquire the specialised external services that they need to meet their innovative potential.

2.6 New pathways are created by interactions between absorptive capacity and innovation

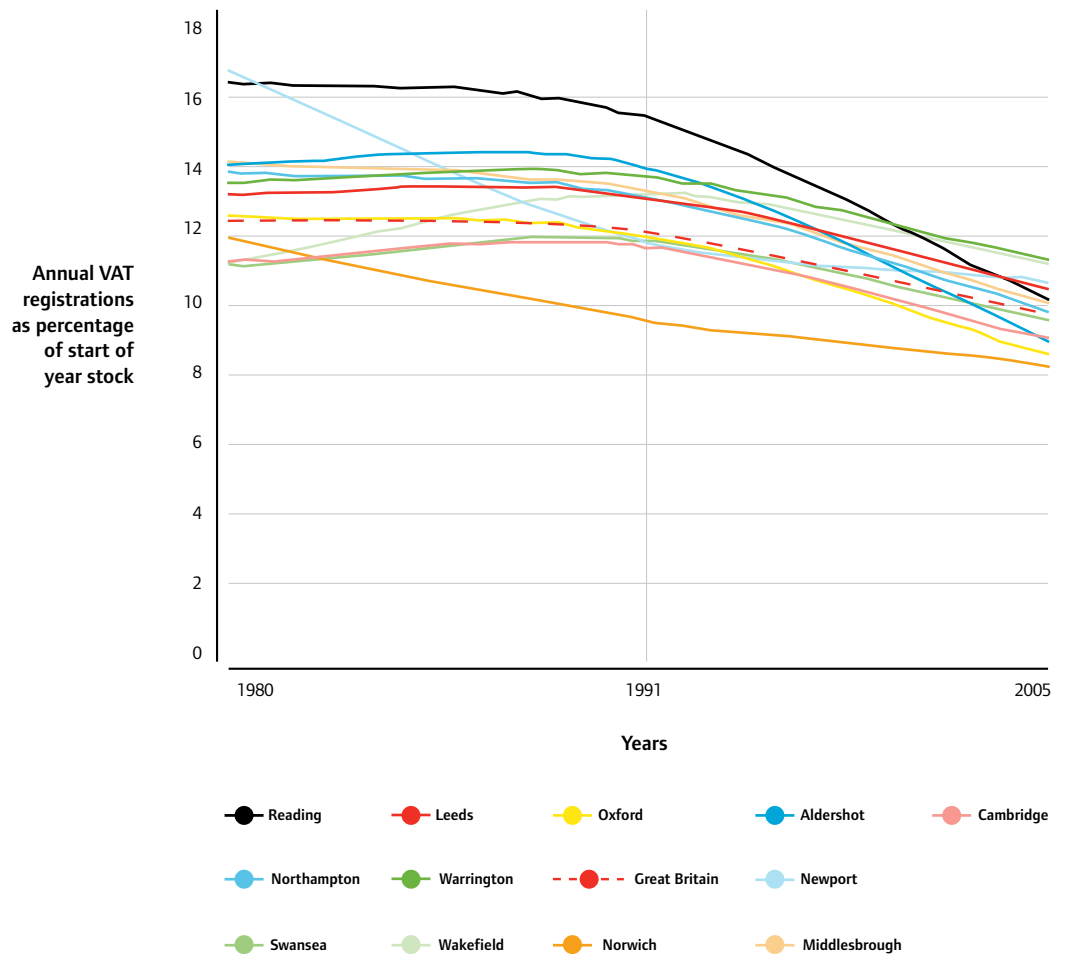
We have argued that the ability of city-regional economies to change or break out of historically determined development pathways is, to a significant extent, based on local capacities to understand, create or adopt and commercialise new knowledge. This represents a complex combination of absorptive capacities and innovation. In this section we turn to the question of how interactive combinations of these capacities may lead to the creation of new pathways. The potential sources of new path creation include:

- Indigenous creation.
- Heterogeneity and diversity.
- Transplantation from elsewhere.
- Diversification into related industries.
- Upgrading existing industries.

Indigenous creation

We have already argued that this rests on the aggregate innovation capacity of a given

Figure 15: New firm formation in selected cities 1980-2005



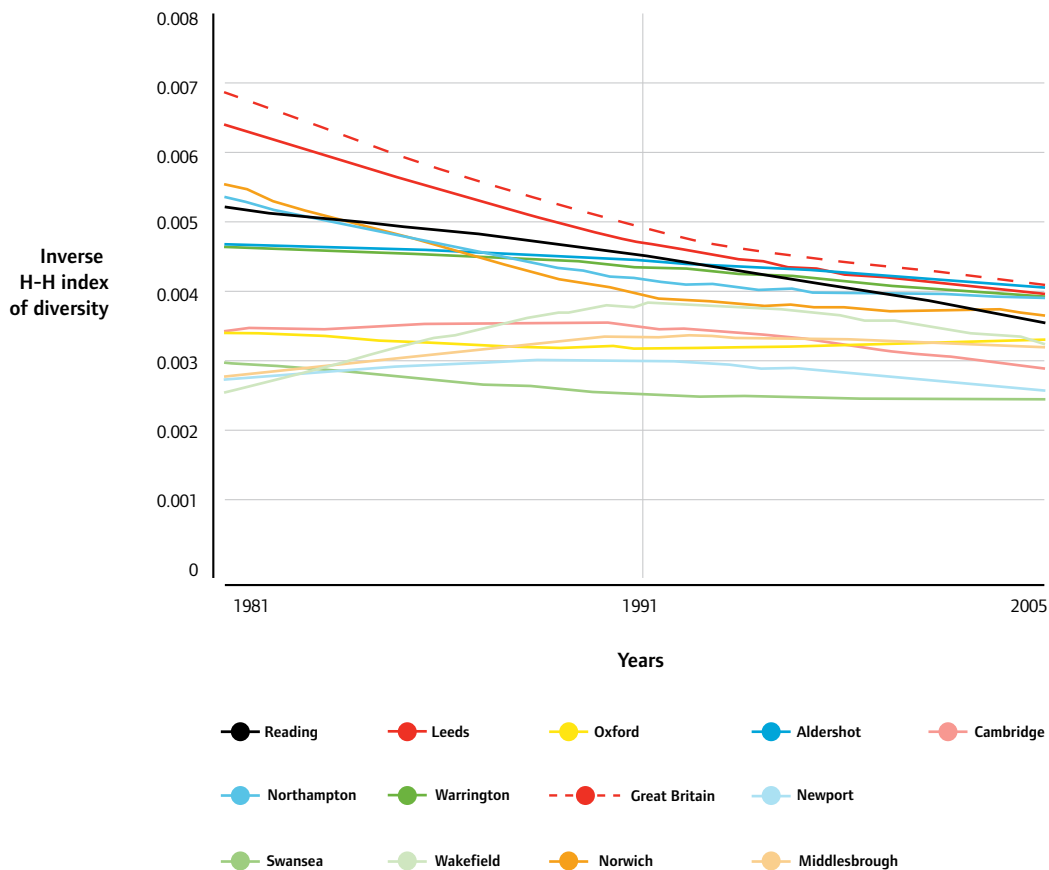
city-regional economy. Much of this capacity is based on the creativity and R&D of existing medium and large firms. Nevertheless, a significant proportion of new ideas are commercialised by new small firms. Figure 15 examines the rates of new firm formation in our sample cities. While average new firm formation fell across Britain during the 1990s, it is noteworthy that some of our more innovative city economies such as Aldershot, Cambridge and Oxford saw even lower numbers of new firms. This may indicate some loss of dynamism in these economies.

Conversely it is also interesting to note the slightly above average rates of new firm formation in some of our less innovative cities such as Wakefield, Newport and Middlesbrough. Although the rate is now declining, this may indicate that the “gales of creative destruction”, to use Schumpeter’s famous phrase (Schumpeter 1939), experienced by their traditional industries may have given local entrepreneurs the incentive to start new firms – partly because of a lack of alternative employment options.

Heterogeneity and diversity

There has been a long-running debate about whether economic growth and the creation of new pathways are driven by heterogeneity and diversity or by specialisation. The question is whether urban economic specialisation or diversification is more likely to produce the external economies associated with the localised spillover of technology and the promotion of local innovation. Marshall’s (Marshall 1890) original theory of localisation economies, developed subsequently by Arrow (Arrow 1962) and Romer (Romer 1990) (known as MAR), focused on the benefits of local industrial specialisation, and this has been carried into much of the ‘new economic geography’ theory, and to Porter’s cluster theory. This contrasts with the work of Jane Jacobs (Jacobs 1969) who argued that the more diverse a city’s economy, the more general the external economies of agglomeration, the more the scope for varied interactions between firms and the more likely spontaneous innovation will occur. She also held, conversely, that the more economically specialised a city is, the more prone it is

Figure 16: Inverse Herfindahl-Hirschman index of diversity in selected cities 1981-2005



to structural and technological ‘sclerosis’, and hence the more vulnerable to shifts in competition, trade and technology.

These propositions can be tested by calculating the inverse Herfindahl-Hirschman (H-H) index of market concentration. Figure 16 shows these calculations for our sample of cities over the period from 1981 to 2005. It may be seen that the British economy as a whole has become less diverse over the period. This is mirrored in most of our sample of cities with the exceptions of Wakefield and Middlesbrough although neither of them was among the most diverse economies by 2005.

The relationship between diversity in the form of unrelated variety and new path creation in our sample of cities is not strong. Thus, Figure 17 shows the correlation between the inverse H-H index of market concentration – diversity – and new firm formation in our sample for 2005. Although the relationship is positive it is not strong: the R^2 is only 0.1782. This suggests that Jacobs’ type variety and diversity on their

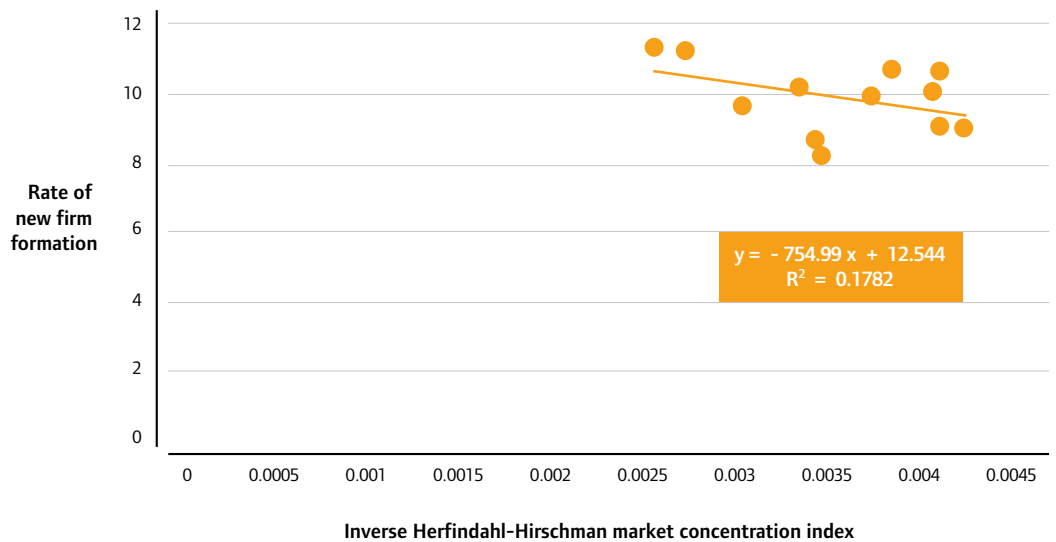
own may not be major sources of new path creation in urban economies. Instead we argue that groups of sectors or ‘clustered variety’ appear more effective at generating new pathways than simple diversity on its own.

We are not able to find relevant secondary datasets to analyse possible transplantations from elsewhere or the upgrading of existing industries in the economies of our sample of cities. This needs the kinds of detailed historical analysis that we begin to use in the next chapter.

2.7 Conclusions

We have argued that, once started, the sectoral structures of city-regional economies develop along those pathways over long periods of time. Cities whose mining, heavy industries and manufacturing made them world leaders in the 19th century still bear the legacies of those activities today. In practice it has proved

Figure 17: New firm formation by inverse Herfindahl-Hirschman index of market concentration in selected cities 2005



difficult for them either to keep their original industries internationally competitive or to create new industries of comparable scale and significance. By contrast, those cities that were largely by-passed by the Industrial Revolution, or started or expanded later in the 20th century, have mostly been able to create newer pathways in more contemporary industries. History matters in both cases.

A key factor in the long-term economic competitiveness of our sample cities has been their capacity either to develop new knowledge-intensive sectoral pathways, something at least partly dependent on their past accumulation of knowledge assets. The historical and cumulative development of particular sectoral pathways – which has been affected by those assets – has determined the nature and types of occupations found in each individual city.

It has particularly influenced their proportion of knowledge-intensive occupations. There is a big contrast between our cities both in the proportion of such occupations and their specific profiles. These differences influence their collective absorptive capacity, including their relative levels of R&D. In some there is very little R&D employment at all; in others it is a major sectoral activity.

Some 96.5 per cent of new scientific knowledge is produced in other OECD economies (AIM 2008). As a result, the relative ability of knowledgeable workers in one city to communicate, link and network with their

peers elsewhere is critical to the acquisition and assimilation of external leading edge new knowledge. The analysis of CIS4 revealed a tendency for firms in the cities with the least absorptive capacities to be more parochial in their searches for collaboration partners. Those with stronger knowledge assets were more likely to collaborate with external partners.

Such findings suggest that the collective absorptive capacity of city-regional economies is both path dependent and cumulative. It is path dependent in the sense that their industrial history determines the occupations located in them. Knowledgeable people are the key to economic development in increasingly knowledge-based and internationalised economic activities. They provide the bases for both indigenous economic development and the capacity to interact with sources of specialised knowledge around the world. It is cumulative in the sense that those who start with the highest levels of knowledge assets are best placed to acquire more of them, especially from external sources.

The key role of cities' local innovation systems is to inject novelty into the urban economy either by creating indigenous innovation or by commercialising innovations originally started elsewhere. Patent applications are one indicator of the local creation of new scientific knowledge. There are major differences between our sample cities in applications made during the 1990s to the European Patenting Office. Firms in the cities with the oldest industrial sectors typically made few if

any patent applications. Conversely, firms in most of the cities with newer industrial sectors submitted above-average numbers of patent applications.

We also found no necessary correlation between the generation of patent applications in a particular city and their use in the same city. New knowledge is not necessarily used in the city where it was created, a conclusion derived from differences in growth rates between high-tech manufacturing sectors. In some cities with the highest rates of patent applications, employment rates in such sectors accelerated whereas in others they declined.

A key feature of innovation is not simply the production of new economically valuable knowledge but also its commercialisation and sale. An important indicator of the relative ability of city economies to commercialise new knowledge is their proportion of knowledge-intensive business services (KIBS). Again we found their proportion highest in most of the most innovative cities and lowest in most of the least innovative. This lack of KIBS in most of the low performing cities illustrates a conundrum for such cities. They need KIBS firms to provide specialised expertise in the commercialisation of innovations but they cannot create enough market demand for their services without commercialising more innovations in the first place.

Such problems illustrate the difficulty of creating new pathways. For reasons not properly explained by the data this may have become more difficult during the 1990s, with declining rates of new firm formation in most of our sample of cities. New firm formation was highest in those cities suffering most from the “gales of creative destruction” experienced in their traditional industries, while some more innovative cities appeared to lose some dynamism with falling rates of new firm formation.

We tested the Jacobs proposition that local variety is a source of new path creation. Here we discovered a general decline in the sectoral variety, as measured by the inverse Herfindahl-Hirschman index of market concentration. Conversely, most became more specialised over the 1980s and 1990s. When we correlated the index of variety with new firm formation we found only a weak positive correlation between them. As a result we argue that clustered variety or groups of specialisations are the most likely to create new pathways.

Part 3: Cambridge and Swansea: contrasting path dependent economies

3.1 A Tale of Two Cities

In this chapter we turn our focus from a multi-city statistical discussion to a more detailed examination of two particular case-study cities selected on the basis of their very different experiences – Cambridge and Swansea. The former, as our analysis of CIS data showed, has been one of the best performing British cities for innovative activity; indeed it regularly ranks as one of the most innovative places in Europe. Swansea, on the other hand, has been one of the worst performing cities, with a very low rate of innovation. The value of this ‘contrastive case-study’ methodology is that it helps to reveal how locally-specific path dependence processes and histories condition local innovation outcomes and developments – either positively (as in Cambridge) or negatively (as in Swansea). As our discussion below reveals, the two cities have followed very different development paths over the last three decades, producing different and self-reinforcing innovation trajectories.

3.2 Path dependent development

The theoretical model outlined in Part 1 posits that the main sectoral development pathways that emerge over time within a city-region economy collectively determine its relative capacity (more precisely, of course, the capacities of its firms, workers and institutions) both to create new knowledge indigenously and to absorb new knowledge from external sources, and thereby to shape its propensity to innovate. History – or place-specific history – matters. The past development of a local economy and its legacy condition the scope and opportunities for new pathways

of technological and industrial development. Cambridge and Swansea illustrate this process in significant ways: the two cities have had quite different economic histories (see Table 1), and their quite disparate innovative performances over recent decades have reflected these differences.

Swansea: the legacy of an old industrial past

Swansea has seen three main phases in its development. Historically, the city was heavily dependent on extractive industries and the production of coal, iron, copper, tin and zinc, earning it the moniker ‘Copperopolis’ in the 19th century, when at its peak, Swansea was producing 60 per cent of the world’s copper requirements. However, by the 1960s and 70s, many of these heavy industries had closed, with the last local coal mine closing in the early 1980s.

The second phase of development was triggered by the decline of these industries. Attracted partly by the pool of low-skilled low-wage labour released by deindustrialisation, multinational companies identified South Wales as a location for their assembly branch plants. One of the first significant inward investments in the electronics industry was the Sony facility in Bridgend in 1973, east of Swansea. This was the first major Japanese investment in Wales, and acted as a catalyst for other inward investors, particularly in the electronics sector. At the height of production, 50 per cent of televisions and 75 per cent of video cassette recorders (VCRs) produced in Europe were made in Wales. These markets have both now effectively disappeared with technological change.

Table 2: Historical evolution of high-tech economies: A Tale of Two Cities

	Cambridge	Swansea
1960	“Cambridge Consultants” formed, by a group of newly graduated scientists and engineers from the university.	Decline of local extractive industries.
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969	Mott report published, recommending the founding of a Science Park.	
1970	Decision by Trinity College to develop the country's first Science Park.	
1971	Outline planning permission granted for Cambridge Science Park.	
1972		
1973	First company, Laser-Scan, moved onto the Science Park.	Sony electronics factory at Bridgend.
1974		
1975		
1976		WDA established.
1977		
1978		
1979	By end of 70s, around 25 companies located on the Science Park.	
1980		Last coal mine closed in Swansea County.
1981		UK's first Enterprise Zone designated in Swansea.
1982		
1983		
1984		
1985	‘Cambridge Phenomenon’ report published by SQW.	
1986		
1987	St John's Innovation Centre established. University publishes its first IP policy for Research Council funded research.	
1988		
1989		
1990	During 1990s, cluster of hi-tech companies in the Cambridge area grew to around 1,200 companies employing around 35,000 people.	Loss of competitiveness based on low cost labour.
1991		
1992		
1993		
1994		
1995		
1996		Planned LG investment does not arrive.
1997	Eastern Region Biotechnology Initiative established.	
1998		
1999	Cambridge Network formed, as a voice for the high-technology business community. Greater Cambridge Partnership formed.	WAG formed.
2000		
2001	University revises its IP policy for externally funded research. Cambridge Angels group formed.	Technium Programme launched.
2002		
2003		
2004	Cambridge Science Park now home to more than 70 R&D companies on the 152 acre site, including new clusters such as photonics, nanotechnology and materials science.	
2005	New IP policy adopted by the university.	Publication of ‘Swansea 2020’, economic regeneration strategy for the city.

Around the same time, the public sector response to the demise of heavy industry in Wales was the establishment of the Welsh Development Agency (WDA) in 1976, which aimed to encourage business development and investment in Wales. A key WDA strategy was to encourage multinational companies to relocate or open branch plants in Wales, particularly in low-cost manufacturing sectors. Sony was joined by Panasonic and Hitachi in taking advantage of the relatively low wage-rates and start-up costs that south Wales offered, as well as the public sector finance available to build new branch plants. One WDA aim was to build up the economy through local linkages, but one respondent suggests that this was not realised:

“The linkages tended not to happen and those that did happen tended to be at the low value end. I’ve looked at some companies, and their local linkages were at the packaging end [...], not on the innovation side.” [Interview SW003]

However from the 1990s, Wales began to lose its cost competitive edge as opportunities opened up for investment elsewhere, particularly in Eastern Europe and Asia. Footloose industries, such as branch plants that require a labour force with few specific high-level skills, began to seek out more cost-effective locations elsewhere, leading to a decline in low-cost manufacturing in Swansea and Wales since the 1990s. As one respondent remembers, of the closure of the Lucas plant in Swansea:

“They had a facility in the Swansea Valley that made wiring looms for cars, very labour intensive, pretty low-tech, but that factory literally went to Eastern Europe one weekend. They put the whole thing on articulated lorries and they moved it to another site, because it was a lower cost place for them to be.” [Interview SW001]

But cost is not the only factor working against South Wales. Technological change has also taken its toll on production in Wales. For example, with the demise of analogue television, Sony closed one of its plants, moving production to Barcelona where expertise in the new digital and plasma technology helped them respond to the changing market.

The experience of LG Electronics in Newport in 1996 is cited by some as marking the end of the large mobile inward investment plants

in Wales. The LG development comprised two distinct projects: LG Electronics was a complex of factories manufacturing cathode ray tubes (for colour television sets and computer monitors) and associated components; LG Semicon was a semiconductor fabrication facility. Within months of the investment programme being announced, the South Korean economy had gone into recession, so most of the planned investment never reached Wales, illustrating the precarious dependence of the local economy on global market conditions.

In response to the loss of jobs in the branch plant industries, the third phase in Swansea’s development pathway was spearheaded by the Welsh Assembly Government (WAG), established in 1999. The government developed a strategy to move Wales up the value chain and focus on developing its knowledge economy. This was also partly encouraged by a shift in the emphasis of European funding towards more capacity-building and the development of a knowledge-based economy. Part of the government’s strategy included the development of start-up incubator and support units, called Technia, developed in partnership with the Welsh Development Agency (now incorporated into the WAG) and Swansea University. The first Technium was opened in Swansea in 2001, and there are now a total of nine throughout Wales. Their aim is to provide infrastructure and business support to new innovative companies, and to provide space for them to develop their ideas and grow into successful knowledge-related businesses. Located on the old Swansea Docks site (now re-branded as “SA1”), Technium 1 provides smaller units, while Technium 2 offers larger units for companies that have outgrown Technium 1’s accommodation. The original public-sector led Technium developments have also recently acted as a catalyst for the private sector to build the next generation of Technium buildings. Work is currently underway to construct a new building on SA1 with additional space for firms that have outgrown the Technium 2 building. In Swansea, there is also a campus-based “Digital Technium” with strong links to the Institute of Advanced Telecommunications at the university. However, these initiatives are not yet large enough to show up in the aggregate data for the city.

Respondents suggest that the Technium concept aims to mirror, on a much smaller scale, the clustering effect of Silicon Valley. But the scale of each Technium development,

Figure 18: Swansea annual employment change 1981-1991 and 1991-2005



with around 10-12 firms on each of three sites, precludes comparison with Silicon Valley.

"In terms of transformational effect on the economy, it's probably too early to say they've had a dramatic effect." [Interview SW006]

However, the Technia have been successful at their own scale in helping a small number of new knowledge-based industries to grow and expand.

Respondents feel that knowledge-based businesses are less fickle than branch plant industries, and so their growth potentially offers a more stable future for Swansea:

"Because it's all about people. If you're a technical expert in one of these knowledge-based companies and you like living in Swansea, you don't want to move to Czechoslovakia [sic] to have a lower wage." [Interview SW001]

Swansea City Council has also recently produced its own economic regeneration strategy, 'Swansea 2020', which includes the 2020 aspiration to become:

"Wales' leading centre for the knowledge economy, recognised for its adoption of innovation, and anticipation of market and technological change." ['Swansea 2020' City and County of Swansea (2005, p.31)]

While there are some signs that such a vision might be realised, through initiatives such as the Technia, respondents feel that there is still some way to go to achieve these aspirations for the Swansea economy.

What Swansea indicates, then, is the difficulty faced by many local economies with a legacy of traditional industries which seek to reconfigure their employment base around new technology and knowledge-intensive activities. New development paths are not easily forged from the legacy of old paths. Employment data give some insight into this issue (see Figure 18). Sectors can be grouped according to the "pathway typology" developed in Part 1 (Figures 3 and 4). Decline is shown not only in the traditional heavy industries, such as 'Mining', but also in their more recent replacements, such as the 'Manufacture of radio, TV and communications equipment'. What is perhaps more striking is that almost all of what were the major employment growth sectors in the

1980s – in many cases experiencing overall growth rates of more than 10 per cent – have since lost their dynamism. These activities include not just some older manufacturing industries (such as 'Manufactured wood products', 'Chemical products' and 'Medical and precision instruments') but also more modern sectors such as 'Computing and related activities'. There is even evidence that the fastest-growing sectors in the 1980s have also been those to experience the most dramatic slowdowns in growth after 1991. Thus 'Manufactured chemicals and chemical products' led employment expansion in the city in the 1980s, registering a 38 per cent increase, but this turned into a small decline between 1991 and 2005. 'Computing and related activities' have also seen a significant slowdown in employment growth, though this sector still remained one of the city's fastest-growing activities in employment terms in this latter period. Employment data indicate 16 'resurgent' and five 'ascendant' pathways. Of those five, only two – 'Other business activities' and 'Financial intermediation' – can be described as knowledge-intensive services. More importantly, R&D activity is not significant enough to be recorded. The data provide some evidence that, although the Swansea economy has been restructuring over recent decades, it has not been moving into indigenously created knowledge-intensive sectors fast enough to compensate for losses in its traditional extractive industries and electronics.

Cambridge: the creation of a high-tech economy

Cambridge has had a very different experience. If Swansea's problem has been escaping its industrial past to find a role in the new information economy, it is the lack of such a traditional industrial past that has proved so favourable in forging Cambridge's success. Much has been written about the so-called 'Cambridge phenomenon' – the transformation of the city from a relatively small, basically service and market town to one of the country's and Europe's most innovative cities (see, for example, Segal Quince Wicksteed, 1985, 2000). In many ways, Cambridge illustrates Peter Hall's provocative assertion that "tomorrow's industries are not born in yesterday's regions". As one commentator puts it:

"You could say that Cambridge's emergence as a high-tech, high-growth and innovative

Table 3: The main science parks making up the Cambridge high-tech cluster

The Principal Science/Innovation/Research Parks	
Cambridge Science Park	Harston Park
St Johns Innovation Centre	Wellcome Trust Genome Campus, Hinxton
Techno Park	Vision Park, Histon
Peterhouse Technology Park	Melbourn Science Park
Babraham Research Campus	Cambridge Technology Centre, Melbourn
Granta Park	Great Chesterford Research Park
Pampisford Park	Cambridge Research Park

Source: Cambridge Enterprise (2004)

economy was, in a way, because it was a sort of 'greenfield' location – there was no prior heavy industrial past to overcome, but instead a first-class university with excellent scientists and technologists, and Colleges with land that they were willing to develop as science parks. It was able to develop a new future without hindrance from its past.” [Interview C001]

Though a modest, service-based market town with little industry (apart from the locally-based airport and aircraft refitting company of Marshalls, a Philips electronics plant, and some agro-chemicals activity), Cambridge was home to one of the oldest and most renowned of the UK's universities. But it never experienced the phase of industrialisation that swept through much of Britain in the 19th and early-20th centuries. Indeed, the Holford Report in 1948 reinforced this lack of industry. Fearful of potential pressures to expand the city, and the likely effects of such an expansion, the Holford Report recommended a strategy of 'containment'. He suggested that the population of Cambridge and its adjacent villages be limited to 100,000 people in order to preserve the special historical character of Cambridge as a university town within a rural setting. This policy was reinforced by the introduction of a strong Green Belt around the city. Cambridge's world-class university, with extensive local land ownership and a traditionally conservative outlook, tended to impose its own anti-industrial hold on the city.

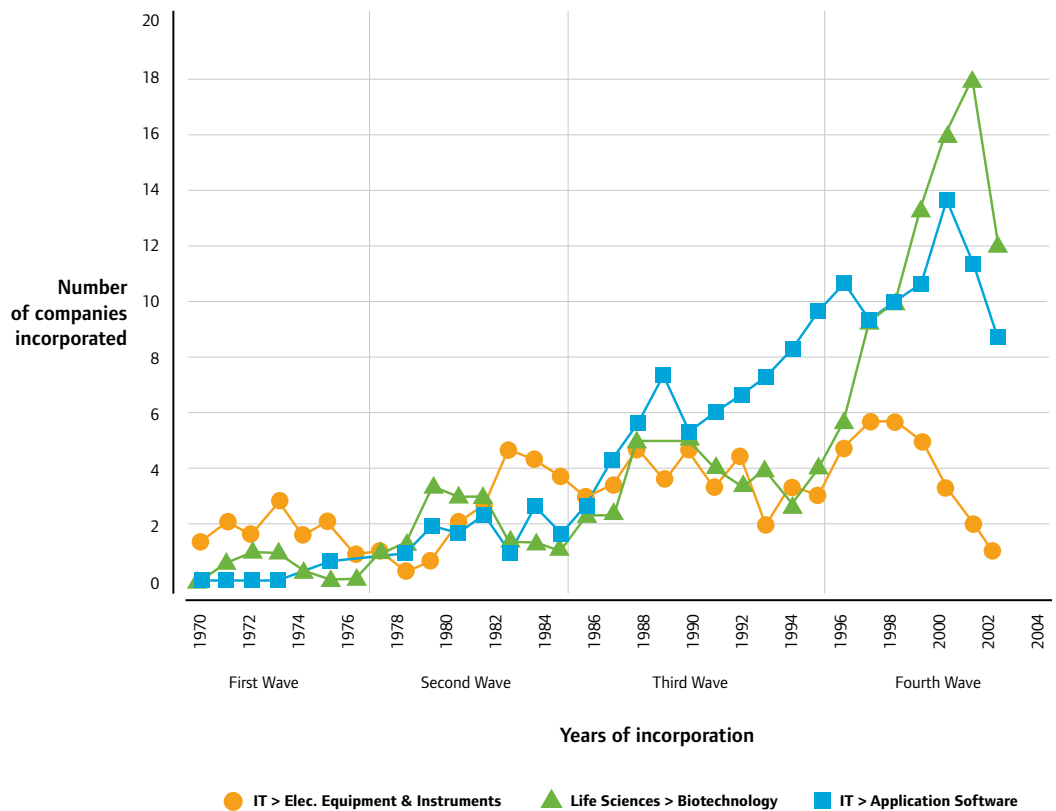
Since the early-1960s, Cambridge has developed on a dramatically different economic trajectory. According to one recent study:

A key trigger event took place in 1960, when a 24 year old Cambridge chemical engineering graduate gathered a group of former classmates and acquaintances to form Cambridge Consultants to “put the brains of Cambridge University at the disposal of the problems of British industry”. Since then, and under different owners, Cambridge Consultants has inspired young scientists and engineers to be technology pioneers, solving real-world problems for clients and spinning out new businesses. And legend has it that the cluster grew from there. [Library House, 2004]

In the same decade, a more permissive stance towards economic development emerged. In particular, the Mott Report in 1969 proposed exceptions to the restrictive economic and industrial expansion policies of the time, by advocating and allowing for the development of science-based and university research-based industries.

Following the Mott Report came the stimulus of the Cambridge Science Park, created by Trinity College in 1970 on some of its land on the northern edge of the city. A further boost came in 1987 when St John's College developed its Innovation Centre adjacent to the Science Park; it was later followed by the Peterhouse Science Park. Over the past 15 years, several other designated sites for innovative small firm incubation and growth have been established around the edges of the city – making some 14 within a radius of about eight miles of the city centre (Table 3). Most are located in just two Cambridge

Figure 19: The growth of high-tech Cambridge – number of innovative firms by year of incorporation



Source: Based on Library House (2004)

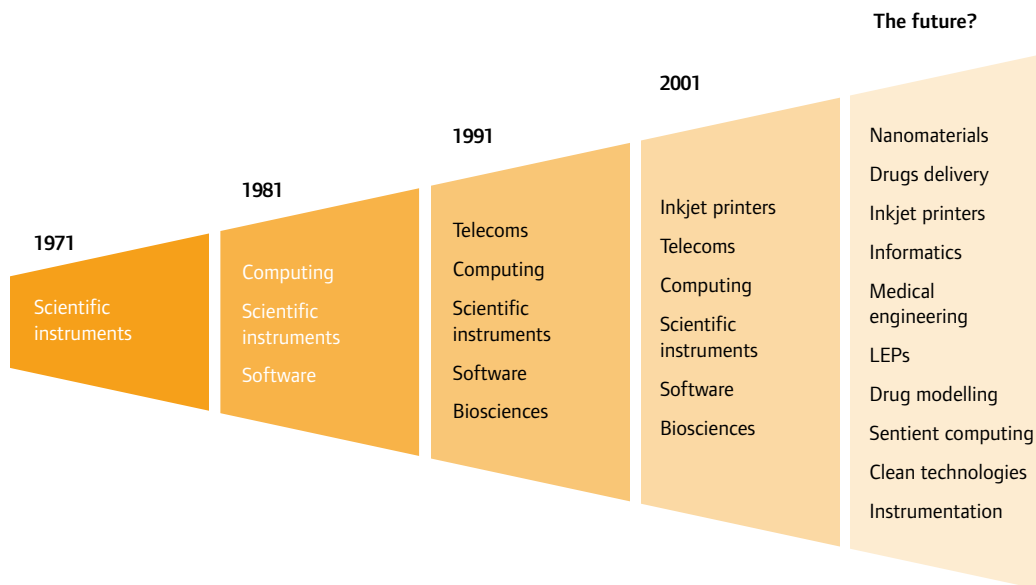
postcode districts – CB4 and CB2; and there is undoubtedly a ‘Cambridge effect’ – one might say a ‘Cambridge brand’ – at work in the location of these centres of innovative activity, in that a CB postcode enables them to identify with, and be externally identified as belonging to, the Cambridge ‘high-tech cluster’. The Cambridge-based venture capital research and advisory consultancy, Library House, estimates that the Cambridge high-tech cluster now contains around 900 innovative firms, employing around 30,000 people. Other estimates take a wider definition, including education, media and other creative sectors, and a wider geographical coverage, suggesting as many as 50,000 knowledge-related workers.

The growth of the high-tech economy occurred in four waves: the early-1970s to the late-1970s; the late-1970s to the mid-1980s; the mid-1980s to the mid-1990s; and the mid-1990s to the present (see Figure 19). These waves, in turn, have to some extent reflected the sectoral evolution of the high-tech base. The early phase of development was based mainly around IT activity, specifically electronic equipment and instruments. The second wave

not only saw another expansion of these IT activities, but also a noticeable development of life-sciences firms, mainly in biotechnology. The third wave was led particularly by IT applications and software. The fourth most recent wave saw further expansion of this sector, but also very strong growth in biotechnology. Some observers now point to a possible fifth wave emerging, based around a major new phase of growth of medical research as part of the enlargement and development programme of Addenbrooke’s Hospital, and the development of an embryonic ‘clean technologies’ cluster (associated with various environmental technologies and processes).

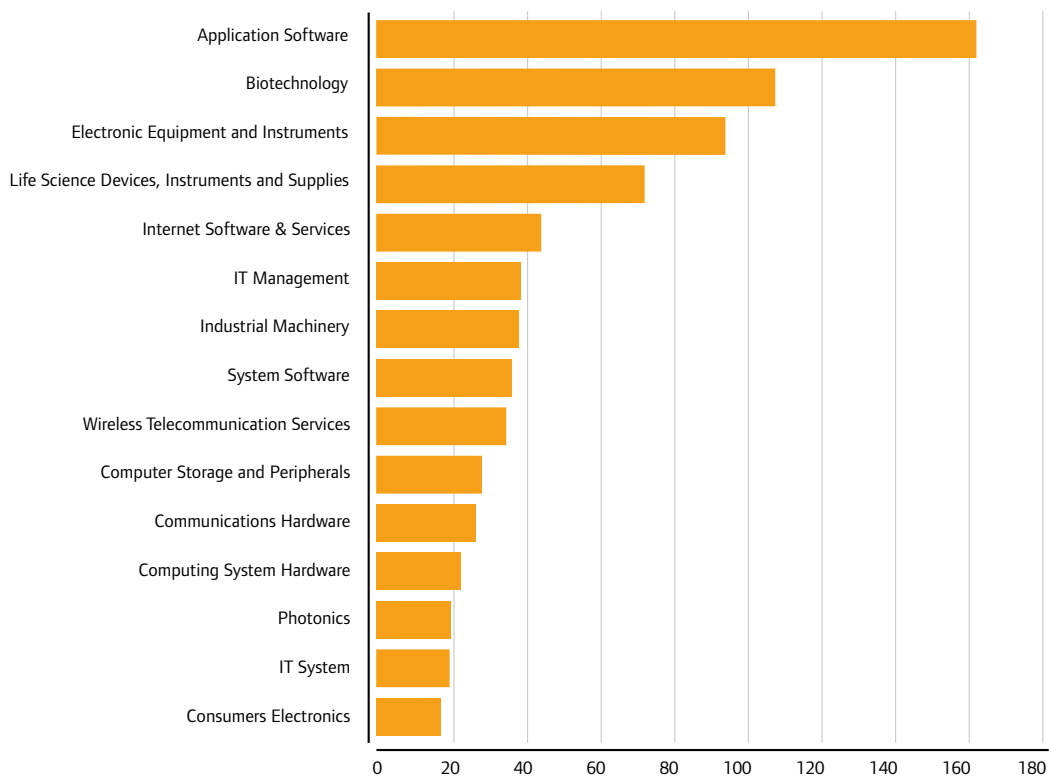
Importantly, over the course of its 35-40 year evolution, Cambridge’s high-tech economy has become progressively more diversified. Local studies and commentators identify up to 15 main sectoral pathways (Figures 20 and 21). While the precise number depends on how different high-tech activities are defined – their boundaries are often fuzzy and overlapping – there is a definite trend towards what might be called the ‘clustered diversity’ of the high-tech economy.

Figure 20: The time-line and diversification of high-tech pathways in the Cambridge cluster



Source: PACEC, Greater Cambridge Partnership, 2003; Interview C003

Figure 21: Subclusters in the Cambridge high-tech economy – according to Library House



Software, Biotechnology and Instruments dominate
Number of Cambridge Cluster companies by Industry Sub-sector: 2004

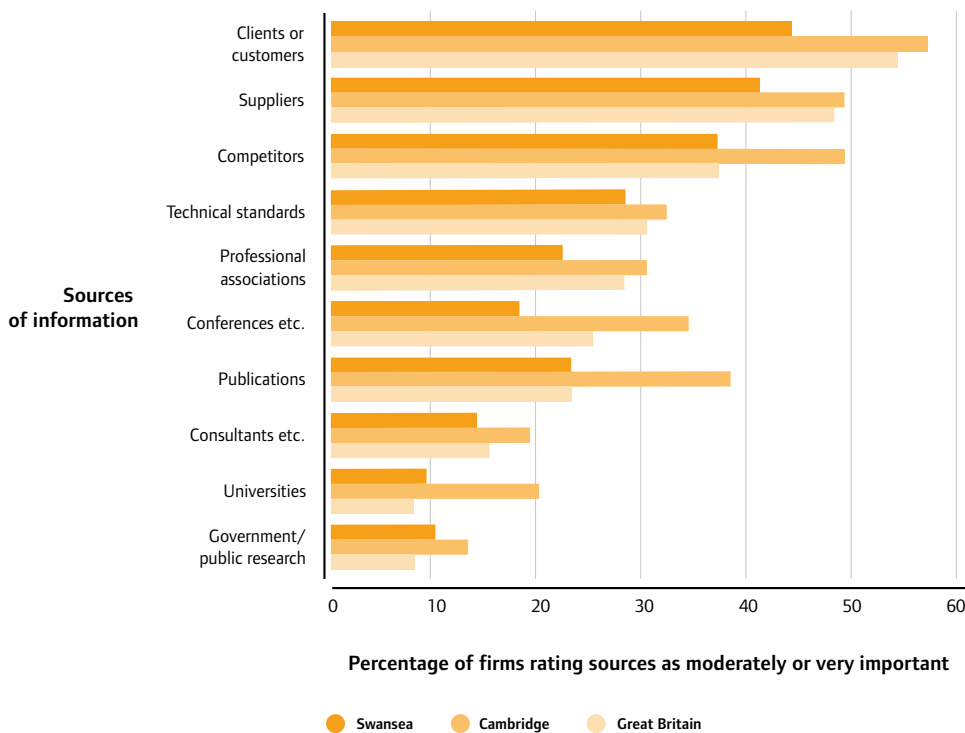
Source: Library House (2004)

Figure 22: Cambridge annual employment change 1981-1991 and 1991-2005



Note: Excludes all sectors with < 100 employees; Excludes agriculture, etc.; Excludes forestry, etc.

Figure 23: Cambridge and Swansea sources of information for innovation 2002-2004 CIS4



It is also clear that, during this diversification, the Cambridge high-tech economy also witnessed some relative shifts in fortune across its sectors. Even here, ‘Computing and related activities’ lost their dynamism during the 1990s. Between 1981 and 1991, employment grew by some 50 per cent, but growth slowed to 11 per cent between 1991 and 2005 (see Figure 22). By contrast, ‘Research and Development’ (which covers a range of high-tech and knowledge-intensive activities) stagnated during the 1980s but has been a leading resurgent sector since. As Figure 24 also shows, most of the city’s (relatively small) manufacturing economy has declined – or certainly lost its dynamism – since the early-1980s. Thus Cambridge, too, shows some similarities with Swansea’s development path though the fundamental composition of its economy is clearly markedly different.

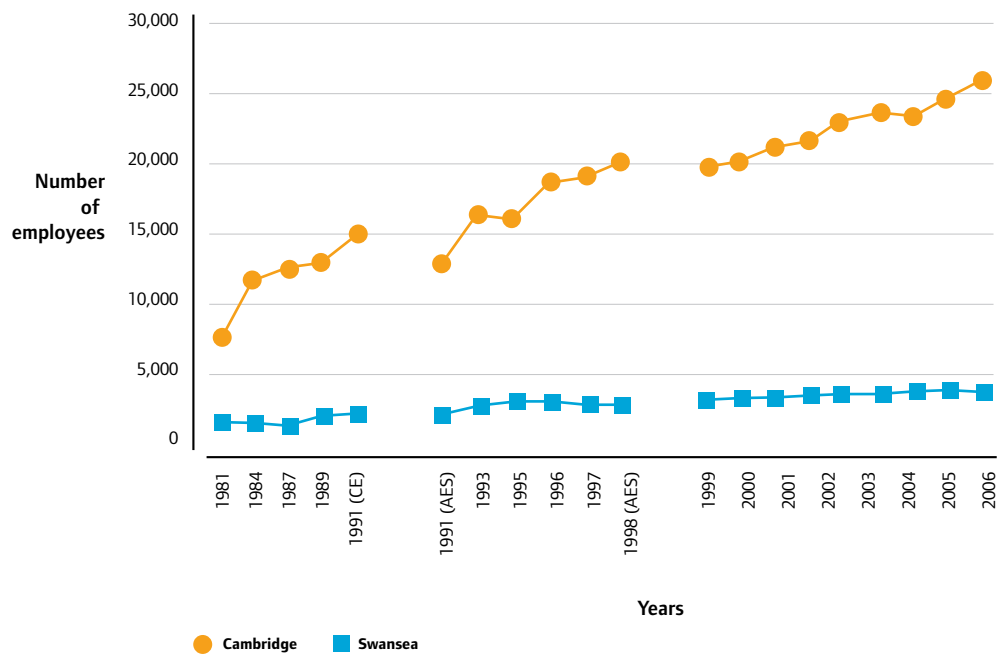
Some key points emerge from this contrasting of the Swansea and Cambridge economies. First, the economic history of an area can exert an important influence – for good or ill – on its subsequent development: ‘history matters’. Second, the creation of new local economic-technological development pathways reflects the interplay of local conditions and factors. Third, as Cambridge illustrates, even with a favourable mixture of local conditions

and events, the development of vibrant new paths of innovative activity takes time (30-40 years in Cambridge’s case). This means that it is difficult for a city with the legacy of an old industrial past to switch quickly into new technologically advanced activities. Fourth, once critical momentum becomes established, new economic trajectories appear to become self-reinforcing and path dependent. Fifth, this path dependent development can itself spawn new technologies and activities as part of an evolutionary diversification process. Finally, growth does not, however, continue unabated without the need for renewal as indicated in Figure 4 (Part 1).

3.3 Absorptive capacity: firms need sources of new external knowledge

As we have seen in Part 1, the ‘absorptive capacity’ of a city-regional economy depends on its firms’ ability to identify, assimilate and exploit new external knowledge. Data as well as information from respondents suggest that there is a significant difference between Cambridge’s and Swansea’s ability to absorb new knowledge into the local innovation system.

Figure 24: Cambridge and Swansea employees in R&D and higher education combined 1981-2006



Knowledge identification

According to ‘absorptive capacity’ theory, the sectoral and occupational structure in a city economy shapes the ability of its firms to identify new knowledge. Data from CIS4 (see Figure 23) suggest that Cambridge firms utilise external information much more extensively than their counterparts in Swansea, and indeed more than the national average; this implies that Swansea firms rely more on internal than external information as a factor in innovation. Furthermore, Swansea firms seem to make less than average use of most information sources aside from universities, government and public research bodies.

This difference is compounded by major variations in the absolute numbers employed in key knowledge-based activities, such as R&D and higher education (see Figure 24). Cambridge has tripled the number of such workers since the early 1980s, in line with the growth of the high-tech economy; their number is currently estimated by CIS4 at around 25,000. As the cluster has grown, so has the pool of knowledge workers, which then reinforces the innovative performance of the economy. The city has thus developed a vital critical mass of such workers:

“There is no doubt that it is the size of the technical, scientific and highly educated workforce that is a key ingredient of Cambridge’s success. Some of these workers

have been drawn from the university, but many also come from elsewhere in the UK, even globally, to work in Cambridge. The cluster is able to attract the knowledge-intensive workers it needs, and there is a significant movement of these workers between firms within Cambridge. In this sense there is a constant circulation of knowledge within the cluster. And such people, by their very nature, are also used to searching for and acquiring relevant information and knowledge from elsewhere.” [Interview CAMB001]

Interviews with Cambridge firms suggest that they use multiple sources of relevant information and knowledge for innovation. As one firm puts it:

“We generate the knowledge needed for innovation in several different but interacting ways. We have our own dedicated research groups of highly qualified scientists and engineers. We appoint people who are thinkers, who can see where technological improvements can be made, and are problem solvers. They are concerned with developing and extending our technologies. They are allowed a certain amount of time – say around 10 per cent – to ‘think outside the box’. Mainly, however, they are working on technological developments, improvements and advances in response to new market opportunities,

the demands of customers and clients, and the challenge of competitors... I'd say much of our technological development is customer- and market-led. Sometimes, we 'de-engineer' our competitors' products. But we are also market leaders, and globally orientated, so there is also an impulse to improve so we stay on top. We do exchange some knowledge and information with similar local companies in Cambridge, but this is mainly around applications and not so much around our core technologies – those which are key to the business's success – we don't share those and the knowledge they contain with others!"

[Interview CAMB002]

Cambridge Consultants, a key player in the Cambridge high-tech cluster (see above) also illustrates the importance of the knowledge base. Its staff do up to 10 per cent of 'off-project' basic research, and are expected to keep up with key developments in their respective scientific fields. But the vast majority of its business is in high-tech product development for customers. Innovation is market-orientated and demand-led: manufacturers and clients engage Cambridge Consultants to develop highly innovative technology-based solutions and developments for products that the manufacturers and clients are hoping to commercialise. Cambridge Consultants has a number of disciplinary teams, including mathematicians, engineers, physicists and material scientists, whose scientific knowledge is brought to bear on the product technology in question: the approach is typically multidisciplinary. The company specialises in radical not incremental innovation, making its knowledge base highly sought after:

"Cambridge Consultants is not particularly interested in providing an incremental innovation service for firms. Most manufacturers and other firms are capable of doing incremental innovation themselves, in-house. We tend to specialise in fee-based R&D for innovation of a more radical kind, much of which requires a multidisciplinary approach which firms can't readily do themselves. For this we employ the best scientists we can. This makes us expensive, but then that means that firms approach and engage us expecting us to produce radical solutions. After 40 years Cambridge Consultants has built up an impressive knowledge base and track record of applying that knowledge to produce highly innovative products." [Interview CAMB003]

In Swansea, the picture is markedly different. There is relatively little R&D and the city is not seen by investors as a 'natural home' for R&D activity. There are few R&D employees, no critical mass as in Cambridge, and hence little obvious reason why R&D activities should be attracted to the city. The result is less use of external sources of information and knowledge for innovation. For example, although the Sony plant at Bridgend now incorporates an R&D facility, this only opened about 25 years after Sony had first located in Wales; one respondent suggests that Sony has few real roots in the local economy.

However, a key principle behind the Technium is the importance of harnessing external new ideas within nascent businesses.

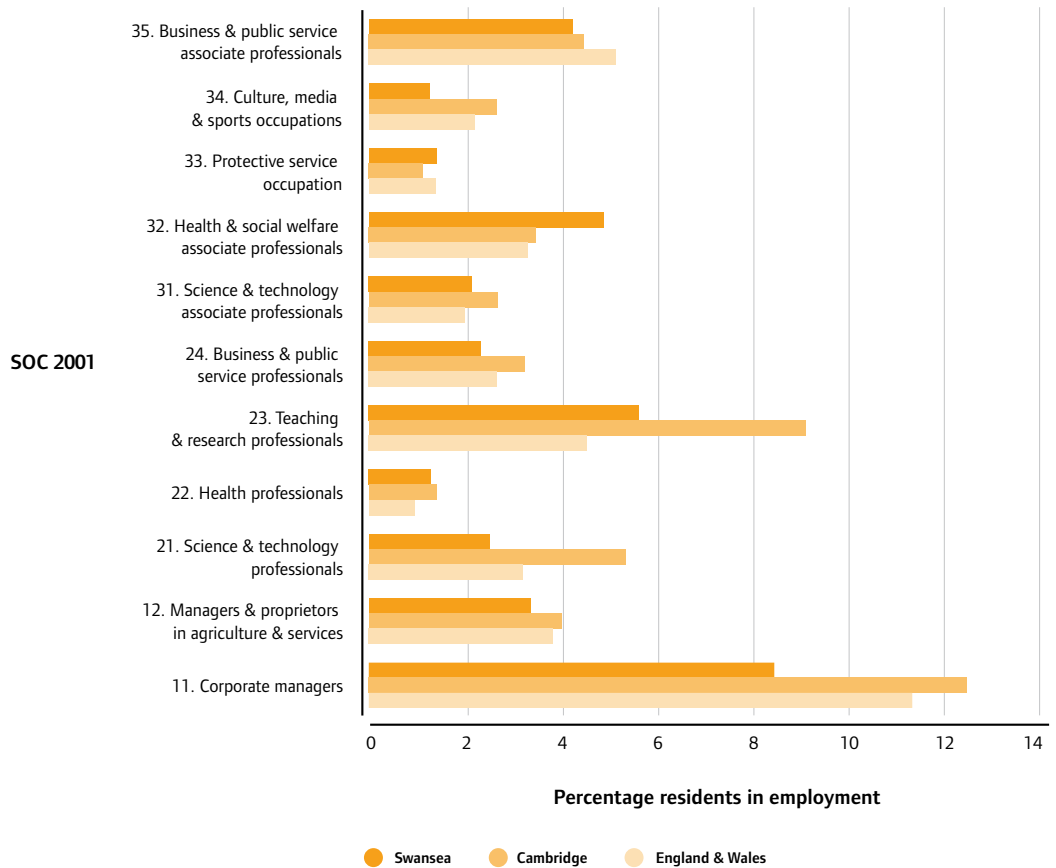
"If you've just got indigenous companies growing and developing in silos [...], then my thinking was "you're just going to get more of the same". You need to bring in new ideas, you need to bring in fresh thinking, and you can do that indigenously, but it's all a bit incestuous." [Interview SW001]

Within Technia, there are examples of inward investor companies working with indigenous companies, in some cases successfully leading to flotation, but they appear to be the exception rather than the norm. Around 10-15 per cent of Technia tenants are inward investors, with the rest being indigenous companies, whereas an ideal ratio would be 50:50. However, the difficulty of attracting inward investors is recognised, as knowledge-based businesses are attracted by local expertise (academic or otherwise), rather than any financial aid or grant assistance on offer. After all, such companies can choose to locate near any British or overseas world-class university. And, the importance of bringing in new ideas for the benefit of indigenous companies has apparently not been fully recognised by policymakers.

A further challenge for Swansea is its reliance on Swansea University as the main source of expertise, both to stimulate local innovative firm formation and to attract new inward investment firms to the city. But it is felt that there is a lack of trust and experience in the communication between industry and the university.

"There are these two different worlds of knowledge; the industrial world of knowledge, and the academic world of

Figure 25: Cambridge and Swansea knowledge-intensive occupations 2001



knowledge, with traditionally different priorities, and whereas those priorities might be very much appreciated in Cambridge, we haven't got the experience in South Wales of universities sharing their knowledge with companies, and companies tapping into knowledge at universities." [Interview SW003]

Despite the much greater flow of knowledge from Cambridge University into local high-tech firms than is the case in Swansea, its extent should not be exaggerated. Research collaboration between Cambridge firms and the university's science departments and laboratories is far from pervasive; not all Cambridge high-tech firms use the university's graduates as a source of staff. In Cambridge, as in Swansea, university research laboratories and local high-tech firms have different priorities, and operate over different time spans. What matters for firms is being able to tap into university research knowledge that has commercialisation potential.

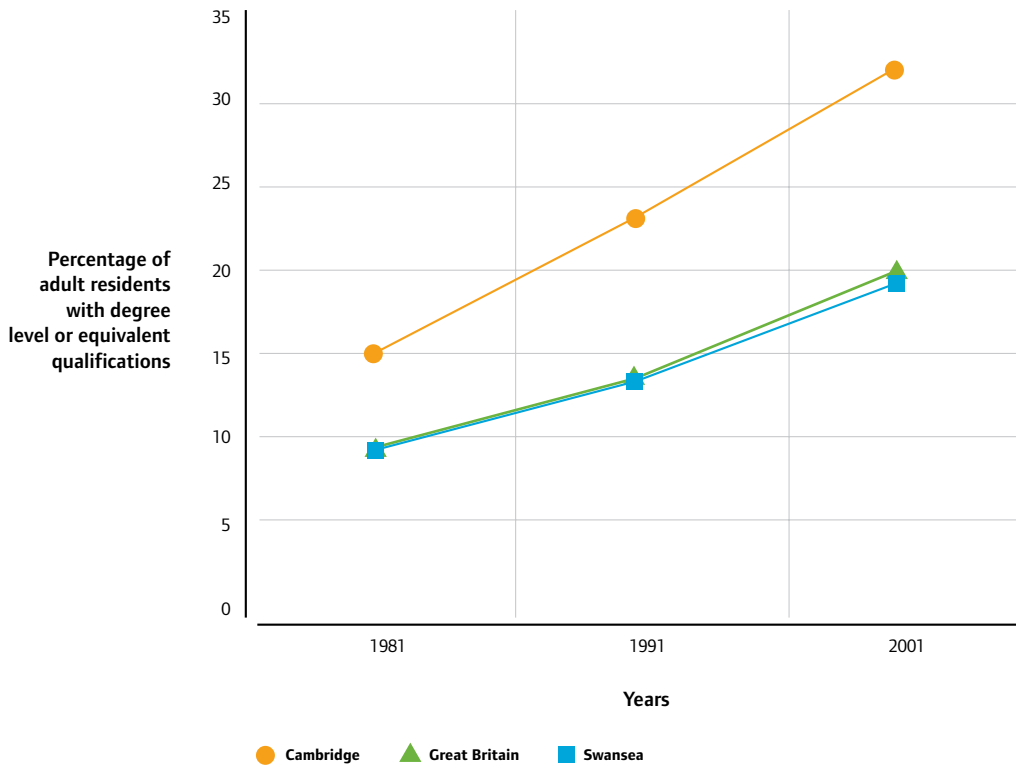
Knowledge assimilation

There are also differences between the ability of the two city economies to

assimilate knowledge. One proxy measure is the relative presence of knowledge-intensive occupations. Cambridge has higher proportions of its workforce in all of the main occupational categories most readily identified with knowledge and technology intensive activity – 'Science and technology associate professionals', Teaching and research professionals' and 'Science and technology professionals' (Figure 25). Similarly, in terms of the proportion of adult graduates (Figure 26) Swansea is similar to the British average, whereas Cambridge scores significantly higher. To some extent, of course the higher proportions of knowledge-intensive workers in Cambridge is itself the result of the city-region's high-tech growth over the past 30 years, but their presence is also crucial in maintaining the momentum of that growth:

The concentration of highly-skilled and highly educated workers – especially scientific and technical people – in Cambridge stands out as one of its key strengths. Even before the cluster's development, as a town with a top quality university – with a long history of major, history-changing scientific achievements –

Figure 26: Cambridge and Swansea adult residents with degree level qualifications 1981–2001



Cambridge had a significant proportion of highly qualified people (though the area around it didn't, and still doesn't). The development of the high-tech economy has both been attracted by that, and of course has in turn itself attracted even greater numbers of well educated workers to the area: it's one of those self-reinforcing things. There is no doubt that knowledge is 'in the air' here... It's a place of intense knowledge creation and knowledge assimilation, to use your term." [Interview CAMB001]

Respondents agreed on the importance of graduate retention for the development of the Swansea knowledge economy. However, many felt that retention was poor, as there are too few local job opportunities, despite the attractive location of the city on the coast with the Gower peninsula nearby. Another commentator from the university questions the university's role in this regard:

"To a certain extent, as a university, we're not really training people up for the local area; we're to give them the skills to go all over the world and that would be a sign of success." [Interview SW006]

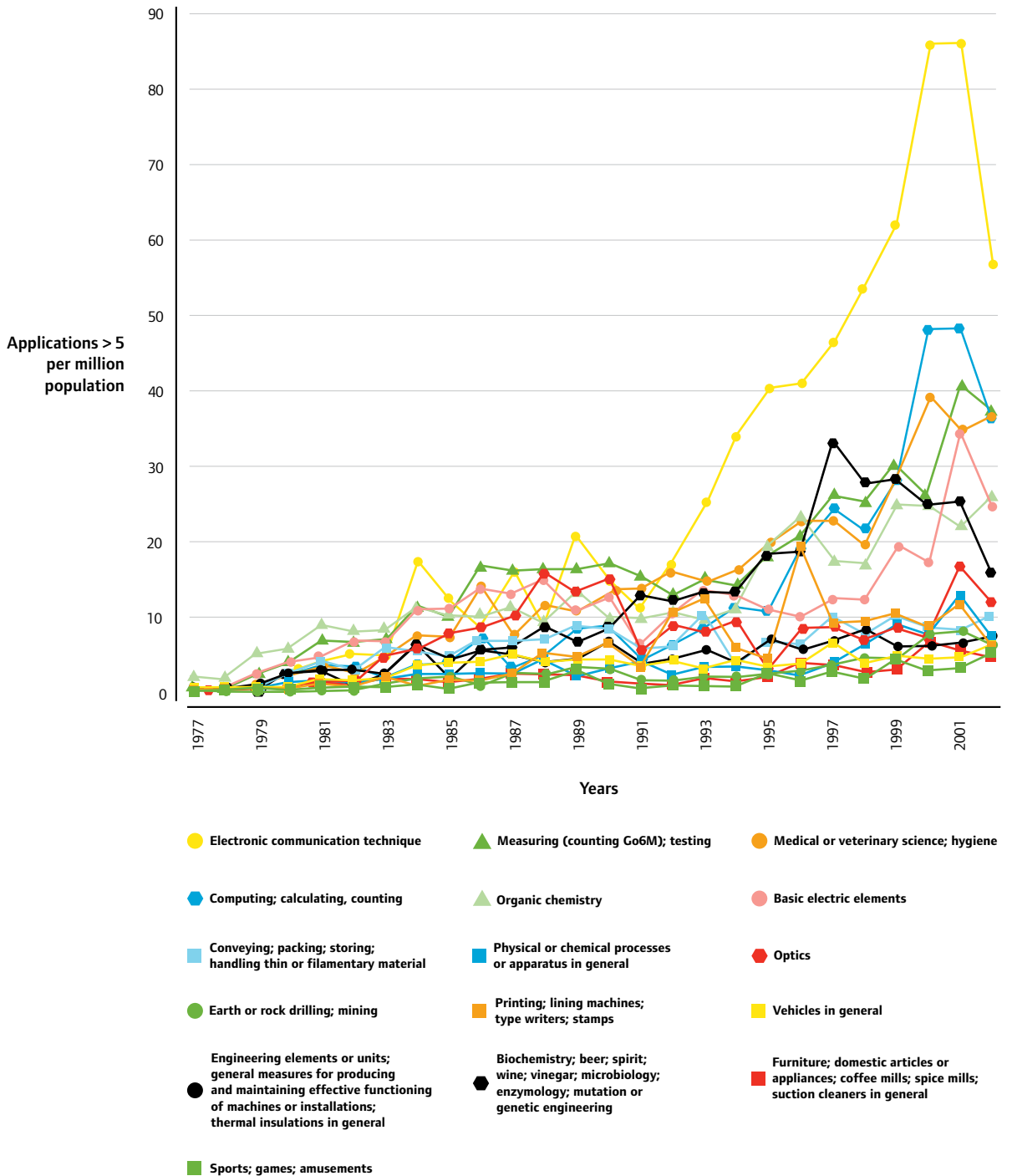
It is suggested that the Technium programme could help retain some Swansea University graduates, although the scale of employment at this level is too small to affect the overall figures. Skills are identified as a significant issue in Wales and Swansea, with the lack of availability of 'good people' a major factor limiting the growth of companies, and their ability to assimilate knowledge.

"It's all very well creating a compelling infrastructure for these companies to grow and develop. If the people aren't there, then you can't. You can't grow without the people." [Interview SW001]

Knowledge exploitation

A local economy's ability to exploit knowledge depends on the number, type and absorptive capacity of its firms. A local firm base that is orientated to knowledge creation is likely to perform well in terms of knowledge exploitation as measured by the innovation rate and the commercialisation of ideas. Cambridge has been developing such a base. The growth of its high-tech cluster has been underpinned by an above-average high firm formation rate (see Figure 19 and Figure 27). In Swansea, industrial legacy has left it with a low new firm birth rate (Figure 27), especially of knowledge-oriented firms.

Figure 27: The explosion of patenting activity in the Eastern region

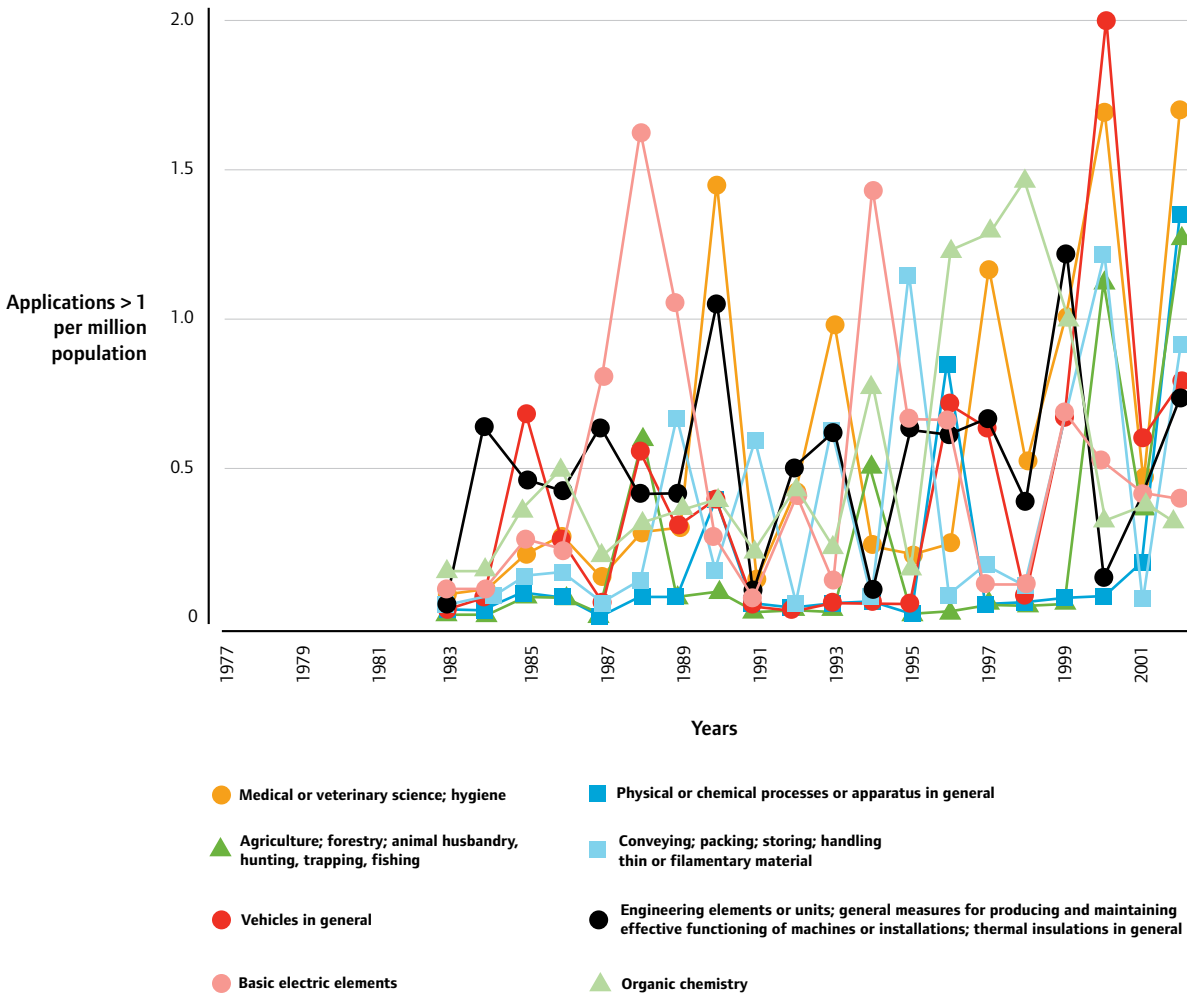


Indeed, much of Swansea's employment growth has been in the public sector (currently around 38 per cent of employment, compared to the UK average of 27 per cent, with the City and County of Swansea, the DVLA, the health service and university the key employers), and there is an under-representation of private sector firms in the city. Similarly, a longstanding grant-dependent culture through UK regional policy assistance and EU funding (Objective 1 up to 2006 and Convergence Funding until 2013) is viewed by many to be a barrier to

private sector exploitation of new ideas. At the same time, some regard the nature of organisational and management expertise amongst Swansea firms as not facilitating knowledge exploitation. Firms in Swansea are described as "not very sophisticated":

"They've got great technical ideas, but no idea if there's a market for it. They don't have management skills. Unsophisticated, I'd say." [Interview SW001]

Figure 28: The lack of patenting pathways in South Wales



For companies within Technium, a recent programme ('Learning Journey') took chief executives from ten Technium companies to Silicon Valley to learn from senior managers within hi-tech companies such as Boeing, Oracle and Intel, how their businesses were run. The programme has been very successful in opening up possibilities for new ways of doing business and thus exploiting knowledge for these firms, but its impact outside participating companies has necessarily been limited.

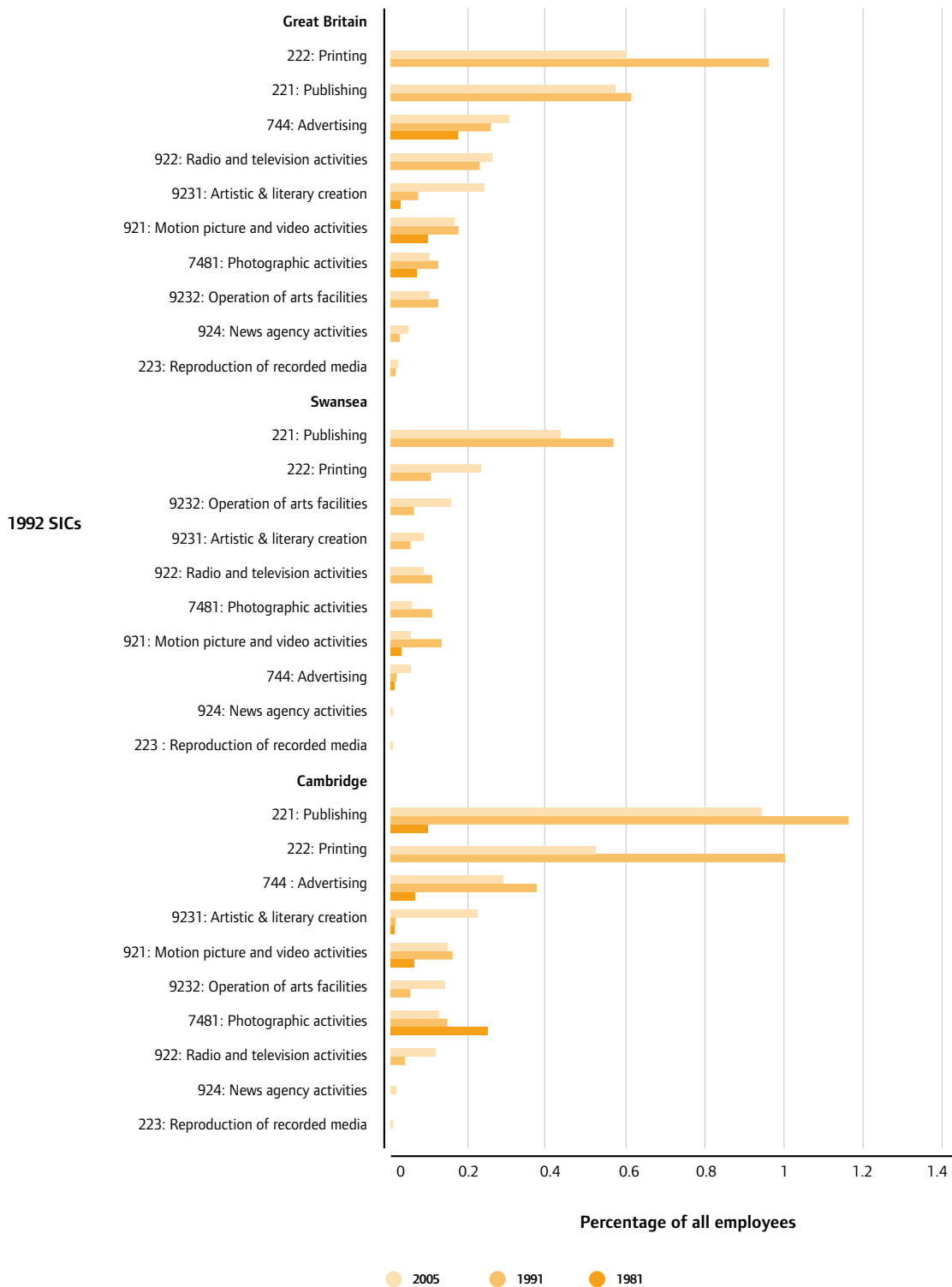
In Cambridge the culture is quite different. The creation and exploitation of knowledge seems to be a key driving force across almost all the firms in the city's high-tech cluster.

"The Cambridge cluster contains numerous cutting-edge firms, in the sense that they constantly seek to develop new technologies and new products. That's part of the atmosphere here. Most firms here

do not serve the local market, nor just the national one, but are global in outlook, and know that unless they exploit ideas that give them an edge in that global market place, their competitors will." [Interview CAMB002]

Yet Cambridge high-tech firms don't always maximise their potential to exploit and use knowledge to grow their businesses into major global players. A common complaint amongst local commentators is that few Cambridge firms grow into large companies, remaining instead in the small and medium sized categories. This is commonly attributed to a lack of managerial skills or the unwillingness of scientist-owners (who are good at creating and applying new knowledge, but not necessarily at management) to pass control over to high-calibre managers (who would be good at exploiting market opportunities and growing businesses):

Figure 29: Cambridge and Swansea narrowly defined creative industries 1981-2005

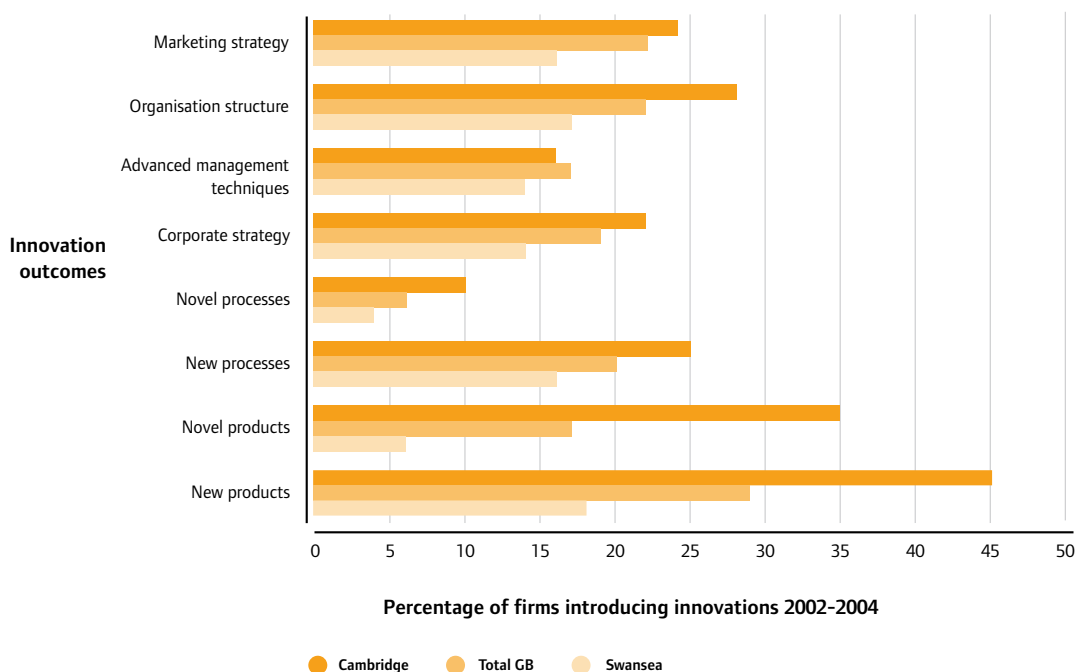


Note: Narrow definition, excluding SICs 72, 742 & 743 (these are included in narrow KIBS).

“One of the curious – and often criticised – aspects of the Cambridge high-tech economy is the general lack of really large global firms – the Microsoft sort of thing. I don’t think anyone really knows

why this is a problem, if it is a problem. It might mean that Cambridge firms don’t actually fully exploit their global potential, but I’m not sure it means they innovate less than they would if they were huge

Figure 30: Cambridge and Swansea CIS4 innovation outcomes 2002-2004



companies – probably the reverse. There is also the complaint that because they remain small, they become prey for global companies based overseas. On the other hand, a not insignificant number of foreign multinationals have been opening research facilities and laboratories in Cambridge recently, Philips being one of the latest.” [CAMB003]

3.4 Local innovation systems: the creation, adoption and commercialisation of new knowledge

Knowledge creation

Their different development pathways mean that the two cities operate quite differently as local innovation systems. Patents provide one proximate measure of knowledge creation and innovative behaviour in a local economy. Unfortunately, patent data by class are not readily available at the level of individual cities, though European Patent Office data (for 1977-2002) exist for larger regions, East Anglia in the case of Cambridge, and West Wales in the case of Swansea. These are shown in Figures 27 and 28. And the available data suggest that quite different innovation systems exist in our two city-regions.

In East Anglia, levels of patenting have risen steadily – dramatically in some activities –

since the late-1970s, when the high-tech cluster began to develop in a concerted way. The growth of patenting in ‘electronic communication techniques’, ‘medical science’ and ‘computing’ has been particularly impressive. West Wales shows no comparable growth: patenting activity was virtually non-existent before the early-1980s; even since it has remained at a fraction of the rates found in East Anglia. Of course, patenting is only a rough guide to innovation, and many patents never see the commercial light of day. But as an indicator of intellectual property development, patents do capture certain aspects of the knowledge creation process. And certainly the enormous differences in patenting rates between the two regions suggest that whilst a dynamic territorial innovation system has emerged and developed in East Anglia – and we know that is this mainly localised in and around Cambridge – no such system can be said to exist in Swansea.

The so-called ‘creative industries’ increasingly interest policymakers. Using the narrow definition of these industries (excluding SIC categories 72, 742, 743), Cambridge also seems to have a lead over Swansea (Figure 29).

The net result of these differences between the Cambridge and Swansea economies in the potential or actual sources of new ideas shows up in CIS4 innovation outcomes (Figure 30). Cambridge outperforms the British

average in all forms of innovation outcome except 'advance management techniques', whereas Swansea underperforms in all forms of innovation outcomes, suggesting that the cumulative characteristics of the local innovation system contribute to the path dependent nature of development. Once a critical mass of innovation is reached it appears to become self-reinforcing, as distinct identifiable innovation and technological paths emerge, as in Cambridge. Not only is there a lack of critical mass in Swansea, which hinders such a self-reinforcing process, the nature of the existing innovation is also generally less radical. Respondents confirm that there is limited R&D within Swansea, which inhibits knowledge creation and innovation outcomes. One of the few Swansea companies cited as successful in innovation is Corus, which sponsors research in the University Engineering School. But while others mention the potential for innovation in the ICT sector in the city, the feeling is that most innovation is not leading edge:

"Whether you say it's product innovation or whether it's just that they're using software, and developing web pages, and these types of things...it's mid-level innovation." [Interview SW003]

Another respondent from the Council comments on the difficulty moving from the ideas stage to patenting:

"With the patents idea, to make it commercially viable, is a hell of a leap of faith. In fact, we and the university have discussed that on numerous occasions, because we've done joint initiatives where we've encouraged people to come forward with their ideas, but where we always failed, is getting that commercialisation of those ideas. Making them venture capital ready, and that's the huge thing." [Interview SW005]

Having ready access to venture capital – and being viewed as a highly innovative place by venture capital organisations – has certainly been a major factor behind Cambridge's success. As the Cambridge high-tech cluster has developed, a local venture capital industry has emerged to serve it – a form of co-evolution – with some significant players, including Amadeus and Cambridge Gateway Fund. According to Library House some 108 companies in the Cambridge cluster are venture-backed, totalling £600m of institutional capital, making it second only to

London, and fourth in Europe (Library House, 2007). Thirty-six per cent of venture-backed cluster companies are in the 'healthcare and life sciences' sector. There is also a thriving local business angel community. The general view is that access to venture capital is a strength of the cluster:

"Not only is there now a healthy locally-based VC market, Cambridge's position close to London means that VC organisations there are within easy reach, and view Cambridge favourably. I don't think venture capital is a problem, though some argue that the British venture capital industry could steer more money into high-tech activity. The key issue is having entrepreneurs who can convince investors, to have ideas that can be brought to market. Cambridge does well here, but can do better." [Interview CAMB004]

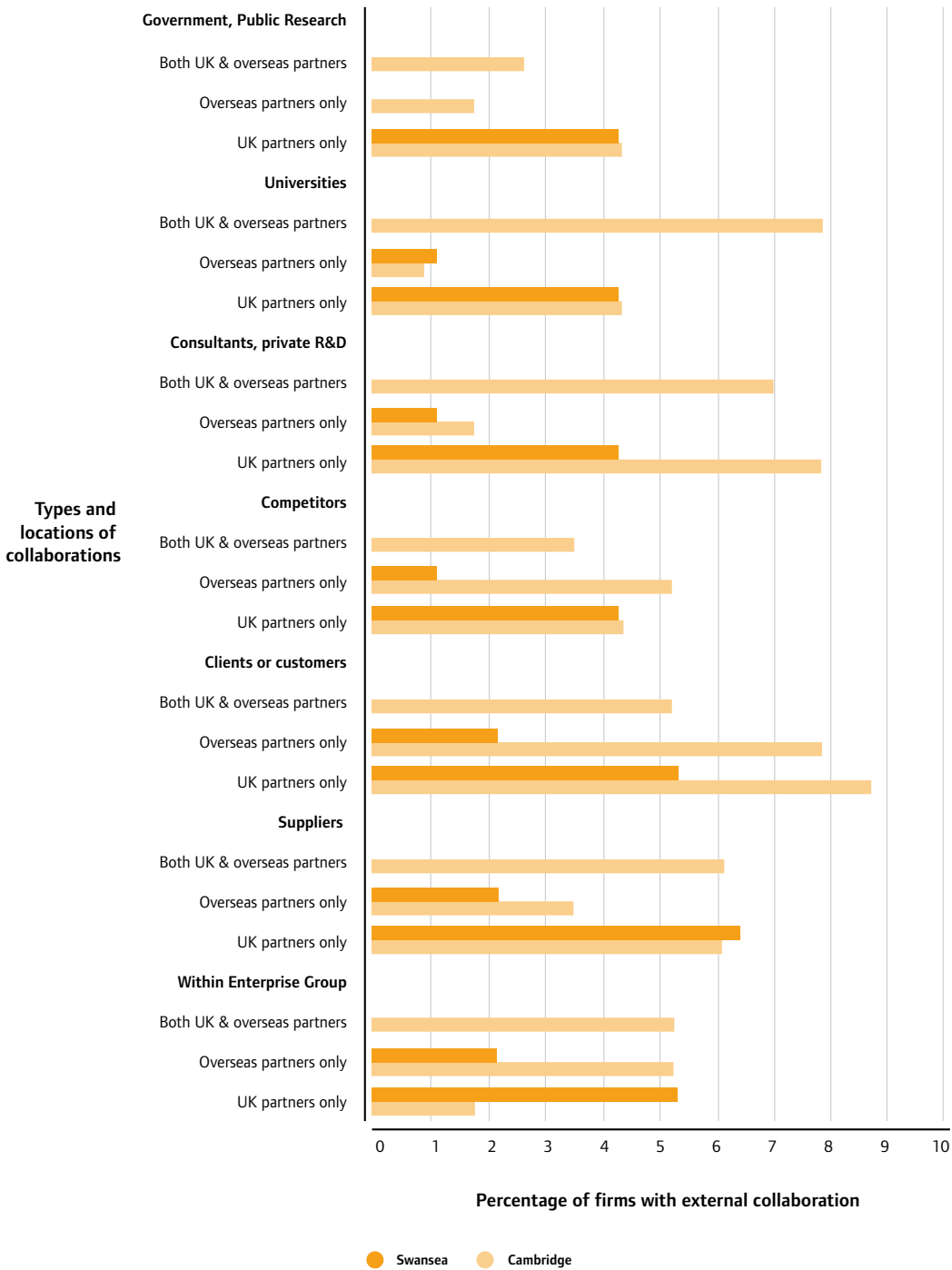
Knowledge acquisition and adoption

External knowledge networks are key to external knowledge identification and absorption. We have seen that an estimated 96.5 per cent of OECD new research knowledge is created outside the UK (AIM, 2008). This makes international knowledge networks particularly significant in bringing in new ideas and knowledge to particular localities.

CIS4 data show that Cambridge firms are generally much more integrated into various networks (government partners, universities, consultants, customers and suppliers) than Swansea firms (Figure 31). Particularly striking is the extent to which Cambridge far outstrips Swansea on almost every type of network, indicating that its firms have much more extensive and intensive relationships with other firms and bodies – and potential access to much richer sets of external knowledge.

"It may be that some Cambridge high-tech firms have relationships with other local firms, and might collaborate in some way with them. But my impression is that for most, like us, the customer base is national and even more importantly international, so links outside Cambridge are the key ones. Our fastest growing market is the Far East and China, so that is where we look for relationships with customers and manufacturers. Global relationships matter much more than local ones. To survive you have to think globally." [Interview CAMB002]

Figure 31: Networks of external collaboration CIS4 2002-2004

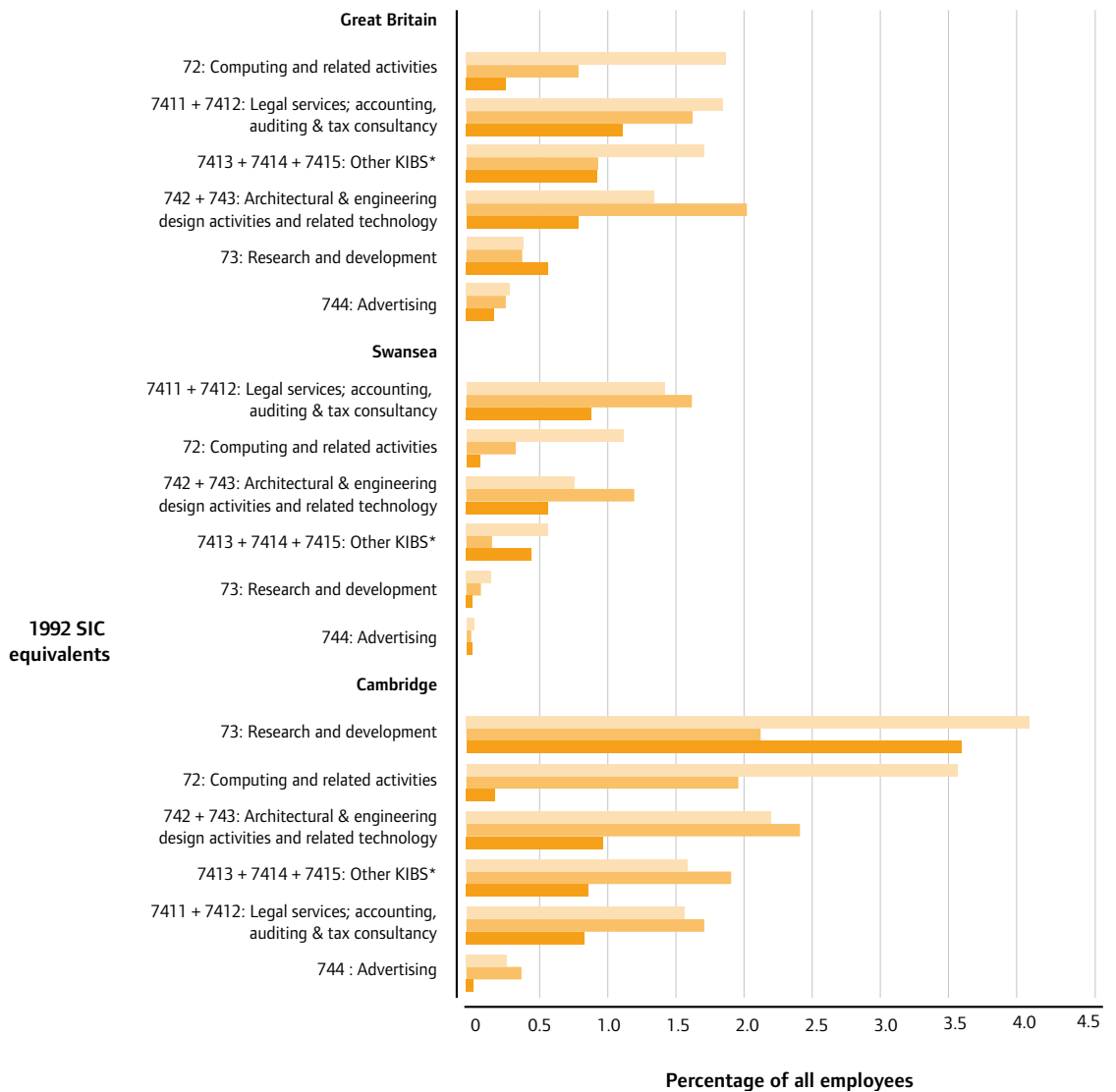


“We monitor what is going on in all of our potential markets. Much of our business comes from the US. So we have recently set up an office in Cambridge, Massachusetts. The people there will be better placed to know what US customers want, to collaborate with them, and push that aspect of our growth strategy. Setting up that office there will allow us to better gain

knowledge from that market, and about our competitors there.” [Interview CAMB003]

In Swansea the importance of overseas networks is recognised by respondents as being critical for knowledge identification and absorption. Through the Technium programme, a number of international networks have been set up, for example, linking with science parks in China, South Korea and the US. However,

Figure 32: Cambridge and Swansea narrowly defined KIBS employment 1981-2005



* 1981 figures for 'Other KIBS' are NOT directly comparable with the 1991 & 2005 figures, as it is not possible to produce an exact match of activities between the 1980 and 1992 SIC (the 1981 figures include a wider set of activities than is counted in 1991 & 2005).

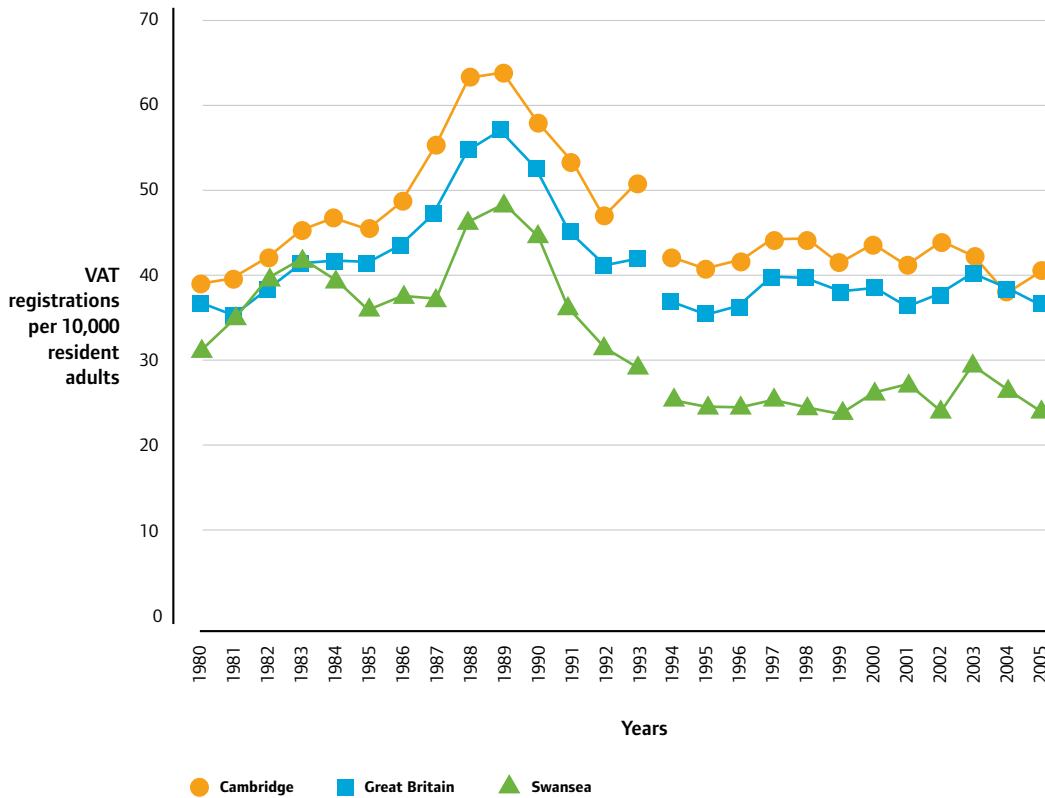
beyond these formal networks, individual firms are said to be constrained in developing their own networks by time constraints normal in start-up companies. The Welsh Assembly Government funds a number of programmes to encourage collaboration, although not everyone agrees that they help knowledge adoption. One company cites a government-supported programme that funds international visits in collaboration with British embassies, of which that particular company had made full use to help set up foreign markets and distributors. However, another respondent gives the example of government funding which encourages firms to collaborate within Wales with other companies and universities,

but does not fund collaboration outside Wales. External knowledge networks beyond Wales are therefore not being actively encouraged through this type of funding mechanism, which is likely to be hampering new knowledge adoption.

Knowledge commercialisation

A key aspect of innovation is the commercialisation of new knowledge: what matters is turning patents into commercial products and services. Knowledge-intensive business services (KIBS) can provide important external expertise for this. Here again Cambridge leads Swansea. Cambridge outperforms the British average in half of

Figure 33: Cambridge and Swansea VAT registrations per 10,000 resident adults 1980-2005



the KIBS sectors and is particularly strong in R&D and ‘computing and related services’, whereas Swansea underperforms in all detailed sectors, and is particularly weak in R&D and advertising.

Interestingly, despite its image as a place of ‘blue-sky’ scientific research, the importance of commercialisation of ideas is stressed by most Cambridge firms.

“At the end of the day, it’s bringing ideas to the market that counts. Companies don’t make money just doing ‘blue-sky’ research. It’s having ideas that can be turned into profitable products that matters. That’s why we work closely with customer firms and manufacturers. They know we can develop and apply advanced and cutting edge technology to make a product idea into a marketable product. That’s where, for us anyway, the technological challenge comes from. That’s what our people are trained to do.” [Interview CAMB003]

In such firms, managerial and marketing expertise is vital, since the general view is that scientists are not always very good at commercialising their ideas.

Although the data does not suggest that Swansea is strong in KIBS, respondents say that local legal and accounting services are of a high standard. For example, a large firm of lawyers located near the Technium buildings specialises in technology expertise, which can serve its companies. Successful commercialisation also depends on identifying markets for new products and services. There are examples of companies in Swansea that have a global outlook on markets, and have commercialised their products accordingly:

“We could not have started this company if we couldn’t have aspired for it to be a global company right from the beginning, because the critical mass in the UK alone was never going to be enough to support the several millions that were spent in development.” [Interview SW002]

New path creation

As we saw in Part 1, technological-industrial evolution can be of two main kinds: path dependent evolution along a given technological-industrial trajectory; and the creation of new paths and new trajectories. New path creation is most readily identified with the introduction of radical

new technologies, products or processes, such as gene mapping and manipulation. How such radical new paths emerge is a vastly under-researched issue. It may follow major breakthroughs in research and ideas from universities, competition and external knowledge sources. There is much debate about whether their emergence is accidental or deliberate (such as a planned break from existing technological paths). A further issue is why radical innovations occur in some places and not others? Our comparisons between Cambridge and Swansea highlight the importance of local history, local conditions and a local critical mass (an 'ecology') of innovative firms in influencing the pace and direction of innovation.

Some innovation occurs within existing firms. Other innovation occurs as a result of new firms being formed (such as spinouts from an existing firm, or from a university by a researcher or team of researchers). Cambridge appears to be a much more dynamic economy in terms of new enterprise formation than Swansea. In Cambridge, new firm formation has been consistently above the British average, whereas in Swansea since the mid 1980s it has been consistently below and the gap in firm density between the two cities has steadily grown (Figure 33).

In Cambridge, we know from Figure 19 that there have been successive waves of new firm formation, each associated with a new technological pathway in the local economy. Spinouts from existing companies have been an important factor in this growth. Cambridge Consultants alone can claim to have spun out more than 40 new firms. It sees this as a critical role within the Cambridge cluster, and perhaps one of its distinctive features. Many spinouts have tended to specialise in a particular technology, and have contributed to the development of both existing technologies and new technological paths. A few have been companies like Cambridge Consultants – fee-based research and technology providers for other firms and manufacturers. University spinouts, investments and start-ups only began in the late 1980s, and did not gather momentum until as recently as 2000. What both Figure 19 and Figure 27 on patents suggest is that successive new paths have been created in Cambridge, adding to the technological variety across the cluster. Whilst these paths may appear distinct, some commentators view them much more as comprising what in Part 1 we called 'related variety', sectors linked to a greater or lesser

extent by common types of knowledge and cognitive frameworks:

"Of course the different technological/ industrial sectors in the Cambridge cluster do different things – quite different things. But most involve advanced computing in one form or another, so there may be more commonality than you'd think. It's as if they all draw on – and thereby add to – Cambridge's fundamental expertise in advanced and applied computing techniques. I wouldn't want to push this too far, but there's something in it. After all, it was in computing that the Cambridge cluster really started – and the Cambridge Computing Laboratory played no small part in this – and advanced computing and software development plays a key part in many of today's firms in the cluster."
[Interview CAMB001]

Whereas in Cambridge, there was no legacy of old industrial paths, in Swansea the problem has been the limited scale of new path creation, compared to the losses experienced with the decline of the old paths. A lot of hope seems pinned on the role that the university could play in helping to initiate new pathways of innovative development.

"You can spin-off from there – that's the engine." [Interview SW004]

It was also recognised that the Technia could be an important catalyst for start-ups in Swansea, but the scale of new firm formation to date has been too limited either to replace firm closures or to show up in the data. No specific clusters of new firms in identified sectors particularly stand out in Swansea:

"To be honest, it's kind of all over the place. You could probably say ICT and software are the biggest ones. [...] It really is quite diverse." [Interview SW003]

One ICT company cited is Vishay Siliconix, which recently opened an R&D facility at the Digital Technium at the university in 2004. With headquarters in Silicon Valley, they chose Swansea as the location for their new design centre due to its proximity to the expertise and specialist graduates at the university. The company will generate intellectual property in the city. Another new pathway, still in its infancy, is Life Sciences, with the Institute of Life Sciences opened at the university in June 2007. In partnership with IBM, which provided a supercomputer for the Institute (Blue C), they

undertake ground-breaking medical research, focusing on building commercial-academic links. However, these appear to be isolated examples of new path creation and firm formation, and as one respondent comments:

“There are examples like that, but I think in terms of ‘significance’ they are probably fewer and far between than we would like, if we’re honest, and we could do with another dozen of those. And then I think we’d be starting to motor a bit.” [Interview SW005]

The limited new firm formation in Swansea is explained by some respondents as a result of the historical dominance of traditional industries in Wales, where an entrepreneurial culture has not been present. The ‘job for life’ system which operated for generations in Wales, primarily through the coal and steel industries, has meant that the spirit of entrepreneurship has not been fostered in local communities, thus leading to below average rates of new firm formation.

“You come back to path dependency, we’ve locked into the thinking “South Wales, we aren’t innovative. Innovation takes place elsewhere, it doesn’t take place in Wales”, so I think there’s that Welsh mentality of also downplaying our achievements. The university’s quite good at that. We do very good things, but we’re in Swansea, so we’re not in London, in Cambridge, we’re outlying in the UK.” [Interview SW003]

It is also felt in Swansea that new spinout firms from the university are being hampered by the burden of academic expectations and institutional bureaucracy.

“I think the problem is, I don’t know if it’s just my perception, but universities are particularly bad at that, certainly on the spinout side. I forget how many companies Swansea University spins out, but it isn’t a great deal, when you consider the initiatives that they had within that. And I think one of the things they’re always told to do is create further links with the SME community in the area, and it’s the one thing that they never do because there’s no money in it.” [Interview SW005]

Another respondent, a venture capitalist and CEO of a high-tech start-up, comments on the difficulties he experienced when dealing with universities:

“There’s an awful lot of innovation in the university, but nothing gets out. And there was no commercial bridge, there was nothing filling that gap to the market place on innovation [...] and I found that is was very difficult to spin companies out of universities. [...] The process of spinning out was painful, and it was a turn off for investors, an absolute turn-off, and in the end, the stuff that we’ve done since then has been our own stuff. If someone’s trying to spin out of a university right now, I’m thinking “Do I really want to get involved?” Because this is going to be a nightmare.” [Interview SW002]

There are at least two examples of spin-ins to the university, where companies set up independently have approached the university, to see if they would like to collaborate. However, it is not clear how common this phenomenon is.

3.5 Concluding remarks

These two contrasting case studies were chosen to illustrate in more detail the ideas expounded in Part 1 and the cross-city findings discussed in Part 2. Cambridge is one of the UK’s and Europe’s most innovative high-tech economies, with its origins in the early 1960s. Cambridge’s subsequent growth gained critical momentum in the 1970s, establishing a process of self-reinforcing path dependency. The initial contingent conditions – a lack of an old industrial past and attendant legacy together with the availability of ‘green-field’ sites, a world-class university and the presence of forward-looking enterprising individuals – all combined to drive the emergence and development of a new high-tech economy. Swansea experienced the opposite trajectory. A city encumbered with declining old industries, a less famous university and a general lack of an individualist entrepreneurial culture, has struggled to reconfigure its past into an innovative high-tech future. Efforts are being made in this direction, but the ‘initial conditions’ have been much less propitious than in Cambridge.

What Cambridge also illustrates is the way that technological trajectories, once established, exhibit tendencies towards path dependence: that is, they also inherit the legacy of their own past. As each technological specialisation has emerged and become positively ‘locked in’, it has formed a pathway for cumulative

innovation. The Cambridge cluster was narrowly focused, in sectoral terms, in the early years. But successive new technological paths have been created, some drawing on pre-existing paths, and others entirely new. The whole process has fostered – and been fuelled by – the co-evolution of a highly entrepreneurial environment, an increasingly positive involvement by the university and a raft of institutions and supporting knowledge-intensive services (such as venture capital organisations) which also make up the Cambridge cluster. In short, a host of external economies of localisation have helped provide the cluster with continued momentum.

Swansea illustrates only too clearly how difficult it is to escape the past, to shed the legacy of an old locked-in economy. But even here, one wonders why it is proving so difficult to forge a new pathway of development? Evidence from other old industrial cities in Europe and the USA suggests that escape is possible. In Part 1 we identified a number of ways such places can reconfigure their economies. In some cases it has proved possible to draw on the skills, specialisms and technologies inherited from the past and upgrade and reorient them towards new, more technologically advanced but related industries and specialisms. In other cases, foreign firms have brought in new technology and new industry that has become the centre of gravity of a new phase of innovative development. It is widely recognised that there needs to be a step change in Swansea – and Wales more generally – and that one potentially successful way of doing that is to bring in new thinking and new companies. As one respondent puts it:

“These companies come into Technium, and they’re two men and a dog, and if they grow to five men and a dog, that’s good, but it would be great if I could find one in there that grows to 500 men and a dog, because I think it’s those step changes that we need.” [Interview SW001]

The challenge for this sort of strategy, of course, is to find the right sort of companies that will embed themselves locally and that will act as a magnet and a catalyst for innovation, entrepreneurship and new firm formation. Cambridge succeeds in attracting the research labs of multinational companies precisely because it already has a thriving high-tech economy. Starting the process from scratch is another matter. Swansea’s earlier attempt to attract foreign companies, in the form of electronics assembly plants, illustrates how

precarious or disappointing foreign investment can be. The city’s failure to develop an LCD and plasma-based television sector to replace its role as a production platform for the old CRT television shows how difficult it can be even to upgrade an existing path of industrial activity. Instead, Swansea has become the location for an expanding public sector, which whilst providing jobs, is not always a basis for innovative economic growth. Indeed, the dominance of the public sector in Swansea is seen by respondents as a hindrance to the growth of innovation and the private sector:

“We exist largely on the public sector, the indulgence of the public sector. And to break out of it, I come back again, we need something transformational.” [Interview SW004]

Having highlighted the success of Cambridge, however, it is also important to note that in the last three years, concern has emerged over the future growth of its high-tech cluster (Library House, 2007). There are several signs that its growth momentum has slowed: patent activity has eased noticeably, the number of new firms has dropped back, and there has been a slowdown in venture-backed investment.

“The ... analysis suggests a rather bleak picture for the Cambridge cluster. Overall the cluster is losing ground to its competitors, particularly London. At a sectoral level, the cluster is strong in stagnating areas such as life sciences but weak in emerging areas like Web, Mediatech and Clean Energy.” (Library House, 2007, p. 23)

There is, then, a debate as to whether Cambridge is missing the boat on Web-based and Media-based innovative activity (so-called soft innovative sectors) – and whether this matters. As the Library House Report acknowledges, London already had a head start in these activities, so it would be unrealistic for Cambridge also to be developing a leading role in this part of the ‘new economy’:

“...the failure of Cambridge to harness the growth of the Web and new media industries is likely the result of the fundamental natures of these new sectors than a specific defect in the development of the Cambridge cluster. London, simply because of its vast size, is far more likely to be a leader in soft innovation.” (Library House, 2007, p.24)

Others point to the high house prices (themselves a product of Cambridge's growth success), the problems with land availability and costs, planning barriers, and pronounced road congestion problems – as negative externalities that may be holding Cambridge back.

There is certainly some validity to these concerns, but the slowdown is by no means taking place across the board, and may have other causes:

“It could be that some firms are facing constraints and that they are losing momentum. But I don't think this is true for all high-tech firms in Cambridge. We are growing at about 15-20 per cent per annum, are about to extend our laboratory space, and have recently expanded in the USA. I know of other firms that are also showing strong growth. It is true that housing, transport and other infrastructural problems have got much worse, and local government and the planning process are a major headache, and these do need urgent action. But I would say that part of the problem – the slowdown that you refer to – could be as much the lack of managerial expertise in Cambridge and the fact the cluster still depends on just a few – the same few – movers and shakers. It's unfair to expect these same people to repeatedly maintain high levels of entrepreneurship and enterprise all the time. Perhaps the key challenge for the cluster is to find more people like them to widen the gene-pool of serial entrepreneurial talent.” [Interview CAMB003]

And it may be that Cambridge has not missed the clean-tech or clean energy wave of innovation. Though the number of such firms in Cambridge is small, it is nevertheless one of the UK's most identifiable clean-tech clusters. This illustrates one of the classic aspects of path creation and path dependence. In the very early stages of a new technology or industry, a number of alternative locations may be equally well placed to develop it – the 'window of locational opportunity' (to use the jargon) is open. But as that sector develops, it is likely to concentrate in some locations, according to the specific technological requirements of the sector and the different specialisms and capabilities of different locations. It remains to be seen whether the hard technologies of the Cambridge cluster can be harnessed towards clean-tech applications.

Part 4: Why do cities differ in innovative performance? Conclusions and some lessons for policy

4.1 Introduction

In this chapter we draw together our findings and interpret them in the light of our initial theoretical approach. We link those findings to the concept of path dependence and the contributions of absorptive capacity and local innovation systems to the creation of new pathways in city-regional economies and the determination of the trajectories that they follow subsequently. In doing this we note the methodological difficulties involved in analysing some elements of the conceptual framework using the available time series datasets that only span a period of around 25 years, when some urban industrial legacies go back over many decades.

4.2 Knowledge, absorptive capacity and local innovation systems

We have argued that knowledge assets and the creation of new knowledge are critical driving forces underlying both the creation of new pathways and the subsequent parameters determining the trajectories that they follow. In particular, the historical development of the aggregate capacities of urban economies to identify, assimilate and exploit knowledge (their absorptive capacity) determines the range of possibilities for their immediate future development. Those possibilities that they explore are controlled by their systemic abilities to make use of these assets to generate or adopt new knowledge and to translate it into commercial products and services (their local innovation systems).

Our evidence on technological lock-in as a source of path dependence is that it can

sometimes lead to decline or to reluctance to adopt new pathways. In Swansea, for example, there have been two major waves of growth and decline as a result of technological lock-in. The local economy was once based on the extractive industries mining coal, iron, copper, tin and zinc. At its peak, Swansea was producing 60 per cent of the world's copper requirements. But a combination of declining natural resources and a failure to break out of and diversify its longstanding mining technologies led to the closure of most of these industries by the 1960s and 1970s. This lesson had not been learned when the second wave of growth developed on the basis of foreign investment in electronics. The technologies used in the production of cathode ray tubes (CRTs) and video cassette recorders (VCRs) were quickly rendered obsolete by the new technologies of plasma and liquid crystal display (LCD) screens and digital recording devices such as DVD recorders. In both cases, the local economy remained locked-in to technologies that were overtaken either by the discovery and exploitation of alternative sources of natural resources or by the invention of replacement technologies. By the time the scale of these "gales of creative destruction" was recognised locally it was too late to do much about it.

Some respondents have suggested that even Cambridge may be subject to an element of technological lock-in. So, despite successive waves of development spanning related developments in IT, life-sciences, software, and biotechnology it can be argued that many of these new pathways are linked by similar cognitive frameworks in advanced computing. Despite this, there are emerging areas concerned with media applications of advanced computing, currently clustered in

London that the Cambridge economy has not yet developed.

With respect to institutions, we have argued that institutional inertia is one possible source of path dependence. By this we mean that if the pace of institutional change lags behind that of economic or other forms of change, this is likely to slow them down or arrest their modernisation. They are then more likely to maintain existing trajectories of development. Many of our private sector respondents in both Cambridge and Swansea criticise the slow pace of change in local institutions. Common complaints are that the universities are too slow in starting or reacting to new economic opportunities, public policy in a number of areas is well behind what is needed to exploit new markets, and that old working practices, such as the expectation of a job for life in the same company, are unrealistic in the face of contemporary international competition.

There are complex and cumulative relationships between the sectoral development pathways followed in individual cities, the resulting occupational and knowledge assets generated by their particular sectoral structures, their consequential abilities to generate new knowledge, and the development of new pathways. Thus, in cities like Swansea, the decline of its traditional extractive sectors left it with pools of unemployed labour with limited retraining potential. Yet a combination of foreign investment in electronics mass production branch plants and growing public sector employment provided new sources of work.

The historical development of this particular set of knowledge assets limits both the range of possibilities that may be explored for the future and the capabilities of the local innovation system. First, as with other cities like Middlesbrough and Wakefield, the development of knowledge-intensive sectors has been slower than elsewhere. Second, this has a knock-on effect on the quality of human capital with lower proportions of both knowledge-intensive occupations and those specifically engaged in R&D or university research in most of the subsequently least innovative city economies. Third, the combination of a few large private sector employers with a large public sector does not foster a culture of enterprise. Fourth, the local innovation system is then characterised by low patenting rates in all of the least innovative cities in our sample. Fifth, this is also accompanied by a lack of local investment

and venture capital markets. Finally, the commercialisation of new ideas is also limited by the low proportions of knowledge-intensive business services in most of the least innovative city economies in our sample, namely Norwich, Middlesbrough, Swansea, Wakefield and Newport.

The cumulative nature of the relationships between the historical development of particular sectoral structures, limited absorptive capacity and weak local innovation systems illustrates the conundrum confronting cities wishing to break out of relative decline. Without the creation of new sectors or the upgrading of old ones it has proved difficult to generate the kinds of knowledge assets or local innovation systems necessary to compete in international knowledge-intensive markets. But, without the presence of adequate absorptive capacity and a dynamic innovation system, it is difficult either to create new pathways or to upgrade old ones. Thus, the problem of creating critical momentum in such economies is constrained both by the limited possibilities created by their previous historical development pathways and by the extent to which the parameters set by their previous histories control the range of practical decisions that can be taken today.

In contrast with all of the least innovative cities in our sample, most of the more innovative urban economies had very little industrial history even by as late as the 1960s. The Industrial Revolution had not touched Aldershot, Cambridge, Oxford and Reading. Subsequent industrial developments in the latter had been mainly limited to motor cars, biscuits and seeds. Northampton and Warrington were medium sized towns before their designation in 1968 for expansion as 'Partnership New Towns'. In this sense the possibilities for the future were relatively unconstrained by sectoral development histories of the past. They also created new pathways in a number of different ways.

Oxford and Cambridge started from centuries of accumulated knowledge in their universities. But the new town expansions of Northampton and Warrington had limited histories of new knowledge creation. Despite this, all four have ended up in the top decile of innovative cities in the 2002-2004 CIS4. One phenomenon that at least three of them share is that institutional changes enabled them to take advantage of the knowledge-based economy. Thus the Mott Report, in 1969, influenced the institutional climate at Cambridge University in favour

of the subsequent construction of some 14 science parks and innovation centres. In Oxford the local governance institutions took a further 20 years to come round to support for the first science park there. The designation of Northampton and Warrington as 'Partnership New Towns' created an institutional framework one of whose main purposes was to enable modern economic development.

In all cases, these developments have taken some time to come to fruition. In Cambridge it took nearly 40 years from the formation of Cambridge Consultants in 1960 for its embryonic private sector knowledge activities to develop into a mainstay of the local economy. From the perspective of its local innovation system it has been the bringing to market of new ideas rather than blue-sky research at the university that has been the driving force of this change. Much the same can be said of Northampton and Warrington which took some 30 years since their designation in 1969 to create and develop their innovative private sector-based pathways.

In contrast with the less innovative cities in our sample, those that reached the top decile in CIS4 have generally benefited from the cumulative development of their critical momentum in terms of local absorptive capacity and innovation systems. On the basis of their sectoral development pathways, Aldershot, Cambridge, Oxford and Reading all developed consistently higher levels of knowledge-related employment than other cities. This was then reflected in higher rates of the generation of new knowledge in the form of patent applications and their ability to commercialise these new ideas as a result of there being more knowledge-intensive business services (KIBS) in those cities. In these cases a virtuous circle of development was established.

In Cambridge, the momentum of its private sector economy has been generated on the basis of five factors: the co-evolution of an entrepreneurial environment; the presence of venture capital; the positive attitude of the university; a raft of institutional changes; and a growing market demand for KIBS. These form a complex and interdependent innovation ecology. This is not a closed system. Cambridge along with Oxford, Warrington and Reading were also the most open economies in our sample. CIS4 data show that they had extensive external knowledge networks across the UK and international economies. Given that some 96.5 per cent of all new scientific research and knowledge in the OECD countries

is created outside the UK (AIM 2008) such openness is a critical source of new ideas for any local economy. Not only does it provide access to new specialised knowledge but also market intelligence and information on what competitors are doing.

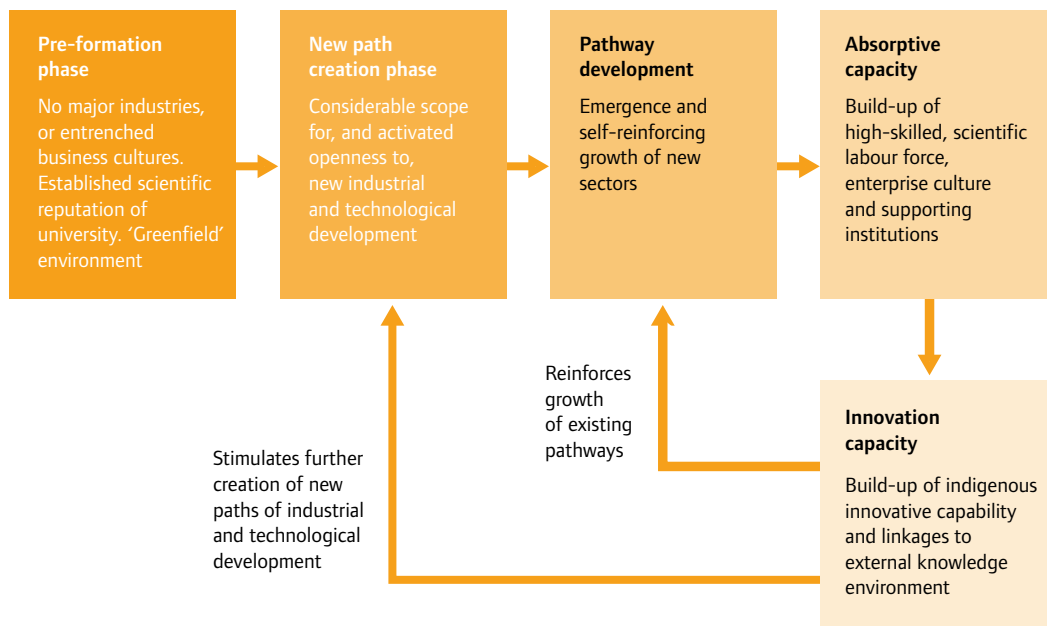
The combination of internal knowledge assets and innovation with national and international scanning for new knowledge and market opportunities marks a major difference between economies like Swansea and Cambridge. The development of an electronics industry in Swansea was hamstrung by its branch plant status and a lack of local knowledge about the technological developments taking place elsewhere in the international economy. These combined to limit the industry to a one product life-span.

In contrast, global relationships matter more in the private sector in Cambridge than local ones. Their ability to make local decisions, based on knowledge of best practice and world markets, has enabled the Cambridge economy to generate successive waves of knowledge-based developments after each preceding wave loses its original dynamism. Thus in the 35 years since 1973 when the first Sony electronics factory was opened at Bridgend, four new successive pathways of high-tech development have been started in Cambridge. While the electronics industry in Swansea has now run its course, there is now some momentum building behind a fifth Cambridge wave of development, in clean technologies.

4.3 Positive and negative path dependence: the cases of Cambridge and Swansea

Our case studies of Cambridge and Swansea suggest that we can distinguish between 'positive' and 'negative' path dependence in the evolution of urban economies. In Cambridge, the experience of the past 40 years has been one of a virtuous process of emergence and self-reinforcing growth of a successful innovative high-tech economy in which both industrial and technological development have continued to expand, whilst their success has stimulated the creation of yet further new paths. These have led to the progressive accumulation of a skill base, enterprise culture and institutional framework all conducive to continued innovative activity (see Figure 34).

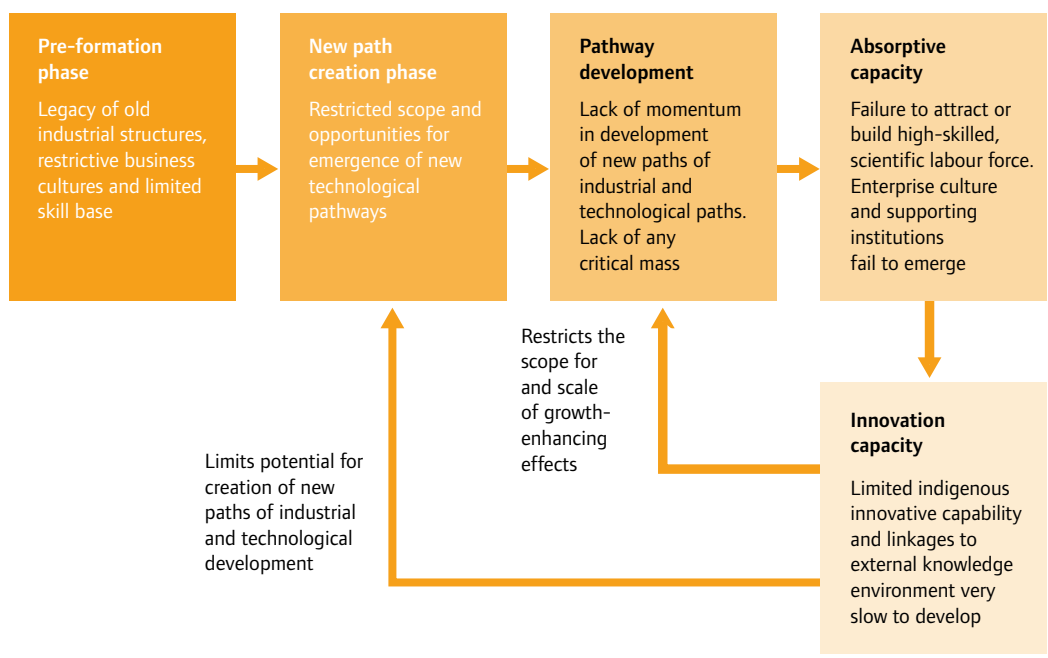
Figure 34: Stylised process of positive path dependent innovative development – the case of Cambridge



Swansea's urban economy has struggled to shed the legacies of its industrial past. The inheritance of the skills, business cultures and institutional structures of that past has not proved conducive to, and has restricted the scope for, the creation, emergence and development of new pathways of industrial and technological growth. The TV industry failed to generate the critical mass and innovative momentum to become a new pathway of

development. And more recent attempts to develop new innovative enterprises have thus far failed to take off. The upshot is that the absorptive capacity of the local economy is limited, and this in turn hinders the growth of its embryonic innovative paths and the emergence of other new ones. Compared to Cambridge, then, Swansea can be said to have been characterised over the past 40 years by 'negative' path dependence (see Figure 35).

Figure 35: Stylised process of negative path dependent innovative development – the case of Swansea



These two studies illustrate how quite different evolutionary paths can arise between urban economies. In large part, these paths reflect how local conditions and constraints inherited from earlier economic development can shape the scope and opportunities for future development – not in any deterministic way, but as a result of locally specific contingent conditions. To be sure, there are certain generic economic processes and mechanisms that come into play once activated by favourable local circumstances and conditions, but it is the locally contingent nature of the latter that is of critical importance, and this is where path dependence takes on a locally dependent nature (Martin and Sunley, 2006). This makes the issue of policy somewhat problematic.

4.4 Policy lessons

The broad policy lessons that we take from this analysis are that it is necessary to think large-scale and long-term as opposed to small-scale and short-term. Those were the only kinds of policy that we found that had a measurable impact either on individual firms or the aggregate figures for city economies. Furthermore, it is essential to build serious policy analysis into proposals from the start in order to ascertain what outcomes they generate on the ground.

In looking for possible policy lessons we adopt an explicitly evolutionary economic approach. This leads us to look for examples of public policy contributions to such phenomena as:

- Path breaking non-equilibrium long-term change.
- Internal (endogenous) sources of economic growth.
- Market opportunities.
- The co-evolution of non-economic factors with economic change.
- The emergence and adaptation of innovation ecologies through time.

Our first insight was that, particularly in leading areas like Cambridge, there is widespread scepticism among private sector firms about the relevance or efficacy of public policy on innovation. When asked to name any policy that had made a positive and measurable difference to their innovation

activities few could do so. Their development was largely based on the identification of market opportunities and organising to meet those demands. In lagging cities like Swansea, although few firms could identify any national or local public policies that had made a significant difference to their innovation performance, they all recognised the significance of the large-scale European Union cohesion funds. Few of the firms we interviewed in Swansea would have existed at all without the EU structural funds obtained as a result of the area's Objective 1 and transition fund status. Some will undoubtedly cease to exist when the transition funds run out in 2013.

Second, in contrast with the minimal impact of public policies targeted specifically at local innovation, several firms noted significant effects arising from other kinds of policy. There was, for example, some criticism of local land use planning as being too slow, bureaucratic and unimaginative in the planning of transport and communications infrastructure and in restrictions placed on the physical development of the new knowledge-based economy. On the other hand, the large-scale town expansion schemes at both Northampton and Warrington proved to be very successful at generating innovations and creating new industrial pathways. Thus, while the plans were developed in the late 1960s and early 1970s, they have taken several decades for their current characteristics to evolve and emerge (Source: Universities' own records).

Third, it is also important to note that the promotion of innovation in itself has not been one of the objectives of these town expansion schemes. Much of what they have achieved, however, has been based on the creation of an innovative set of institutional and cultural phenomena that positively encourage new economic growth and along with this, almost unintentionally, innovation. These findings point to the need for public policy to establish or encourage the co-evolution of institutional, cultural and economic change in local development trajectories. What is needed is a planning system dedicated to change and expansion, an entrepreneurial culture and a search for market opportunities. This needs to be combined with a well-educated workforce.

Fourth, the town expansion schemes in our sample cities also illustrate the need for large-scale policies combined with broad enabling objectives and the acceptance of considerable system redundancy, or the

opportunity to duplicate and experiment. Thus the town expansion plans were based on a broad set of objectives, none specifically targeted on innovation. The universities of Cambridge and Oxford are also large-scale institutions with multiple objectives out of which innovations sometimes emerge. In 2004 the approximate number of researchers needed to generate one spinout company from Cambridge University was 756 while in Oxford it was as high as 2,202. These figures indicate that it is important to tolerate considerable system redundancy within multiple objectives institutions like universities if wider outcomes such as innovation is to emerge.

Fifth, we also found the systemic and interrelated nature of local innovation systems was important in determining their relative abilities to generate and commercialise new knowledge. The combination of historic knowledge assets and research into new ideas could generate local markets for specialised services such as venture capital and KIBS. Where these developed simultaneously they could impart critical momentum to a city's development trajectory. We only have examples of this kind of momentum developing as a direct result of market demand, as in Cambridge. But, public policy should be used more effectively than it is now to create demand for innovation through public procurement in big spending activities like defence and health. They should be used to generate new market demand in lagging economies, though this would require a high degree of sophistication in the construction of policies designed to create market opportunities rather than to deal with 'market failures'.

Sixth, we also found that social ties with strong local social networks could be a barrier to starting and developing new ideas. In Swansea, for example, the strong local social networks embedded in generations of working in large industries with expectations of jobs for life effectively limited the search for new ideas from outside Wales. In contrast, some of the firms we interviewed in Cambridge claim that their global networks are more important to them than any local ones. In general it appears that the more open city systems that are connected with world-wide knowledge sources and collaborators usually possess greater innovative momentum than those that are more locally embedded. As a result, policies such as Welsh Assembly Government support for international visits and links with British embassies to enter new markets and establish distributors appeared to be more effective than

its efforts to encourage local Welsh business networks.

The need for international knowledge networks is paramount. Innovation is increasingly based on internationally distributed systems. The key city-regions are also increasingly marked by the development of systemic innovation involving sectors located in other key cities. In geographical terms this world of innovation is both spiky – with a number of key hubs – and connected. The most significant hubs include:

- USA – Silicon Valley, Seattle, Austin, Raleigh, Boston.
- Europe – Stockholm, Munich, Helsinki, and also Israel.
- India – Bangalore.
- Far East – Beijing, Singapore, Seoul, Shanghai, Taiwan, Tokyo.

British cities that aspire to join them must be internationally connected and develop specialised niches.

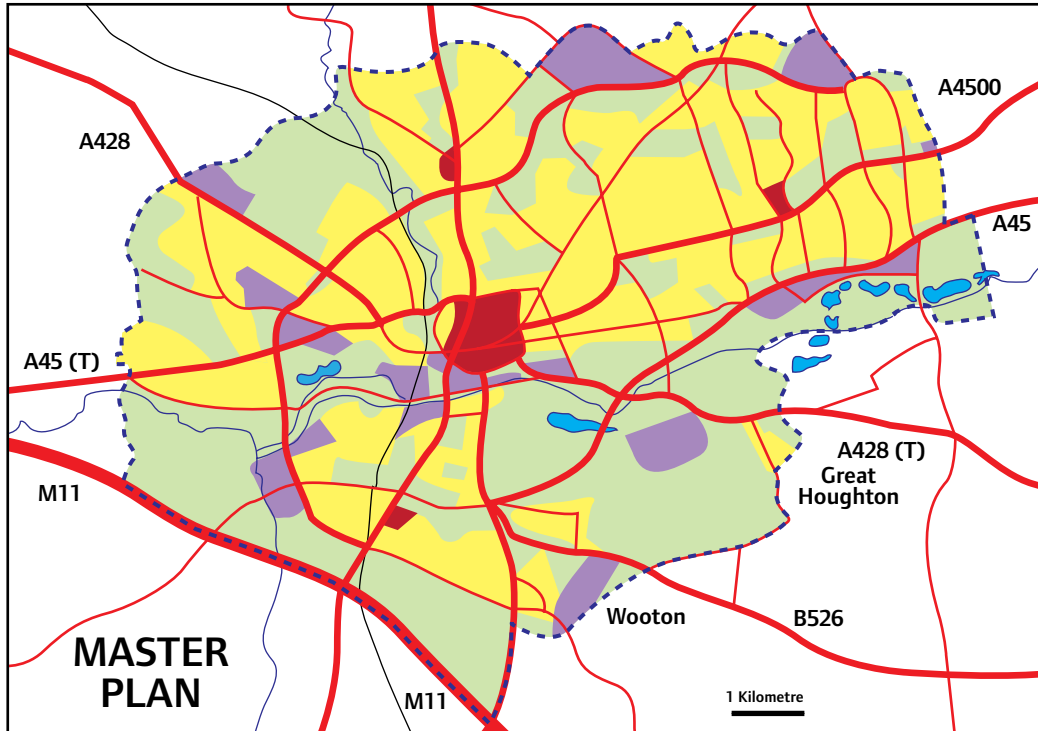
Seventh, in all the most innovative cities in our sample the historical development of their current successes took between 30 and 40 years. Public policies that played a role in their early years had not foreseen what emerged several decades later. Many of the complex outcomes of the interplay between early policy decisions and market forces arose not so much as a result of some guiding intelligence but more as an unpredictable emergence of the interplay of the activities of different interest groups. In this sense it appears that it would not have been possible some 40 years ago to have devised a suite of public policies that would have ensured today's outcomes. Public policies for innovation should therefore be broadly enabling, tolerant of system redundancy and sufficiently large-scale and long-term to adapt to change. They should enable continual radical and systemic innovations to evolve and emerge in ways that cannot be foreseen today.

















Finally, we argue that path dependence raises some difficult policy issues. For one, it suggests that the range of positive feedbacks (such as those from external networks) that promote path dependence offer policymakers 'windows' for policy intervention. Such interventions may involve the manipulation of private sector technology decisions by various means including taxes and subsidies, information

or technology transfer programmes, and deliberate university and government sponsored innovation schemes. But such windows of opportunity may be narrow, and are likely to be both locality-specific and long-term. Yet, the very same path dependence processes suggest that policy should endeavour to keep such 'windows' open to avoid lock-in to a restricted technological path.

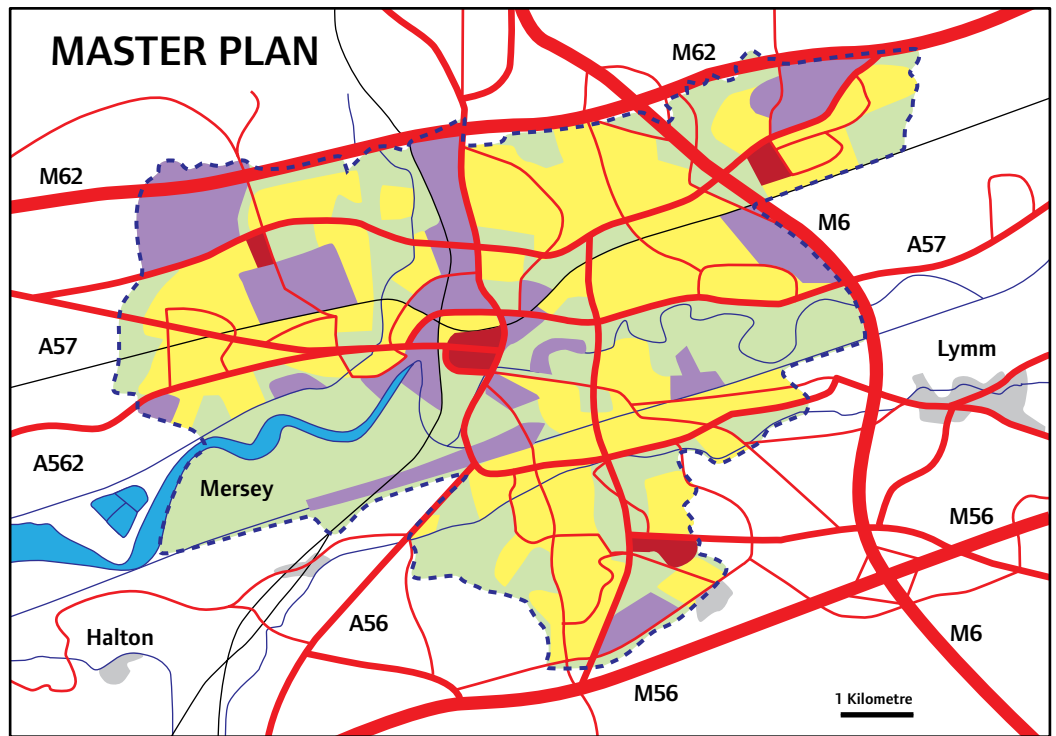
Appendix 1: Maps

















Map 3: Northampton Master Plan 1969



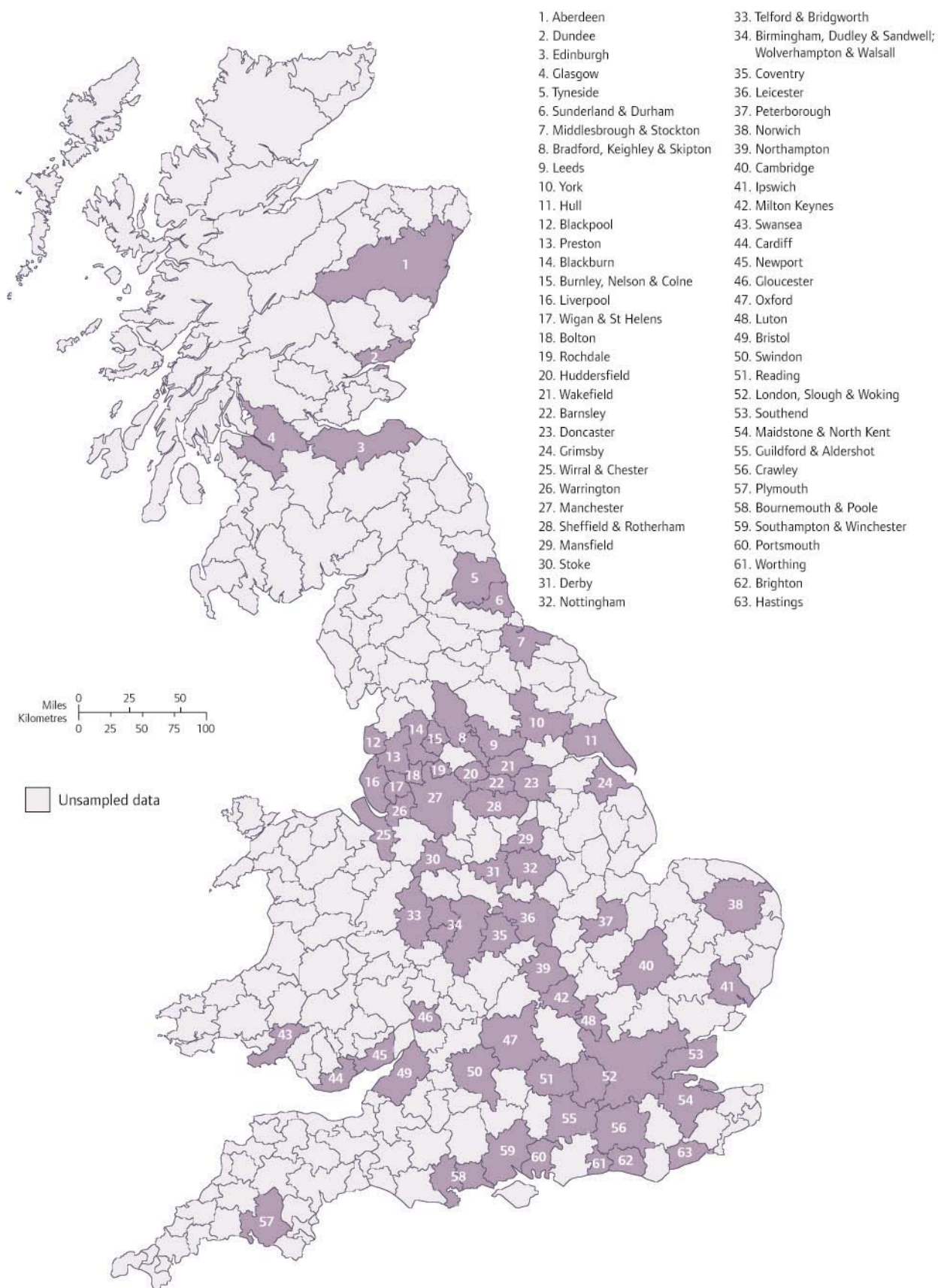
- | | |
|--|---|
|  Residential areas |  M11 Motorways |
|  Commercial areas |  A40 Main roads |
|  Industrial areas |  B526 Minor roads |
|  Designated park |  Railway |
|  Undeveloped areas |  Transit routes |
|  Lakes and rivers |  Transit stations |
|  Other urban areas |  Rivers |
|  Areas outside New Town |  New Town boundary |

Map 4: Warrington Master Plan 1972



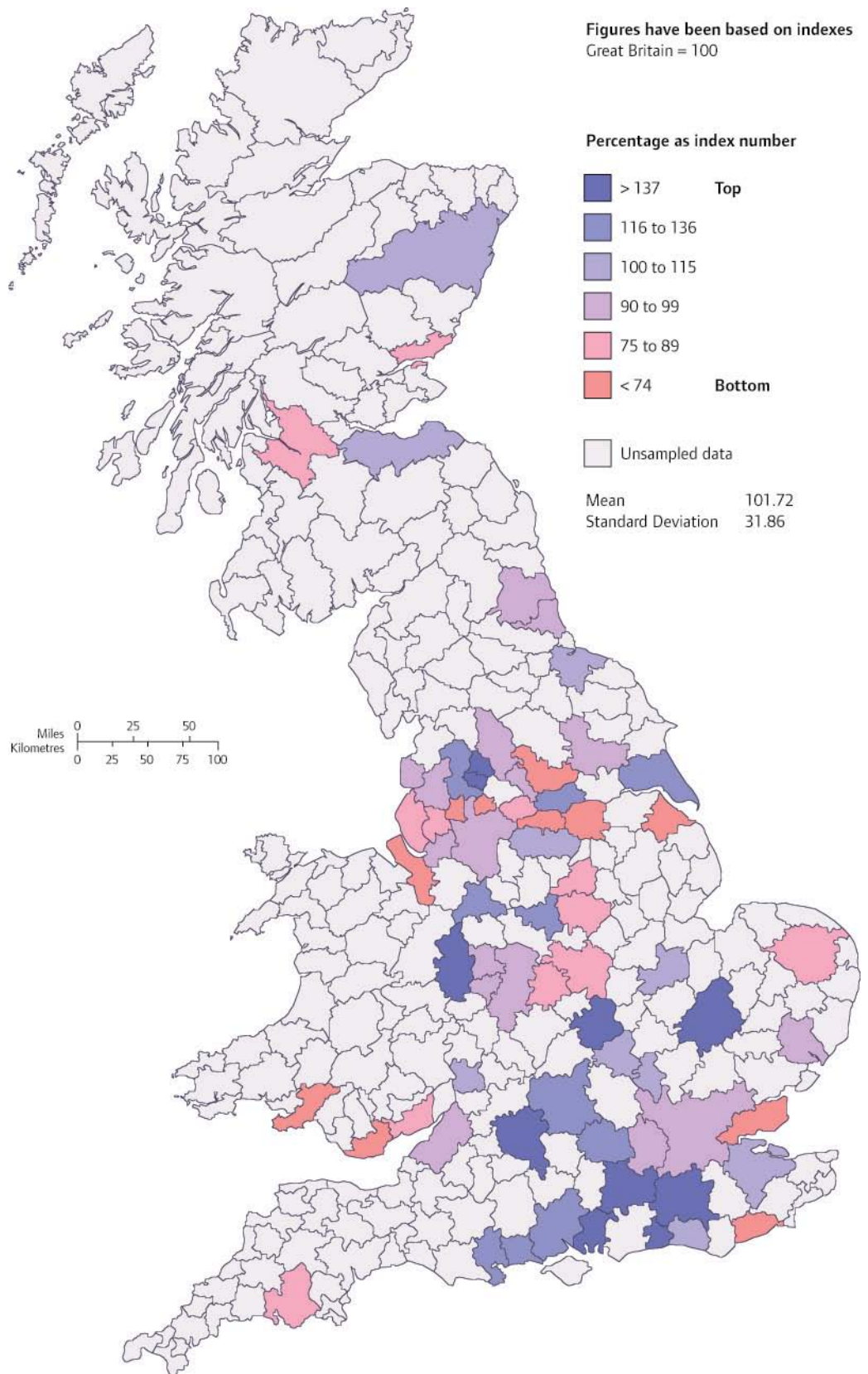
- | | | | |
|---|------------------------|---|-------------------|
|  | Residential areas |  | M11 Motorways |
|  | Commercial areas |  | A40 Main roads |
|  | Industrial areas |  | B526 Minor roads |
|  | Designated park |  | Railway |
|  | Undeveloped areas |  | Transit routes |
|  | Lakes and rivers |  | Transit stations |
|  | Other urban areas |  | Rivers |
|  | Areas outside New Town |  | New Town boundary |

Map 5: Travel-to-Work Areas with core populations > 125,000 in 2001



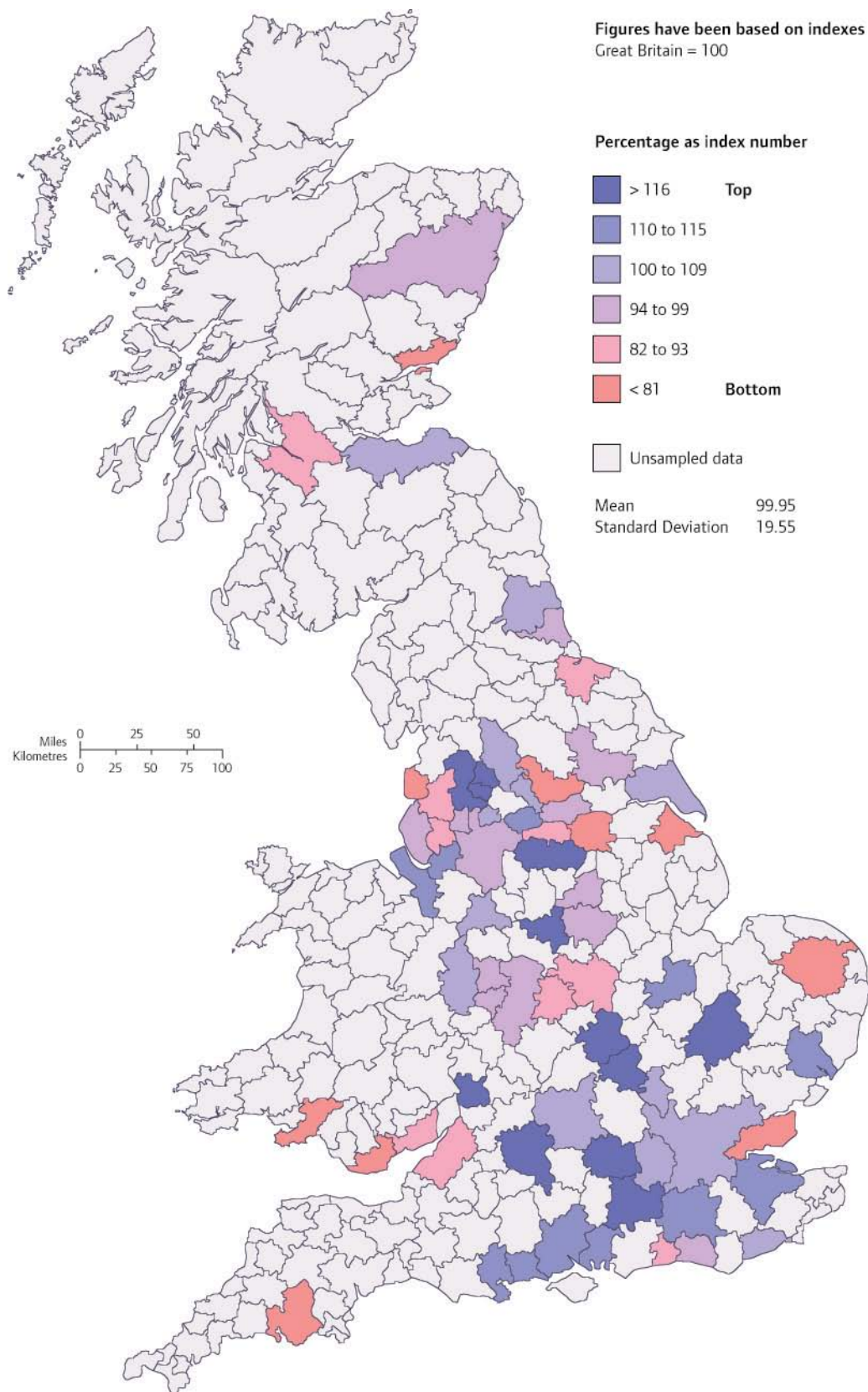
Source: Travel-to-Work Areas 1998. National Statistics.

Map 6: Analysis of innovation outcomes of novel products in GB cities CIS4, 2002-2004



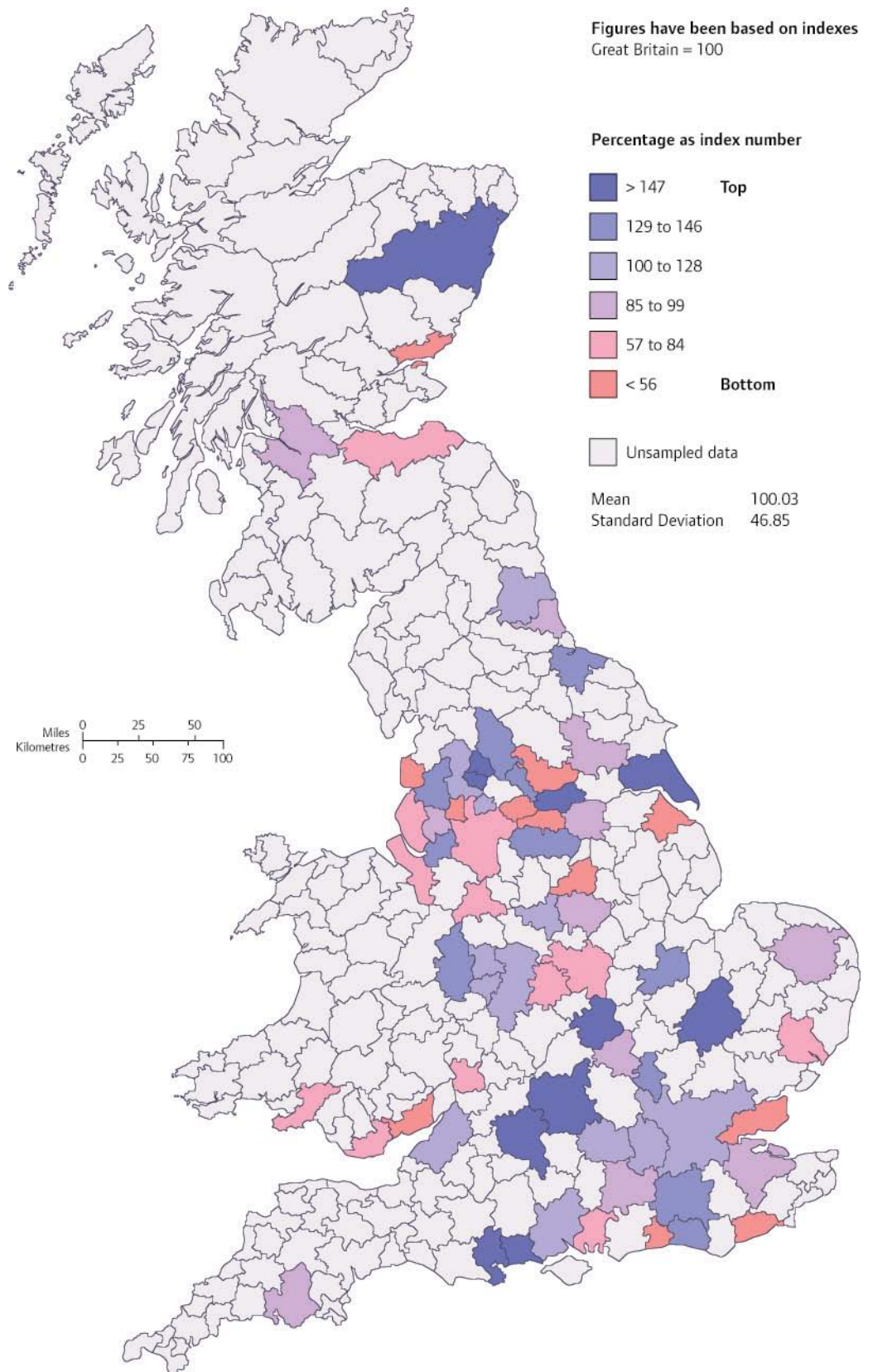
Source: Travel-to-Work Areas 1998. National Statistics.

Map 7: Analysis of innovation outcomes of new products in GB cities CIS4, 2002-2004



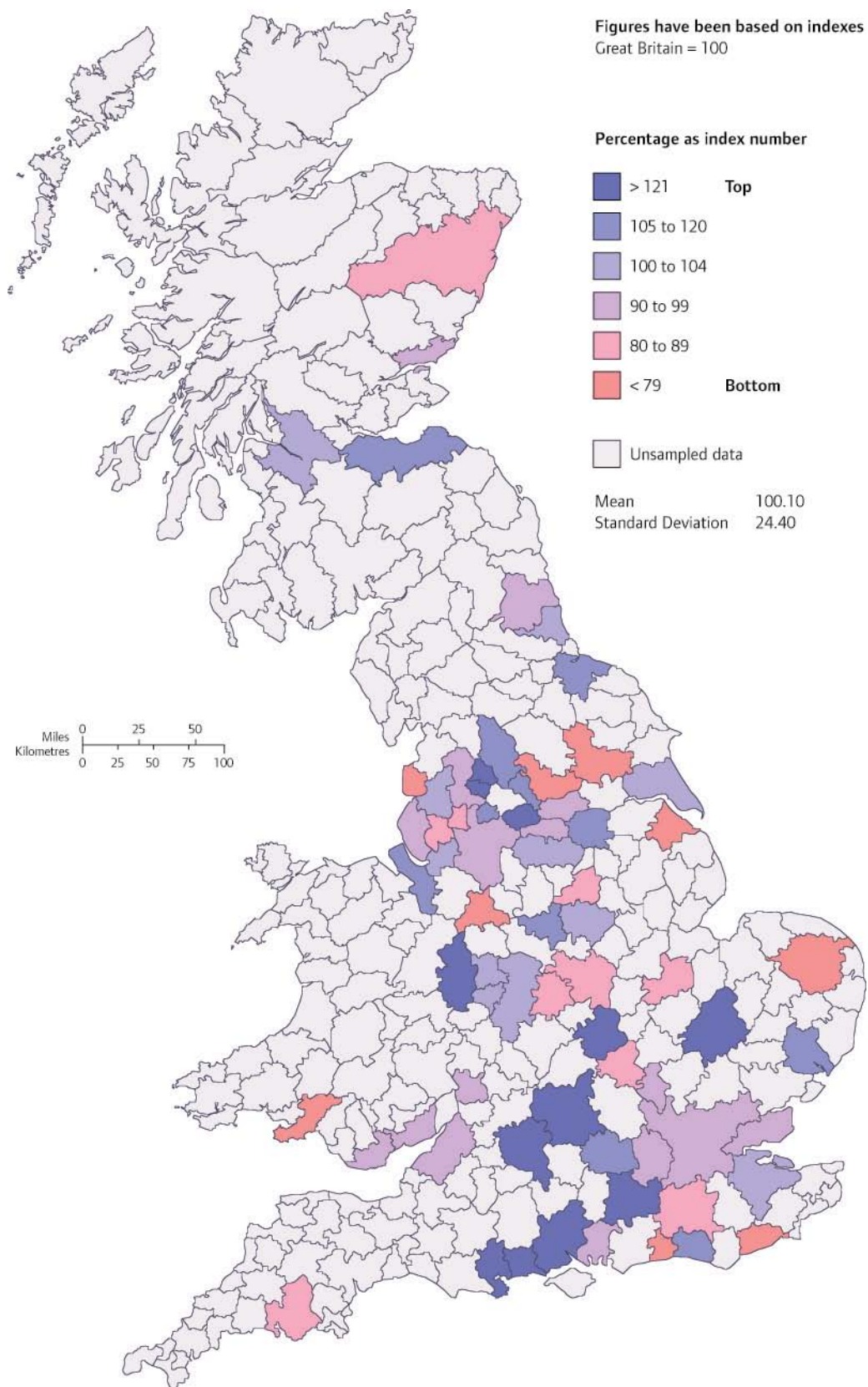
Source: Travel-to-Work Areas 1998. National Statistics.

Map 8: Analysis of innovation outcomes of novel processes in GB cities CIS4, 2002-2004



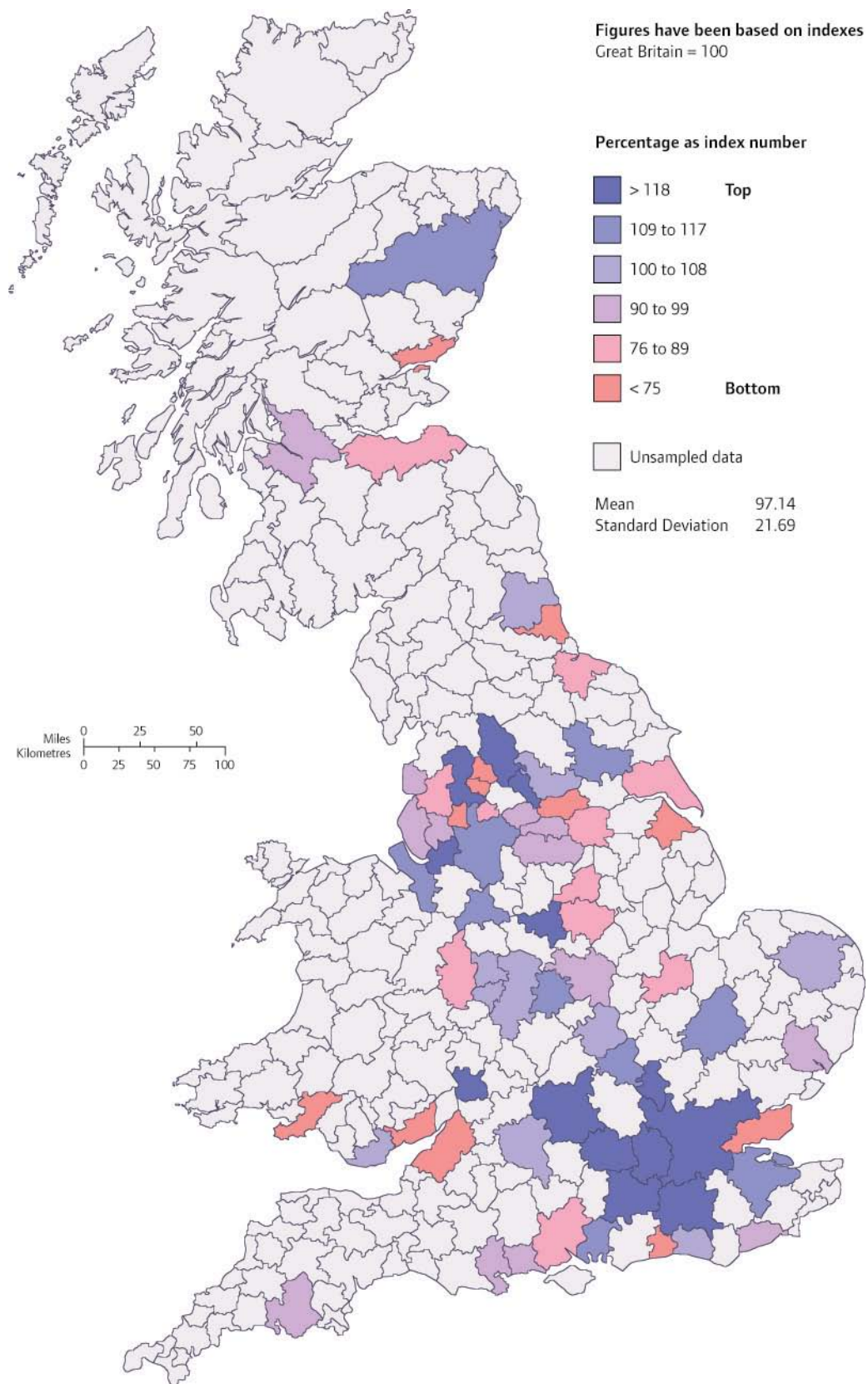
Source: Travel-to-Work Areas 1998. National Statistics.

Map 9: Analysis of innovation outcomes of new processes in GB cities CIS4, 2002-2004



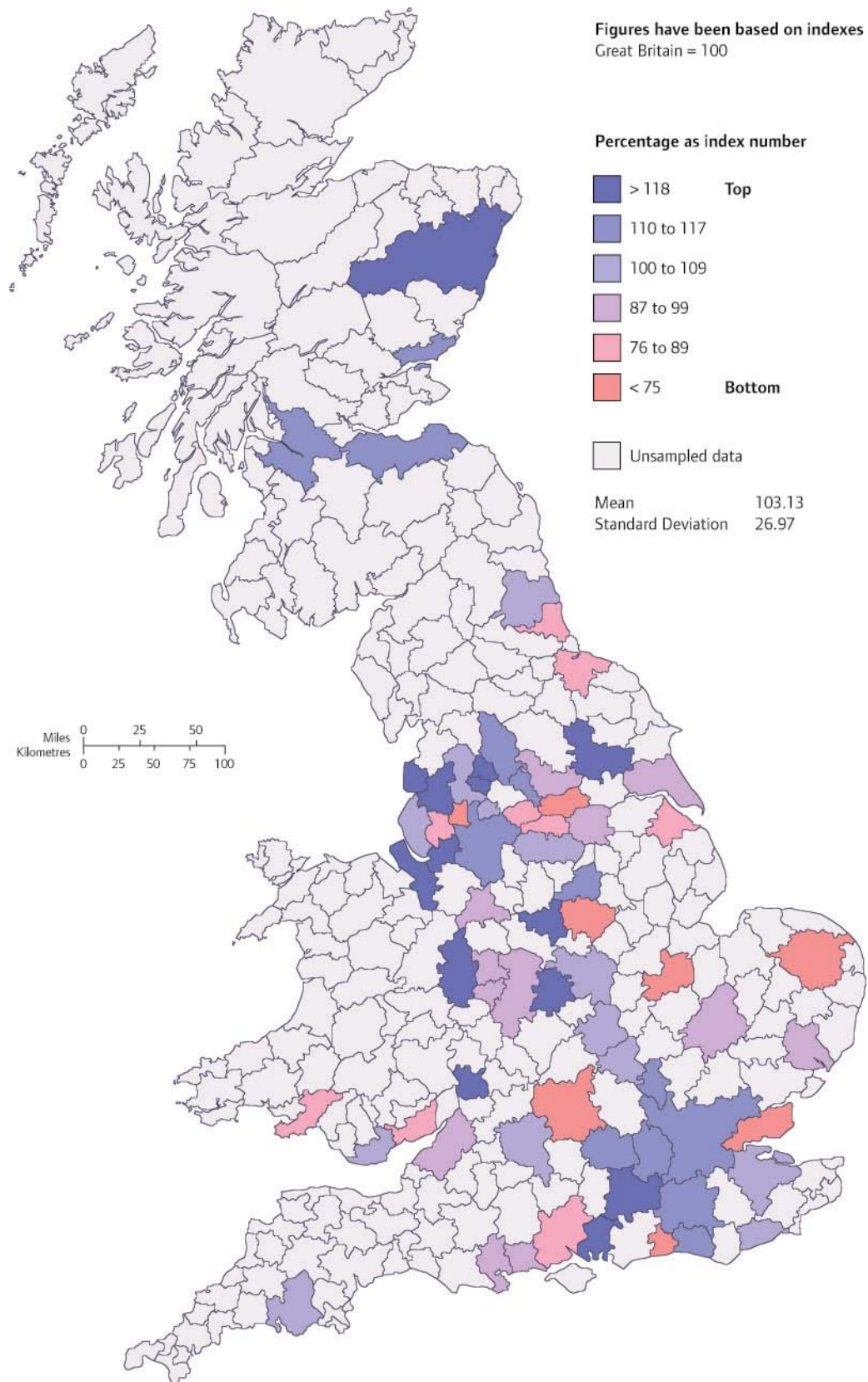
Source: Travel-to-Work Areas 1998. National Statistics.

Map 10: Analysis of innovation outcomes of new corporate strategy in GB cities CIS4, 2002-2004



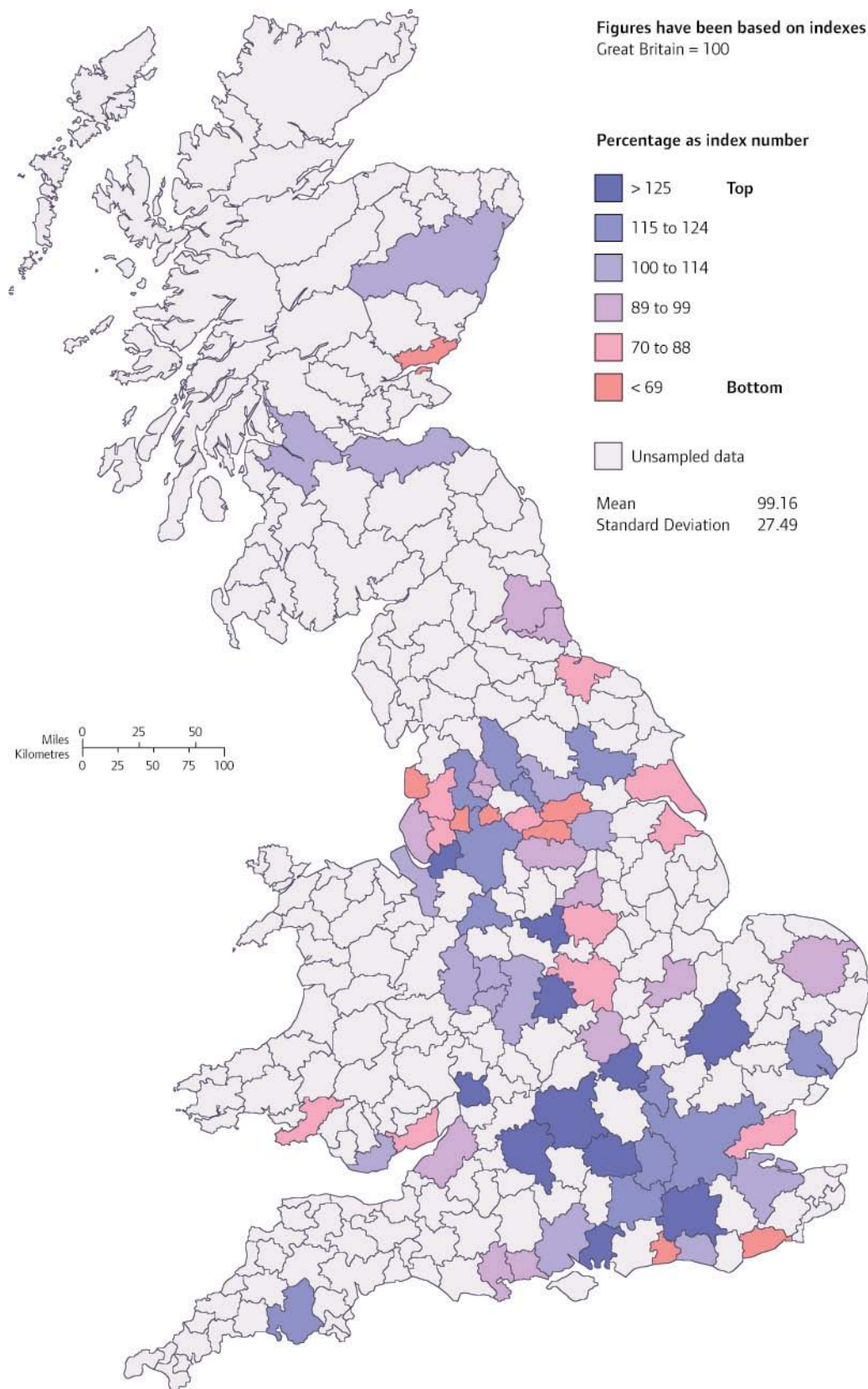
Source: Travel-to-Work Areas 1998. National Statistics.

Map 11: Analysis of innovation outcomes of advanced management techniques in GB cities CIS4, 2002-2004



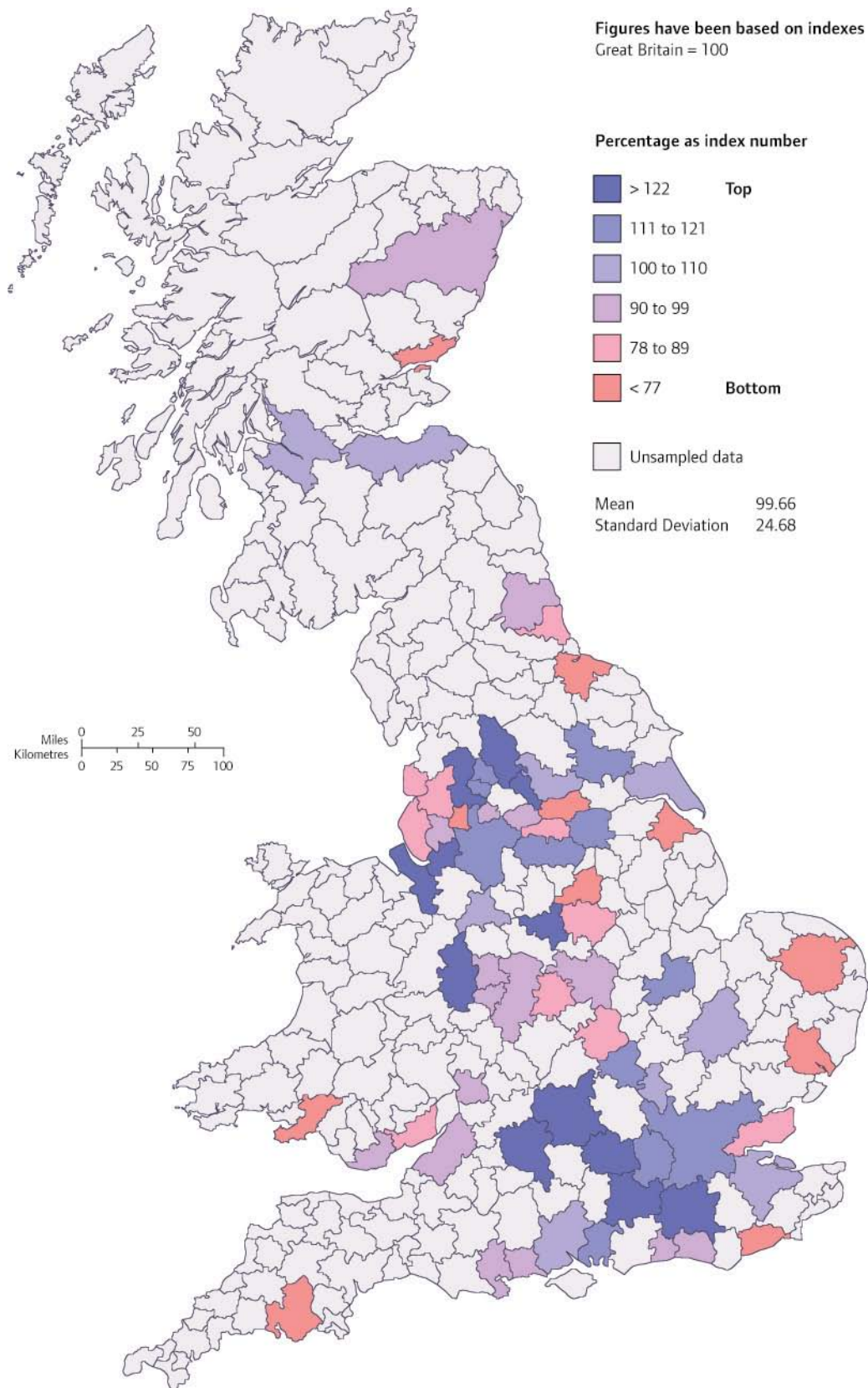
Source: Travel-to-Work Areas 1998. National Statistics.

Map 12: Analysis of innovation outcomes of changes to organisation structure in GB cities
CIS4, 2002-2004



Source: Travel-to-Work Areas 1998. National Statistics.

Map 13: Analysis of innovation outcomes of changes to marketing strategy in GB cities
CIS4, 2002-2004



Source: Travel-to-Work Areas 1998. National Statistics.

Appendix 2: Secondary data indicators

This Appendix provides further information on the range of secondary data indicators used in the study, including details of data sources, definitions and data limitations. The secondary data indicators have been used to provide evidence on absorptive capacity and innovation systems in each of the 12 case study city-regions. In addition, time series data has been used to explore the evidence for path dependent development and new path creation in these cities over the last 25 years (since the early 1980s). The indicators used in the study are listed in Table 1 below.

For each indicator, this Appendix provides the following details:

- Description of the indicator.
- Time series – the years for which data has been obtained. For most indicators, this is the economic trough years of 1981, 1991 and 2005. However, for some indicators a full time series of annual data has been obtained from 1980/1981 to 2005/2006.
- Data source – details of the data source or data provider.
- Geographic basis – a brief description of how data has been matched to city-region boundaries. For most indicators, data for local authority districts has been best-fit to 1998 TTWA boundaries.
- Definitions – details of sectoral and other definitions used, special analytical techniques, etc.
- Comments – a description of any important data limitations, e.g. due to discontinuities in time series data; poor geographic fit to city-regions; missing data, etc.

Table 4: List of secondary data indicators

Topic / Theme	Indicators / Secondary data
Path dependent development	
Development pathways	Location quotients
Structural change	Sectoral employment change
Differential effects	Shift share analysis
Other	Population Employment change GVA per capita Employment in tradable sectors Visible exports per capita
New path creation	
New path creation & new pathways	Firm births per capita Firm density per capita
Local innovation systems	
Knowledge creation	University 5* research departments Patent applications per capita Employment diversity index Employment diversity within sectors Employment in creative industries
Knowledge adoption	Innovation outcomes Geography of knowledge networks
Knowledge commercialisation	Firm deaths per capita Age of businesses Employment in KIBS sectors
Absorptive capacity	
Knowledge identification	Information sources for innovation Employment in R&D
Knowledge assimilation	Occupational breakdown of workforce Adult qualifications (degree level)
Knowledge exploitation	None

Indicators of path dependent development

Table 5: Location quotients – 2-Digit (1992 SIC)

Indicator	Location quotients for 2-digit sectors (1992 SIC).
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	Location quotient is the sector's share of city-region employment, expressed as a ratio of the sector's share of national (Great Britain) employment. A location quotient above 1.0 indicates a sector specialisation in the city-region, relative to the national average.
Comments	None.

Table 6: Location quotients – 3-Digit (1992 SIC)

Indicator	Location quotients for 3-digit sectors (1992 SIC).
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	See definition above for 2-digit sectors.
Comments	Location quotients for 1981 are missing for some 3-digit sectors; this is because it is not possible to obtain an exact match between the sectors used in the 1980 SIC and 1992 SIC.

Table 7: Sectoral employment change

Indicator	Employment change in 2-digit and 3-digit sectors (1992 SIC).
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS, 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	None.
Comments	Data for 1981 is missing for some 3-digit sectors; this is because it is not possible to obtain an exact match between the sectors used in the 1980 SIC and 1992 SIC.

Table 8: Shift share analysis

Indicator	Shift share analysis, based on employment change in 2-digit sectors (1992 SIC).
Time series	1974, 1981, 1991, 2005 (economic trough years).
Data source	ONS: 1974 & 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for 1991 & 2005 is for 1998 TTWAs; data for 1974 & 1981 is for 1984 TTWAs.
Definitions	<p>Shift share analysis is a technique used to identify the relative contributions of industry structure or mix versus other non-structural factors to overall employment change in a city-region.</p> <p>The analysis identifies two principal measures:</p> <p>1) Structural shift – this measures the structural influence on employment change, and reflects the mix of industries in the city-region.</p> <p>2) Differential shift (also referred to as the regional or competitive shift) – this measures the contribution to overall employment change due to each industry in the city-region growing at a faster or slower rate than its national growth rate. It removes structural effects, and allows examination of a residual element which includes non-structural influences such as policy. The differential shift provides a measure of the effect of the city-region’s competitiveness on employment change.</p>
Comments	There are some temporal and geographic discontinuities in the underlying employment data series, due to changes in industrial classifications and TTWA definitions. This means that it is not possible to carry out shift share analysis over the full 1974-2005 period; results for the shorter 1991-2005 period are not affected by these problems.

Table 9: Population

Indicator	Resident population in city-region.
Time series	1981 to 2006 (annual).
Data source	ONS, mid-year population estimates.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries.
Definitions	None.
Comments	None.

Table 10: Employment change

Indicator	Number of employees in employment.
Time series	1981, 1991 & 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	None.
Comments	Persons working on a self-employed basis are excluded from the figures.

Table 11: GVA per capita

Indicator	Gross value added (GVA) per capita at constant (2000) prices.
Time series	1980 to 2005 (annual).
Data source	Cambridge Econometrics, GVA estimates; plus ONS, mid-year population estimates.
Geographic basis	Data for NUTS3 areas is best-fit to 1998 TTWA boundaries.
Definitions	Figures are estimates of workplace-based GVA, in which the income of commuters is allocated to their place of work.
Comments	None.

Table 12: Employment in tradable sectors

Indicator	Percentage of city-region's employees in tradable sectors (as defined below).
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	Tradable sectors are defined as the following 1992 SIC sections: A, B & C (agriculture, forestry/fishing, mining & quarrying), D (manufacturing), J & K (financial, real estate & other business services).
Comments	None.

Table 13: Visible exports per capita

Indicator	Value of visible exports per capita (current prices).
Time series	1996 to 2002 (annual).
Data source	HMRC, discontinued sub-regional trade data series; plus ONS, mid-year population estimates.
Geographic basis	Varies, but mainly NUTS3 areas (although some NUTS2 areas), which are best-fit to 1998 TTWA boundaries.
Definitions	None.
Comments	Trade data for West Yorkshire is available only at NUTS2 level; separate figures for Leeds & Wakefield city-regions cannot therefore be derived.

Indicators of new path creation

Table 14: Firm births per capita

Indicator	Annual VAT registrations per 10,000 resident adults.
Time series	1980 to 2005 (annual).
Data source	Department for Business, Enterprise & Regulatory Reform (previously DTI), VAT registration statistics; plus ONS, mid-year population estimates.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1980-1993 data).
Definitions	None.
Comments	Trends in the numbers of VAT-registered enterprises are affected by changes in the VAT registration threshold. The threshold was increased by a significant (much higher than inflation) amount in 1991 and 1993.

Table 15: Firm density per capita

Indicator	VAT-registered enterprises per 10,000 resident adults.
Time series	1980 to 2006 (annual).
Data source	Department for Business, Enterprise & Regulatory Reform (previously DTI), VAT registration statistics; plus ONS, mid-year population estimates.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1980-1993 data).
Definitions	None.
Comments	Trends in the numbers of VAT-registered enterprises are affected by changes in the VAT registration threshold. The threshold was increased by a significant (much higher than inflation) amount in 1991 and 1993.

Indicators of new path creation

Table 16: University 5* Research Departments

Indicator	Number of 5* and 5-rated university departments.
Time series	1992, 1996 & 2001 (RAE years).
Data source	HEFCE, Research Assessment Exercise (RAE) results by institution and unit of assessment.
Geographic basis	Universities are allocated to 1998 TTWAs according to the location of their main campus.
Definitions	The highest grade in the 1996 & 2001 RAE was 5*; the highest grade in the 1992 RAE was 5.
Comments	Numbers are also expressed per 100,000 adult residents.

Table 17: Patent applications per capita

Indicator	Annual EPO patent applications per million resident population.
Time series	1977 to 2002 (annual); although data for some city-regions is missing for some of the earlier years.
Data source	Eurostat, Regio database; plus ONS, mid-year population estimates.
Geographic basis	Data for NUTS2 areas is best-fit to 1998 TTWA boundaries.
Definitions	Applications are broken down by IPC section and class.
Comments	NUTS2 areas do not provide a good geographic fit to 1998 TTWA (city-region) boundaries. In some cases, the NUTS2 area includes more than one city-region, and separate figures cannot therefore be obtained for these cities (e.g. Cambridge & Norwich; Leeds & Wakefield).

Table 18: Employment diversity index

Indicator	Herfindahl-Hirschman diversity index for the city-region's employment base.
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS, 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	<p>Herfindahl-Hirschman diversity index is calculated as the sum of the squared percentage employment shares of all 3-digit sectors of the 1992 SIC (except for 1981 which is based on the 1980 SIC at 3-digit level).</p> <p>Higher index values indicate a less sectorally diverse employment structure.</p> <p>The index can be standardised by multiplying the H-H index value by the number of sectors and dividing by 100; an equal distribution of employment across all sectors would then produce a standardised index value of 100.</p>
Comments	The 1981 index is not directly comparable with that for 1991 and 2005, due to the use of a different version of the SIC.

Table 19: Employment diversity within sectors

Indicator	Herfindahl-Hirschman diversity index, showing employment diversity at 3-digit level within 2-digit sectors (1992 SIC).
Time series	2005 only.
Data source	ONS, 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	<p>See definition of Herfindahl-Hirschman index above.</p> <p>Higher index values indicate less employment diversity within the 2-digit sector.</p> <p>To allow comparisons between 2-digit sectors, all index values are standardised by multiplying the H-H index value by the number of 3-digit sub-sectors and then dividing by 100. With an equal distribution of employment across all 3-digit sub-sectors, the standardised index value will be 100, regardless of the number of sub-sectors.</p>
Comments	None.

Table 20: Employment in creative industries

Indicator	Percentage of city-region's employees in creative industry sectors.
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	<p>The definition of creative industry sectors is based on that used by the Department for Culture, Media & Sport, although some variations are necessary in order to obtain comparable time series data back to 1981.</p> <p>For 1991 and 2005, the definition is based on the 1992 SIC and includes the following activity codes: 22 (publishing & printing), 72 (computer & related activities), 74.2 (architecture, engineering & related technical consultancy), 74.3 (technical testing & analysis), 74.4 (advertising), 74.81 (photographic activities), 92.1 (motion picture & video activities), 92.2 (radio & TV activities), 92.31 (artistic & literary creation), 92.32 (operation of arts facilities), 92.4 (news agency activities).</p> <p>For 1981, the definition is based on the 1980 SIC, and includes the following activity codes: 34.52 (gramophone records/pre-recorded tapes), 47.5 (printing/publishing), 49.3 (photographic processing), 83.7 (professional/technical services), 83.8 (advertising), 83.94 (computer services), 97.11 (film production, distribution/exhibition), 97.41 (radio/TV services, theatres, etc.), 97.6 (authors, composers/own account artists).</p>
Comments	There is a degree of overlap between the creative industries and KIBS sector definitions (see below); 1992 SIC codes 72, 74.2, 74.3 and 74.4 are included in both definitions.

Table 21: Innovation outcomes

Indicator	Percentage of firms introducing new or novel products; new or novel processes; and wider forms of innovation (i.e. new corporate strategy; advanced management techniques; changes to organisational structure; and changes to marketing strategy).
Time series	CIS4 survey covers innovation activities in 2002-2004.
Data source	DTI, UK Innovation Survey 2002-04 (CIS4) dataset.
Geographic basis	The CIS4 dataset uses the firm's postcode sector as a geographic reference; this is used to allocate firms to 1998 TTWAs.
Definitions	'New' products/processes are defined as products/processes new to the firm, but not necessarily new to the market or industry (significantly improved products/processes are also included in the definition). 'Novel' products/processes are defined as products/processes new to the firm's market or industry, i.e. introduced by the firm before its competitors.
Comments	None.

Table 22: Geography of knowledge networks

Indicator	Location of co-operation partners used by firms in their innovation activities (local/regional; UK national; other Europe; other countries).
Time series	CIS4 survey covers innovation activities in 2002-04.
Data source	DTI, UK Innovation Survey 2002-04 (CIS4) dataset; responses to questions 17 & 18 in CIS4 survey.
Geographic basis	The CIS4 dataset uses the firm's postcode sector as a geographic reference; this is used to allocate firms to 1998 TTWAs.
Definitions	Local/regional partners are defined as those within approximately 100 miles of the enterprise.
Comments	None.

Table 23: Firm deaths per capita

Indicator	Annual VAT de-registrations per 10,000 resident adults.
Time series	1980 to 2005 (annual).
Data source	Department for Enterprise, Business & Regulatory Reform (previously DTI), VAT statistics; plus ONS, mid-year population estimates.
Geographic basis	Data for local authority districts is best fit to 1998 TTWA boundaries (pre-1996 districts are used for 1980-1993 data).
Definitions	None.
Comments	Trends in the numbers of VAT-registered enterprises are affected by changes in the VAT registration threshold. The threshold was increased by a significant (much higher than inflation) amount in 1991 and 1993.

Table 24: Age of businesses

Indicator	Age of VAT-registered enterprises.
Time series	None; data is for March 2006.
Data source	ONS, Inter-Departmental Business Register (IDBR).
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries.
Definitions	The IDBR gives each enterprise a 'birth date' which is taken as the earliest registration for either VAT or PAYE.
Comments	None.

Table 25: Employment in KIBS sectors

Indicator	Percentage of city-region's employees in KIBS sectors.
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	<p>KIBS sectors are narrowly defined, using the definition adopted in Simmie & Strambach (2006).</p> <p>For 1991 and 2005, the definition is based on the 1992 SIC and includes the following activity codes: 72 (computer & related activities), 73 (R&D), 74.1 (legal services, accounting/auditing, market research, business & management consultancy, management of holdings), 74.2 (architecture, engineering & related technical consultancy), 74.3 (technical testing & analysis) and 74.4 (advertising).</p> <p>For 1981, the definition is based on the 1980 SIC, and includes the following activity codes: 83.5 (legal services), 83.6 (accounting/auditing), 83.7 (professional/technical services), 83.8 (advertising), 83.94 (computer services), 83.95 (other business services), 83.96 (central offices) and 94 (R&D).</p>
Comments	The figures for 1981 are not directly comparable with those for 1991 and 2005. This is because it is not possible to obtain an exact match between the sectors used in the 1980 SIC and 1992 SIC. The 1981 definition is slightly wider than that used for 1991 and 2005.

Indicators of absorptive capacity

Table 26: Information sources for innovation

Indicator	Importance of different sources of information used by firms in their innovation activities.
Time series	CIS4 survey covers innovation activities in 2002-2004.
Data source	DTI, UK Innovation Survey 2002-04 (CIS4) dataset; responses to Question 16 in CIS4 survey.
Geographic basis	The CIS4 dataset uses the firm's postcode sector as a geographic reference; this is used to allocate firms to 1998 TTWAs.
Definitions	None.
Comments	None.

Table 27: Employment in R&D

Indicator	Percentage of city-region's employees in R&D sector.
Time series	1981, 1991, 2005 (economic trough years).
Data source	ONS: 1981 Census of Employment; 1991 Annual Employment Survey; 2005 Annual Business Inquiry.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	R&D is 1992 SIC category 73 (for 1991 & 2005 data); and 1980 SIC category 94 (for 1981 data).
Comments	Reliability of AES/ABI data on R&D employment for certain cities appears to be affected by re-classification of employment, particularly between the R&D and higher education sectors; this is a particular problem with the R&D employment data for the Oxford city-region.

Table 28: Occupational breakdown of workforce

Indicator	Occupational breakdown of residents in employment.
Time series	1981, 1991, 2001.
Data source	ONS: 1981, 1991 & 2001 Census.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	Data for 1991 & 2001 is based on the Standard Occupation Classification (SOC 2000); data for 1981 is based on socio-economic groups.
Comments	Figures for 1981 are not fully comparable with those for 1991 & 2001, due to the use of a different occupation classification. However, it is possible to compare higher order occupations (i.e. managerial, professional and associate professional/technical occupations) on a consistent basis across all three years.

Table 29: Adult qualifications (degree level)

Indicator	Proportion of adult residents with degree level or equivalent qualifications (NVQ Level 4 or 5).
Time series	1981, 1991, 2001.
Data source	ONS: 1981, 1991 & 2001 Census.
Geographic basis	Data for local authority districts is best-fit to 1998 TTWA boundaries (pre-1996 districts are used for 1981 data).
Definitions	Population base for 1981 and 1991 is all persons aged 18 and over; population base for 2001 is persons aged 16-74 years.
Comments	None.

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