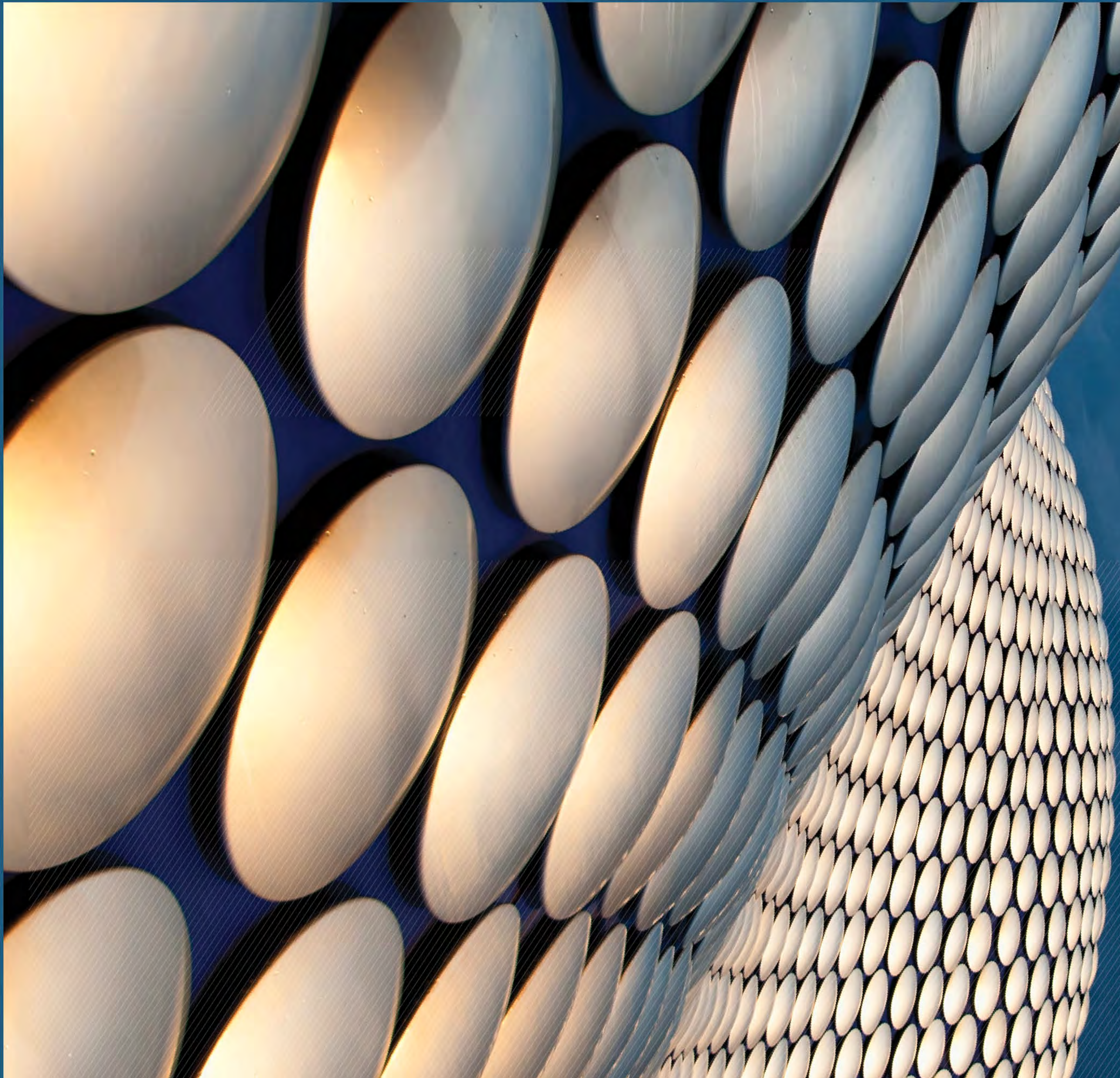

# Tech Country

Looking beyond London in search of Britain's technological future

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# Executive Summary

London's "Silicon Roundabout" (or Tech City to give it its official name) has been a happy discovery for the Government. Right under its nose, within a short cab ride of Westminster, and reasonably near the former Olympic site, they have stumbled upon what could be Britain's answer to Silicon Valley... perhaps.

That the Government has displayed such enthusiasm is hardly surprising; playing host to a successful cluster can bring enormous economic and social benefits as clusters generate and drive prosperity for businesses, individuals and indirectly the national economy itself. However, clusters like Tech City typically require decades of patient, sensible macroeconomic and industrial policy-making if they are to reflect their archetype, Silicon Valley. Unfortunately these timeframes do not coincide easily with short election cycles and even shorter media cycles. As a result governments often cannot resist the temptation to tinker at a microeconomic level, or attempt to "create" clusters with grand infrastructure schemes. That Britain is tentatively feeling its way through the worst economic downturn in half a century only makes this problem more acute.

In all the excitement surrounding Tech City, it can be easily overlooked that Britain as a whole has a long history of playing host to high technology clusters, and looking beyond the M25 there are many clusters with decades of development already completed. This report then, is an attempt to shift greater attention to technology clusters beyond the M25. It does so by adopting a systematic method to examine a series of case studies from a sample of clusters and agglomerations from around Britain. Examples such as Cambridge and Bristol display what it takes to compete in some of the world's most competitive high-tech industries; we learn from the oil and gas industry in Aberdeen, and Formula One in the Midlands that world beating technologies can arise from unexpected origins; and from Manchester we look at over a decade and a half of development is beginning to take shape. Each case study aims to provide a perspective on the range of challenges and advantages inherent in each example. Collectively, they provide input to a set of policy recommendations in the following areas:

***Knowledge Workers***
The importance of highly trained workers in the technology based industries cannot be understated. All the clusters researched for this report rely on a steady, and expanding stream of highly skilled workers. This will require not only an expansion of science and technology in UK universities, but also changes to immigration policy, and how that policy is communicated overseas.

***Funding and Finance***
When the development of an industry relies on supply of capital, it can be tempting for policymakers to flood the market with capital. However we recommend that first and foremost a steady supply of private capital should be the preferred basis for investment in a healthy ecosystem.

***Regulatory Policy***
We are reminded that regulatory policy should be developed with the ends in mind, rather than the means. Over-regulation and excessive red tape are sure ways to snuff out dynamic innovative environments.

***Transport Infrastructure***
Public funding does have a place in providing a suitable environment to do business; many of the clusters studied were established due to strong national and international transport links. Ensuring the quality of these links helps ensure growth in the future. However the current impasse on HS2 rail links and the expansion of Heathrow jeopardises Britain's future growth.

***Industrial Policy***
Businesses are often at their most innovative and effective when they straddle traditional industry grouping, however this can mean that industrial policy aimed at helping one industry can have unintended effects on others. Consequently, the Department of Business Innovation and Skills (BIS) should make the understanding of UK clusters a priority.

***Developing Networks***
Networks are vital to developing successful clusters, though they must be allowed to form as grassroots movements first to ensure a cluster develops its own DNA. However networks need not be restricted by geography. Clusters will develop wherever meaningful interaction drives the spread of ideas.

***Cultural Considerations***
The final area of policy consideration is one of culture, and here a combination of myth and cynicism acts to hold back development of technology clusters. It is virtually impossible to "legislate" cultural change; however the centralised nature of British Government provides the opportunity to influence the nation's cultural agenda.

With a clearer understanding, it is hoped that these cases will provide an informative guide as to how government can seek to use policy to 'tune' these existing clusters to achieve higher performance without submitting to the temptation of grabbing headlines with grand follys in cluster creation.

Of course the sample of case studies is not the entirety of clustering in the UK. There are many other examples such as the computer games industry in Edinburgh, offshore energy in the Northeast, agri-tech businesses in Norfolk, and a developing technology network in Cornwall to name just a few[1]. So it is hoped that the methodology developed for this study can provide a means to identify and analyse other technology clusters as well, providing central and local policymakers with the tools to develop these other clusters to their full potential. Ultimately this is the aim of innovation in Britain and that of the BVCA – not just a tech city, but a Tech Country.

*1 There is also a growing body of informative tech cluster maps for UK businesses, two excellent examples can be found in Appendix 8.*

# Economic Clustering: A Theoretical Summary

As discussed in the Executive Summary, this paper uses a collection of case studies to provide insights into a handful of clusters across the UK. However before we move into the case studies, it is worth briefly touching upon some of the theoretical aspects of clustering, and how they are viewed by this paper. With this understanding, there will be a summary of the methodology used by this report for the analyses of the case studies. The expanded version of the theoretical aspects of this report can be found in Appendices 1, 2 and 3.

## Clusters in brief

Clusters present a unique challenge to policymakers. On the one hand, if you find yourself host to one, they provide enormous economic benefit, but on the other hand they are capricious and usually impervious to creation. Indeed, efforts to do so regularly fail (O'Mara, 2010) (Starobin, 2011), but this hasn't stopped many governments from trying. However knowing that the benefits of clusters for economic growth are desirable, it is useful to be aware of the basics.

***Clusters cannot be created, but can be destroyed***
Despite the many efforts of policymakers over the years, the clusters that survive and thrive are inevitably the ones that form organically over time. The best advice for policymakers, then, is to focus on economic policy that encourages businesses and investment generally and avoids interventionist tinkering.

***Clusters restrict as well as promote growth***
Clusters form in environments where certain resources exist in the right balance. Naturally, this leads to localised competition between firms whilst providing opportunity for growth. However, these localised resources have their limits, and much like an oasis in desert, some firms can become trapped in a cluster. They reach a point where they cannot grow any larger than local resources allow and they lack the will or capability to move to a larger cluster. When this occurs local firms become trapped and growth becomes stunted unless they move on.

***Clusters are highly competitive***
Healthy clusters thrive on competition at virtually every stage of the supply chain; the more fierce the competition, the better for the cluster. As such, what is good for the cluster ecosystem is not necessarily good for the component firms. For the individual firm, survival comes from the ability to acquire and make more efficient use of resources, and build social capital whilst forming alliances which will aid in their efforts to survive. Firms that are more successful in this pursuit will survive and succeed in a cluster; importantly they are also more likely to be able to compete globally.

***Clusters are not a single industry***
Clusters often contain a range of differing though complementary industries. This can present many challenges for policymakers. Firstly, it makes them difficult to identify using the UK Standard Industry Classification (UK SIC 2007), so clusters based on complementary industries or technology clusters in "low tech" industries may be missed entirely. Secondly, because firms may be in different, but complementary industries, industrial policies that only impact one industry can have unintended consequences; few policymakers need reminding of the disastrous impact of the "picking winners" approach in the 1970s.

***Clusters are not static***
It may seem a truism to state that clusters are dynamic, however this aspect is sometimes ignored. With all the focus on cluster growth policymakers can be blind to cluster maturation, and decline. By identifying and understanding the various stages of a cluster's growth cycle, policymakers can develop options that are best suited to provide the most positive impact on a cluster, particularly at the late stages of a cluster where policy can have a real impact.

## Methodology in brief

Just as the nature of clusters is complex, so the methods by which we analyse them need to be multifaceted. Although clusters are not new (clusters as we know them now have probably always existed in some form), since their identification as "agglomerations" by economist Alfred Marshall near the turn of the 20th Century, a range of academics have made efforts to refine their study:

> *Economic geographers like Scott, Amin and Thrift, Harrison, Kelley, and Grant, Markusen, and Asheim also discuss the subject. They came up with concepts such as local industrial specialization, spatial economic agglomeration, and regional development to discuss the trend. Furthermore, numerous terminologies have been suggested to define the concept—"industrial districts," "new industrial spaces," "territorial production complexes," "neo-Marshallian nodes," "regional innovation milieux," "network regions," and "learning regions." (Aziz and Norhashim, 2008)*

However for the purposes of this report with its case study approach, three key elements are considered, each with its own method of examination:

### *Consideration 1: Is it a cluster?*

This is a surprisingly challenging question to answer as the use of the term has become diluted as it has come into more common use. This report uses the expanded definition developed and popularised by Michael Porter (1998, 1990). Therefore to help correctly identify all the necessary elements of a cluster for each given case study, this report will also utilise Porter's Diamond Model (as displayed in Fig. 1), a complete explanation of its application can be found in Appendix 2:

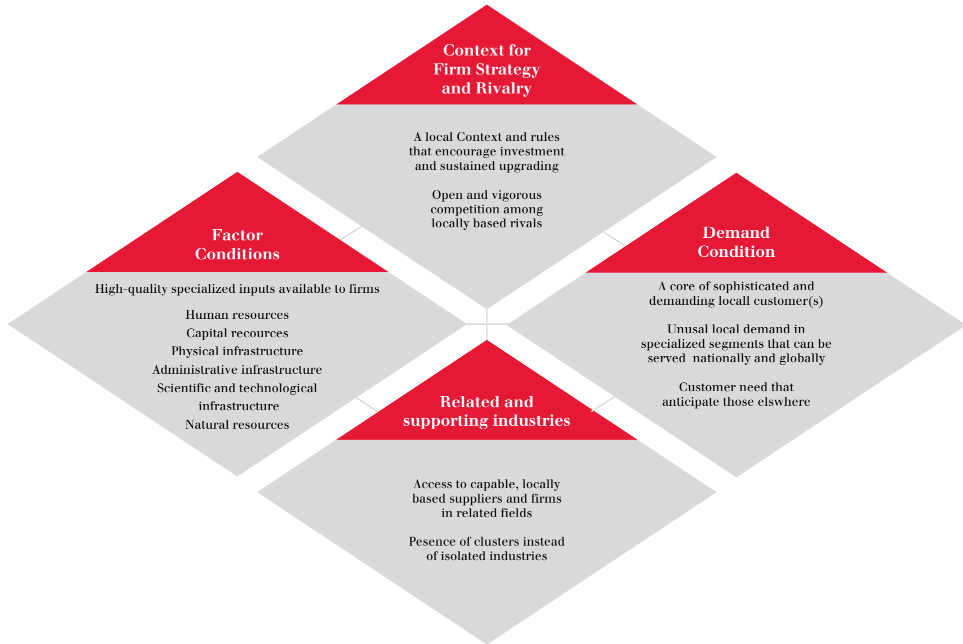



*Figure 1 – Porter's Diamond Model*

## Consideration 2: Where is it in the clustering lifecycle?

A challenge to Porter's methodology is that the identification of a cluster is just the first step, the next is to identify where the cluster is in its lifecycle. Whilst there are many models for this development/dynamism, this paper will analyse the case studies using the six stage model (as displayed in Fig. 2) discussed by Aziz and Norhashim (2008) which has the benefit of being highly practical in its nature.

Covering the phases Antecedence, Embryonic Cluster, Developing Cluster, Mature Cluster, and Declining Cluster/Transformation, the Aziz and Norhashim model provides recognition of the crucial early and late phases of the cluster lifecycle which in many ways are the most significant for policymakers. (A complete explanation of its application can be found in Appendix 2) . In this model, the ideal situation is to be constant cycling back into a Developing phase. This displays the ability of the cluster to keep up with new the latest innovations and transform itself to meet market requirements.

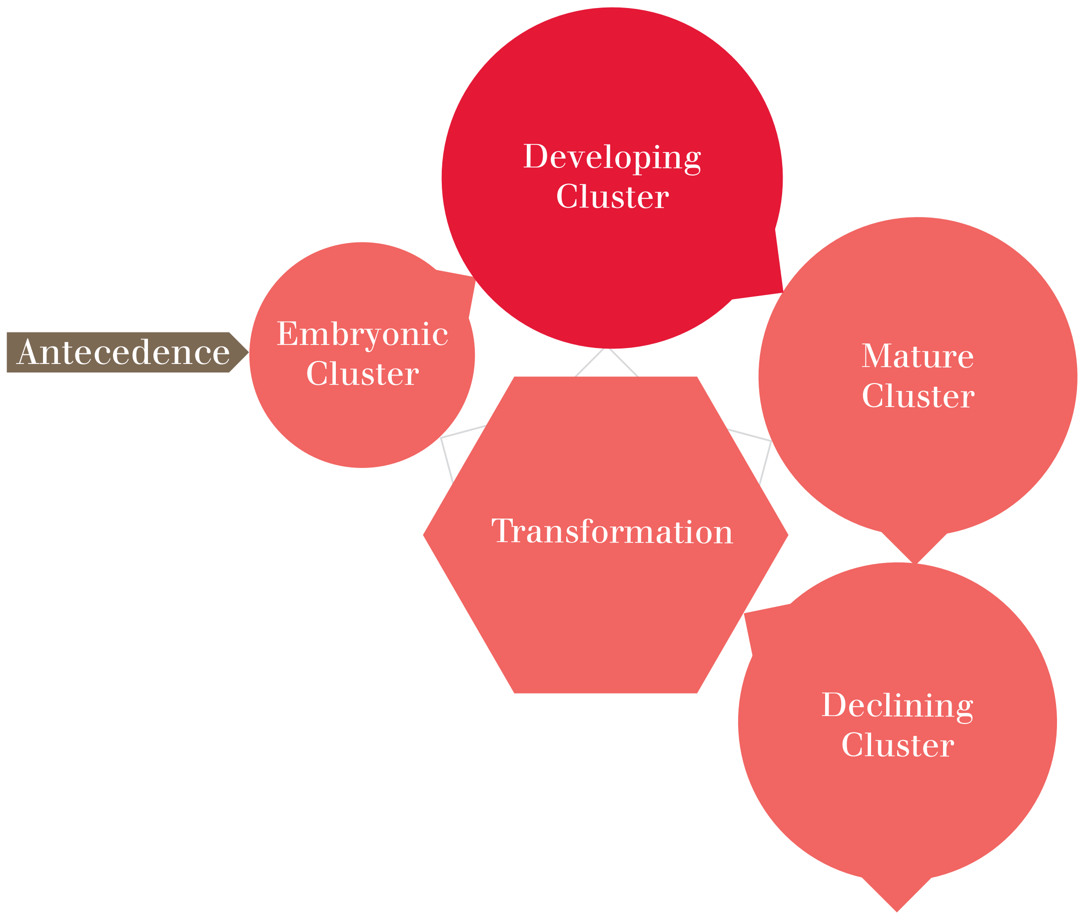



*Figure 2 – 6 Stage Cluster Lifecycle Model Aziz and Norhashim (2008)*



## Consideration 3: Does the cluster operate effectively?

In many pursuits, key to a successful outcome is the ability to visualise what success actually looks like. The rationale that success will be easier to achieve if the outcome is known beforehand is compelling; if the process is tracked from start to finish, milestones, problems and issues can be identified.

In the case of technology clusters we are fortunate to have an excellent template available to study, Silicon Valley. Whilst this report is far from the first to use Silicon Valley as a model, we hope to avoid the common pitfalls, and the misguided tendency of governments to replicate the outward appearance of that region. These pitfalls are usually a result of policy designed to create the next Google or Facebook; instead this report will use the factors identified by Clark (2011) as key to the success of Silicon Valley – Culture; Knowledge/Experience; Finance; and Networks – and analyse the case studies, by comparing them with this 'model'. (A complete explanation of the application of the model in Fig. 3 can be found in Appendix 3).

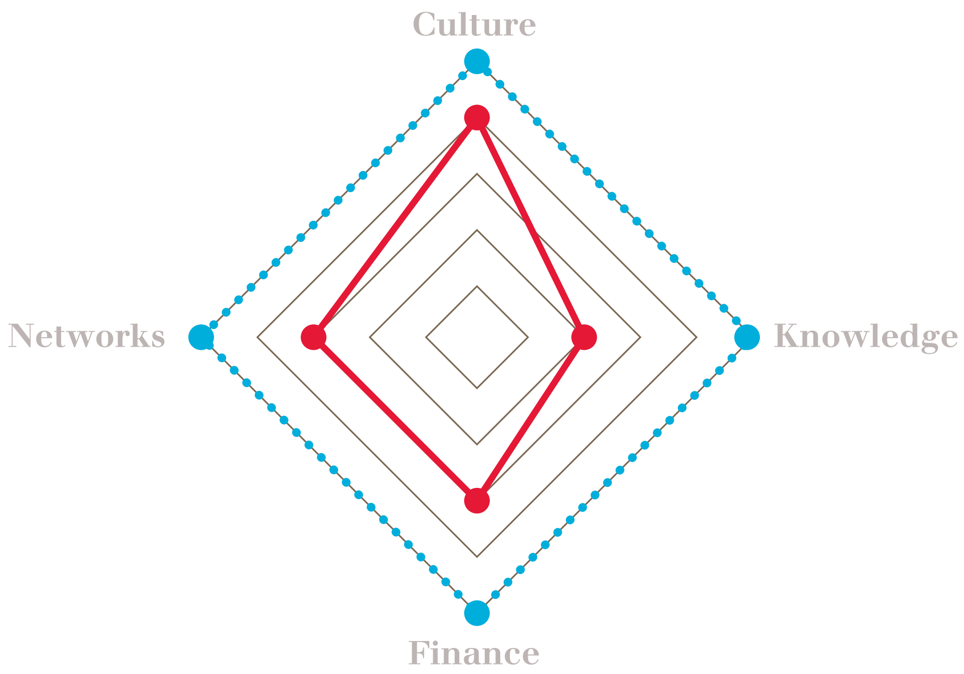



*Figure 3 – 4D Comparative Model*

## A synthesised methodology

By using these three models to better understand the key aspects of the case studies under consideration, this report hopes to provide a comprehensive set of tools for policymakers. By synthesising these models – Diamond Model, Dynamic Model and Comparative Model – into a single framework we are able to develop a holistic view analytic method to examine the five case studies.

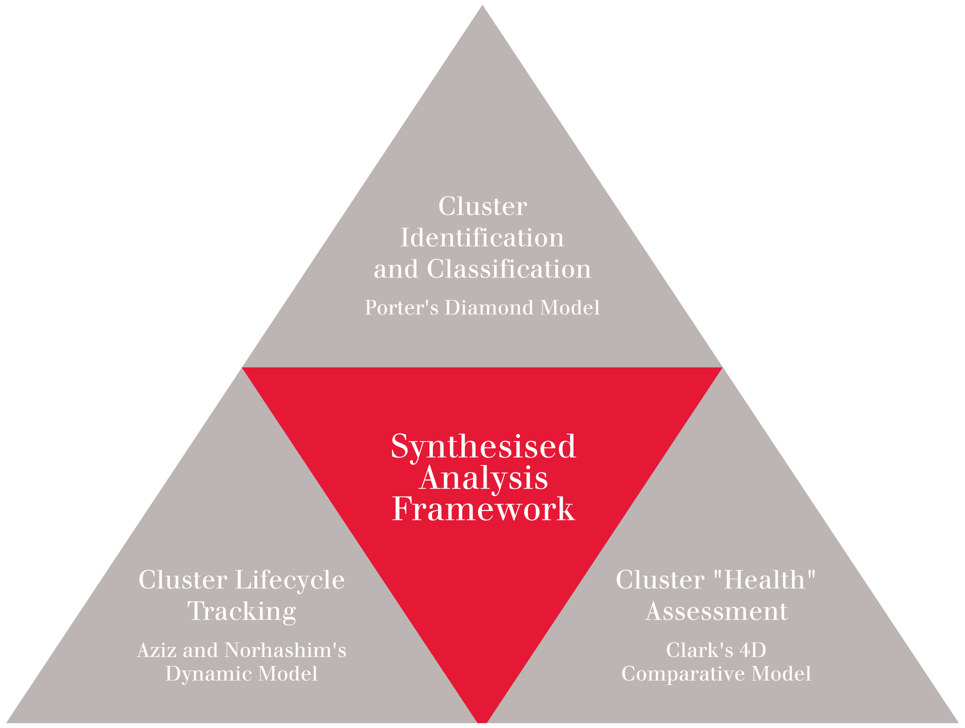
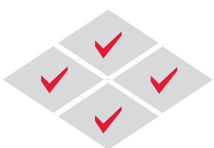
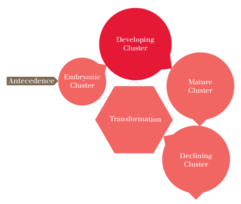
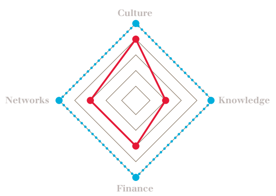



*Figure 4 – Synthesised Analysis Framework*

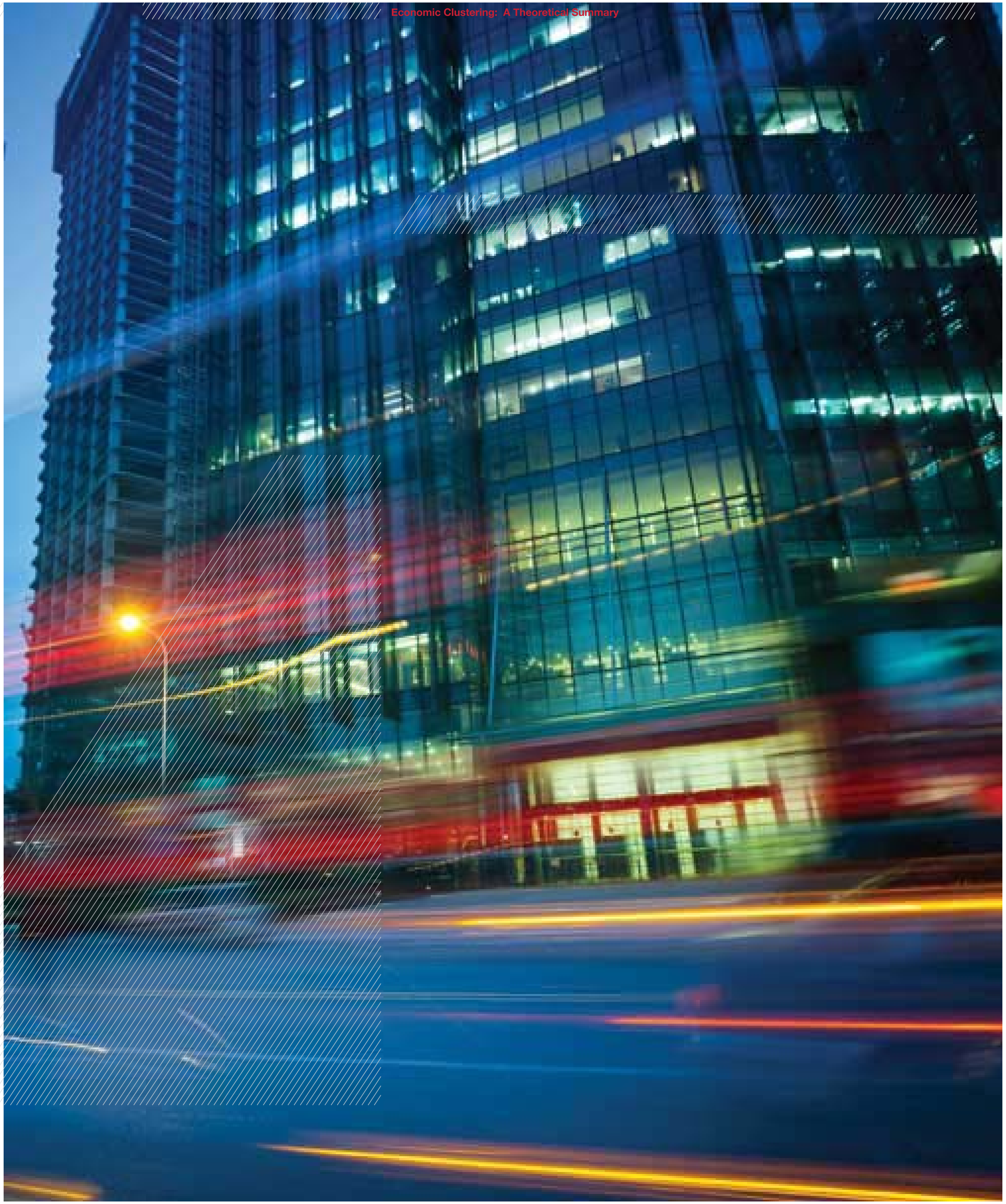
Porter's Diamond Model enables us to identify clusters and their nature accurately amidst a sea of underdeveloped, generic agglomerations. Using Aziz and Norhashim's Dynamic Model we are able to assess the development stage of the subject clusters. Finally, by using the Comparative Model we are able track key indicators of cluster health comparison to an idealised example. Each of the elements makes use of a theoretical diagram which can prove a useful diagnostic tool. To enable an "at a glance" understanding, simplified icons of these diagrams will appear at the start of each case study to act as a diagnostic toolkit.








It is hoped that by demonstrating the efficacy this diagnostic toolkit allows, it can be applied to help develop insights into other clusters and agglomerations elsewhere.



# Why study clusters?

***Britain and clusters***

What we now call clusters have always existed in Britain, particularly following the industrial revolution. Some, like the cotton mills of Manchester, the naval ports like Southampton, the great shipyards of Glasgow and Belfast, and the financial markets in the City of London are imbued into British culture, heritage and the landscape itself. It is unsurprising that these great industrial clusters have been centres of enormous economic growth nor that amongst the economic challenges of today, efforts are being made to recreate centres of industry in a modern way. However, amidst this policy rush it is important to consider that most of these clusters arose either spontaneously based on proximity to resources (whether primary resources, commodities, capital, or human resources) or because of favourable geography. They also contained aspects and participants, and followed lifecycles that are very familiar to those researching modern clusters.

So clusters are not new to Britain. Yet for some reason Britain, like so many places, seemingly falls into the trap of trying to replicate the success of Silicon Valley in the belief that this (admittedly very successful) ideal of technology clusters is the only type capable of delivering economic impact. In doing so, Britain fails to recognise either the existence of, or peculiarities of, indigenous technology clusters. Similarly this misguided approach also fails to enable an understanding of the "universe" of British clusters, much less the ability to develop policy suitable to aid their continued development.

***National blind spot***

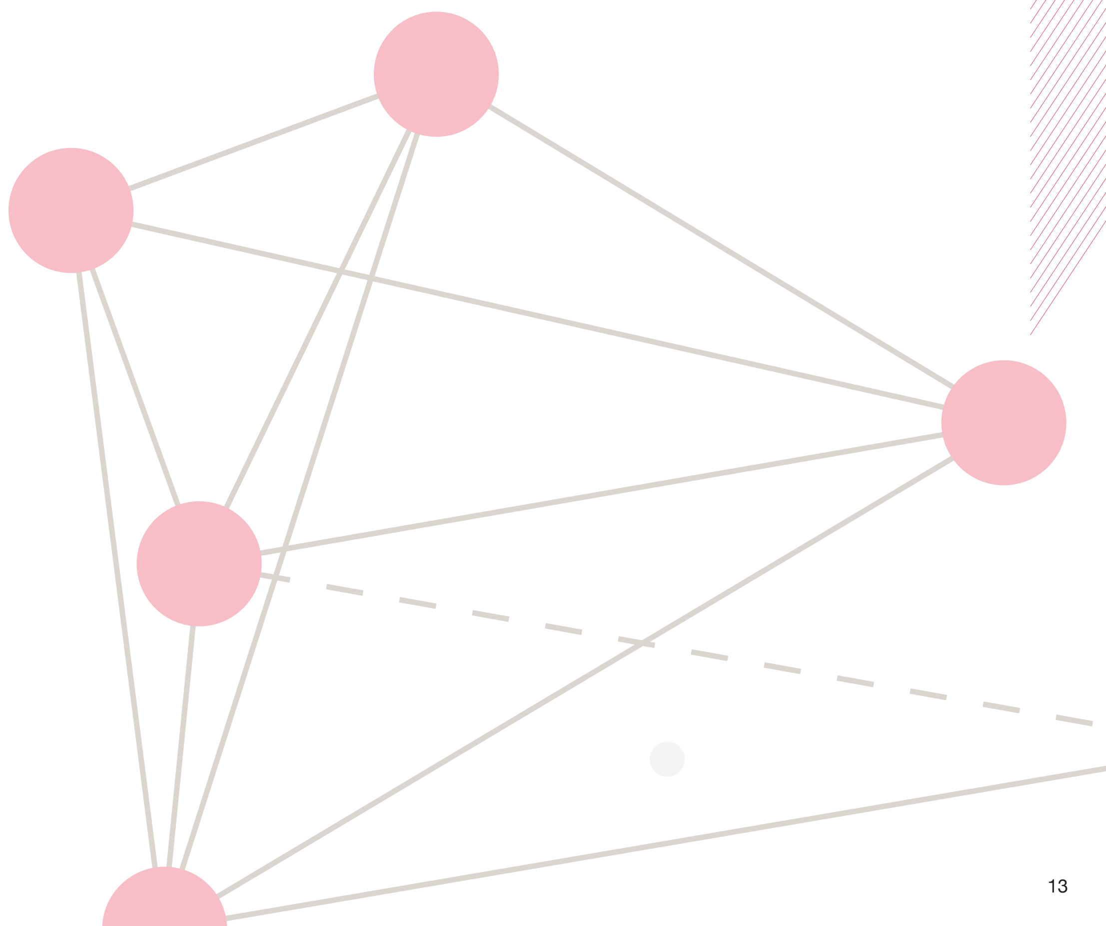
This focus on finding a Silicon Valley results in a lack of awareness and appreciation of the scale of development beyond the M25, the unfortunate consequence is something of a national "blind spot". As the BVCA has engaged with its members and their portfolio companies around the UK we have been reminded that this country is rich with technological activity in a wide variety of forms. The nation as a whole contains businesses every bit as innovative as those decamping to Tech City, some in clusters that have been growing and developing, often over a number of decades. This lack of recognition can have a number of causes: clusters may be in unfashionable industries; they may be geographically remote (from London); they may not fit a traditional definition of clustering, or they sometimes fall through cracks as they don't fit within official definitions such as the Industry Classification Benchmark or within standard orthodoxy of operation, such as is expressed in the Sainsbury Report (2007). Yet there is much we can learn from where these clusters find themselves today and how with the same attention and focus placed on Tech City in London, they have the potential to develop into global centres of excellence, powering regional economic growth.

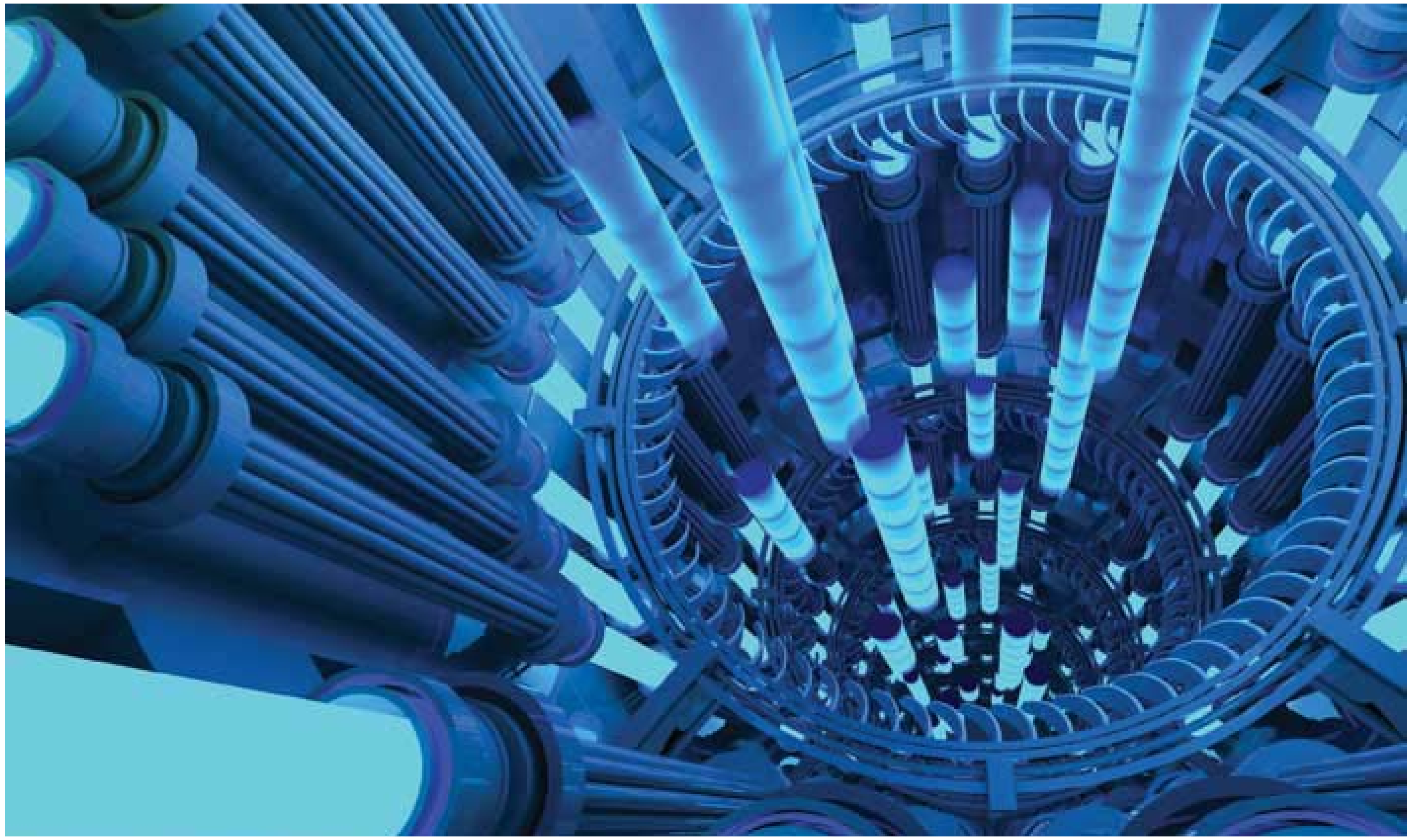




***Clustering DIY***

This report then, is an attempt to shift greater attention to technology clusters beyond the M25. It does so by adopting a systematic method (see Appendices 1, 2 and 3) to examine a series of case studies from a sample of clusters and agglomerations from around Britain. Each case study aims to provide a perspective on the range of challenges and advantages inherent in each case. With a clearer understanding, it is hoped that these cases will provide an informative guide as to how government can seek to use policy to 'tune' these existing clusters to achieve higher performance without submitting to the temptation of grabbing headlines with grand follys in cluster creation. Of course the sample of case studies is by no means the entirety of nascent clustering in the UK, so it is hoped that the methodology developed for this study can also provide a means to identify and analyse other technology clusters and agglomerations, providing central and local policymakers with the tools to develop these other clusters to their full potential.





# Cambridge – Patience pays dividends

It would be impossible to develop a report such as this without including Cambridge as a cluster model. It is by far the most established, widely recognised and best placed British cluster for future growth. Having evolved progressively since World War II (if not before) it is a cluster that can provide us with many lessons that can be applied across the country.

Cambridge is also quite unique; despite its relatively small size, it has been able to become highly effective in a range of industries, which whilst seemingly disparate are actually connected by their relationship with the university, with each other, and with the unique system of relationships that suffuse Cambridge. Today, Cambridge is home to a range of innovative companies spanning key technology areas including computing (hardware and software), biotech and physical sciences – their common denominator is a basis in applied research and above all many years of patient, grassroots development.

## Background

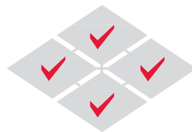
It should be noted that this section is not intended to provide a history of the innovation in Cambridge, there are many excellent sources already[2]; instead, the intention is to focus on the genesis of the Cambridge cluster – a small moment of cultural change that turned a world renowned seat of learning with almost 800 years of history and took it down a path that would lead to the Cambridge of today.

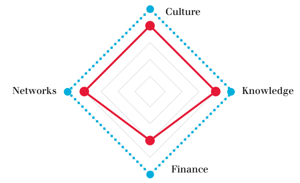
[2] *For an historical account, a good starting point would be The Cambridge Phenomenon (Kirk and Cotton, 2012)*





| Quick Facts | Cluster Location: *Cambridge* |
|---|---|
| Technology Claim to Fame | Home to the UK's premier ICT firms |
| Key Technology Focus | ICT |
| Other associated technologies | Life Sciences and Physical Sciences |
| Key point in history | 1960 – Founding of Cambridge Consultants |
| Keystone Companies/Institutions | Cambridge University; Cambridge Consultants, ARM; Autonomy; Cambridge Silicon Radio; OneNucleus; Cambridge Network |
| Economic Highlights | 1,525 firms with combined revenues of £11.8bn |
| Cluster Challenge | Continue to attract top talent amidst fierce global competition. |




Whilst it is common to assume that the university is the driving force behind the Cambridge cluster, this is not entirely correct. Rather it is a combination of institutions that provide the impetus for innovation. Barrell and Littlewood (2006) summarise these institutions as the university itself, which provided the impetus to transform itself from a "medieval seat of learning to a great educational centre and wealth-creating knowledge-based business centre"; the technological consultancies which acted as an incubator to a family of businesses in a diverse range of technologies whilst providing close links back into the university; and the establishment of institutional research and development, which attracted a range of corporate investors to inject capital and knowledge back into the university. These three institutions, then, act in harmony to create a cycle of innovation.

It is important to note that although these sources place an emphasis on institutions, this is not to say that they are not monolithic 'authorities', in fact the opposite is more accurate:

> *The development of the Cambridge high-tech cluster has been very much a bottom-up initiative. (East of England Technopole Report, 2009)*

The "institutions" as such, were a collective of individuals responding to developing opportunities; consequently the growth of Cambridge was a grassroots development, often in the face of institutional resistance. Tim Eiloart and David Southward founded Cambridge Consultants in 1960, as an effort to provide opportunities for technology transfer for academics out of the university and into industry. They did so struggling in the face of existing institutions which were reluctant to see Cambridge become more industrialised:

> *...attitudes towards the newer companies were frosty to say the least – not only on the part of Cambridge University, which frowned on 'commerce', but also on the part of town planners and the City and County Councils, which actively sought to prevent any industrial expansion in Cambridge and the surrounding area. (Kirk and Cotton, 2012)*

In this manner the structure of the organisation itself encouraged grassroots participation – a supply of individual researchers to meet the needs of local businesses. It was the establishment of this pattern that led to many of the businesses which in time became household names. Arguably, the genuine foundation of the Cambridge Cluster lies in this drive to unlock the knowledge that hitherto was retained within the university. As we examine later in this case study, this was a significant act. That cultural shift was a vital change of direction and set the tone for much that followed. It also created a process that today, uniquely positions Cambridge as host to a heterogeneous cluster of businesses in a world of clusters (Silicon Valley included) that are tending towards homogeneity.

# Cambridge – Patience pays dividends

## Analyses

To get an understanding of what makes Cambridge run today, this paper will analyse it using the three dimensions outline in the previous discussion on clustering. First of these will be an analysis using Porter's Diamond Model.

### Porterian Analysis

***Factor Conditions***

The Cambridge cluster plays host to a range of high-quality inputs, starting with the university itself. The infrastructure and capabilities of this world-class university provide the environment around which the human resources of Cambridge are able to develop. However, the university itself isn't the sole contributor (there are many top level universities producing high quality graduates which are unable to develop in the same manner as Cambridge). More pertinently, the multifunctional organisations, such as Cambridge Consultants, provide a diversity of the roles listed by Porter as crucial to the input of a successful cluster – human and capital resources, administrative, informational and scientific and technological infrastructure. In fact it can be readily argued that Cambridge Consultants and its peers brought together many of these key factor requirements that allowed the cluster to be established.

> *It is generally acknowledged that there are three separate sets of institutions: the university; corporate research laboratories; and a range of technical consultancies, which have combined to give the city of Cambridge a strong technology skills base. This has produced world-class research, plenty of commercial know-how and sufficient business management expertise to develop a track record of success. (Barrell and Littlewood, 2006)*

As the area has received greater focus over the years, so other resource and infrastructure providers such as government offices, science parks and formal entrepreneurs and investor networks have formalised the institutional roles (East of England Technopole Report, 2009). Finally, and crucially for the establishment of a 'critical mass' for the cluster, the area now plays host to a self-sustaining venture capital (VC) market. Up to the 1990s, many businesses at the time were financed – uncharacteristically for young technology ventures – by debt finance. This unusual circumstance did provide reasonably consistent access to capital; however the arrival of genuine VC in the 1990s set the stage for businesses such as ARM and Autonomy to grow rapidly and eventually go public. Their success in turn attracted even greater amounts of venture capital.

***Context for Firm Strategy***

Like any cluster based around a world class academic institution, Cambridge is highly competitive; the rivalry amongst researchers can easily transition into competition between rival businesses. However in Cambridge, competition has its own character, perhaps reflecting the cluster's unusual path taken to commercial focus. A peculiar aspect of this transition affected (and still affects) competition in the area. Whilst there is a competitive spirit in the area, it is not cut throat; this comment from the same source describes this well:

> *A particular feature of the cultural shift is what people refer to as the 'Cambridge spirit'. The Cambridge spirit is described as an attitude where people willingly help others without expecting anything in return. (Kirk and Cotton, 2012)*

Whilst this quote perhaps overstates the uniqueness of this type of attitude (such attitudes are relatively common in technology clusters), it does give a perspective into how competition between firms is perceived in Cambridge – and perhaps gives an indication as to how Cambridge has been able to play host to a range of industries.

***Related and Supporting Industries***

As mentioned at the start of this profile, diversity of innovation is a true strength of Cambridge. This diversity is further enhanced by Cambridge's close geographical links – within two hours drive exist major financial and commercial centres, top research hospitals and major pharmaceutical headquarters, access to aerospace industries, heavy industry and manufacturing as well as a range of other innovation-hungry industries. By virtue of these links, Cambridge has an abundance of the supporting industries required to operate as a vibrant cluster:

> *Whilst most industry clusters tend to get stuck in the one specialism, the Cambridge Phenomenon is one of the very few multi-sectoral clusters in the world. This is partly the result of the innovation establishment's ability to adapt business models from one technology to another, but also by the continued breadth of research taking place in the universities and institutes that form an integral part of the cluster. (Kirk and Cotton, 2012)*

***Demand Condition***

Even at its earliest stages, this cluster was demand-driven. Within the foundation of Cambridge Consultants lay the need to connect industry with academic research. Today, the cluster exhibits the symbiotic nature of the relationship between industry and research required by Porter's model. As Cambridge developed in sophistication and scale dynamics came into play, access to London's many industries as well as international links via Heathrow airport enabled Cambridge to reach many sophisticated global customers.

### Dynamic Analysis

As technology clusters go, it would be fair to describe Cambridge as a slow burner; at the equivalent stage of its development Silicon Valley had played host to businesses from Intel to Google. Despite its rate of progression however, Cambridge has been able to adapt and change as different technological waves moved through the industry - especially during the key transition between hardware and software. Cambridge has always been firmly rooted in 'real tech' (defined as business backed by genuine intellectual property (IP) development). It rode the transition between hardware and consumer products that were prevalent in the 1970s and 80s, into software and IP related businesses in the 1990s:

> *The region has seen outstanding growth in knowledge-based businesses over the last 30 years, the growth of the Cambridge cluster being a prime example. In 1978 there were around 20 high-tech companies in the Cambridge area. Today Cambridge is home to 1,400 high technology ventures employing around 43,000 people. (East of England Technopole Report, 2009)*

The challenges of the recent financial crisis have done little to change the dynamic state of the cluster. Indeed, though it is only three years since the publication of the East of England Technopole Report, latest calculations put the number of businesses at over 1,500, employing more than 53,000 people and with a combined revenue of nearly £12bn (Armstrong, 2012). Such growth is evidence of the ability of Cambridge to renew its offering and focus.

When faced with maturing industries the cluster has been able to transform its dynamic state from Maturity back into the more dynamic and productive Developing state – its focus on research providing the impetus for this continual transformation.

[3] *Originally known in 1990s as Advanced RISC Machines.*

# Cambridge – Patience pays dividends

## Comparative Model Analysis

It is when we analyse Cambridge via the Comparative Model that this report argues its true potential becomes apparent; what we see are parallels with the earlier stages of Silicon Valley.

It is difficult to overstate the impact the cultural shift had on prospects for businesses in Cambridge. At the time Cambridge Consultants was established, the area of Cambridge was like most academically-focused environments in this country – innately suspicious cum hostile towards efforts to commercialise research – if not more so in light of the 750 years or so of academic history:

> *Many people say that the prevailing attitude in Cambridge University prior to the 1970s could be encapsulated in the phrase, 'How dare you want to make money'... Even after the Science Park was established at the beginning of the 1970s and spin-out companies gradually began to appear... there were plenty of academics who disapproved. (Kirk and Cotton, 2012)*

So overcoming this institutionalised antipathy towards commercialised innovation was crucial to creating an environment welcoming to entrepreneurial endeavour. Whilst not dramatic, change was encouraged by gradual but significant efforts of many individuals and businesses during the 1960s and 70s. By the time Britain itself was ready to be comfortable with enterprise and entrepreneurship through political change in the 1980s, Cambridge was able to benefit from the previous years of transition. These attitudes have only become more firmly entrenched with the activity of the tech booms in the 1990s. That this attitude remained resilient within the academic and business community despite various economic challenges is proof that this new mindset has taken root.

The establishment of Cambridge Consultants unlocked the human resource potential of Cambridge academia bringing it to bear on local industries; in this it was highly effective with a side benefit of a small but steady increase in levels of experience amongst the area's entrepreneurs. This knowledge and experience is carried through generations of start-up funding and provides the foundations of the positive future facing Cambridge.

If cultural change sparked development of the Cambridge cluster, the "powder keg" was the arrival of more systematic forms of equity funding in the 1990s. Prior to this time, financing for firms in Cambridge was varied and idiosyncratic: 'bootstrapping' via consulting work was common; as was the use of retained earnings from sales; government financing or R&D programmes. Unusually by today's standards, even banks were common sources of quite considerable amounts of capital, with Barclays particularly playing an active role (Kirk and Cotton, 2012). However, changes in legislation in the 1990s provided an easier means for a public stock market exit for many Cambridge firms. The resulting success of some of these initial public offerings (IPOs) drew both VC investors (some of whom like Hermann Hauser of Amadeus Capital Partners were former entrepreneurs themselves) and a far more systematic approach from angels who had begun to form syndicate groups. This transition into equity-based financing saw Cambridge finally develop a critical mass with a recycling of capital to match the recycling of knowledge. Though Cambridge does not provide the scale and consistency of big exits to put it into the same league as Silicon Valley, the necessary elements are in place to continue this growth. In time, this report argues, the recycling of capital and knowledge will drive ever larger increases in exit size.

A genuine strength of the Cambridge cluster is the superb networks that have been established over its many decades of development. Starting as informal groups of like-minded individuals, today the networks in Cambridge are a diverse ecosystem of formal and informal organisations covering the spectrum of needs – from entrepreneur specific groups such as Ideas Space,

[4] *Bank loans for technology companies are highly atypical given the risks involved and relative lack of collateral businesses were able to provide.*

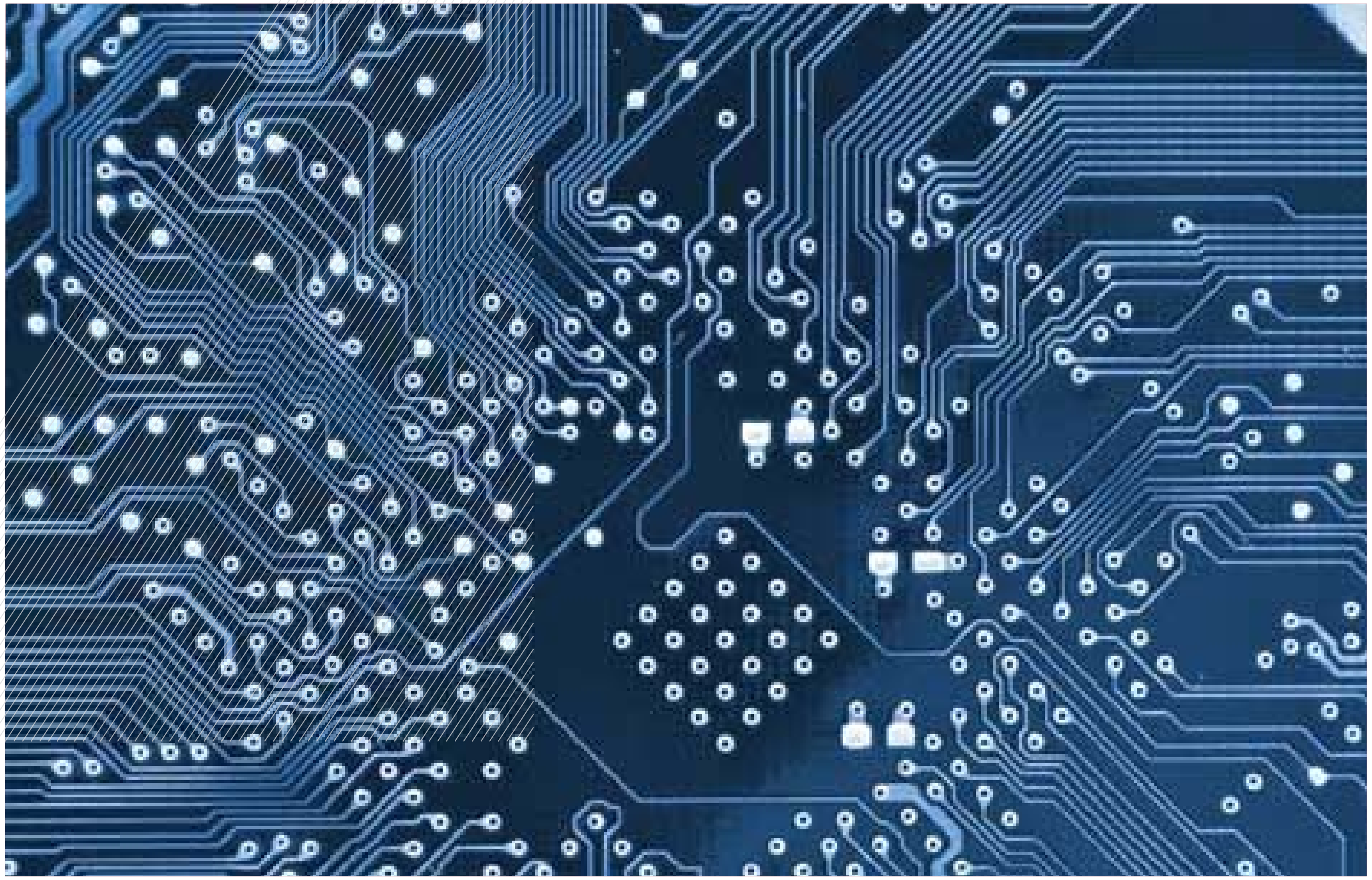


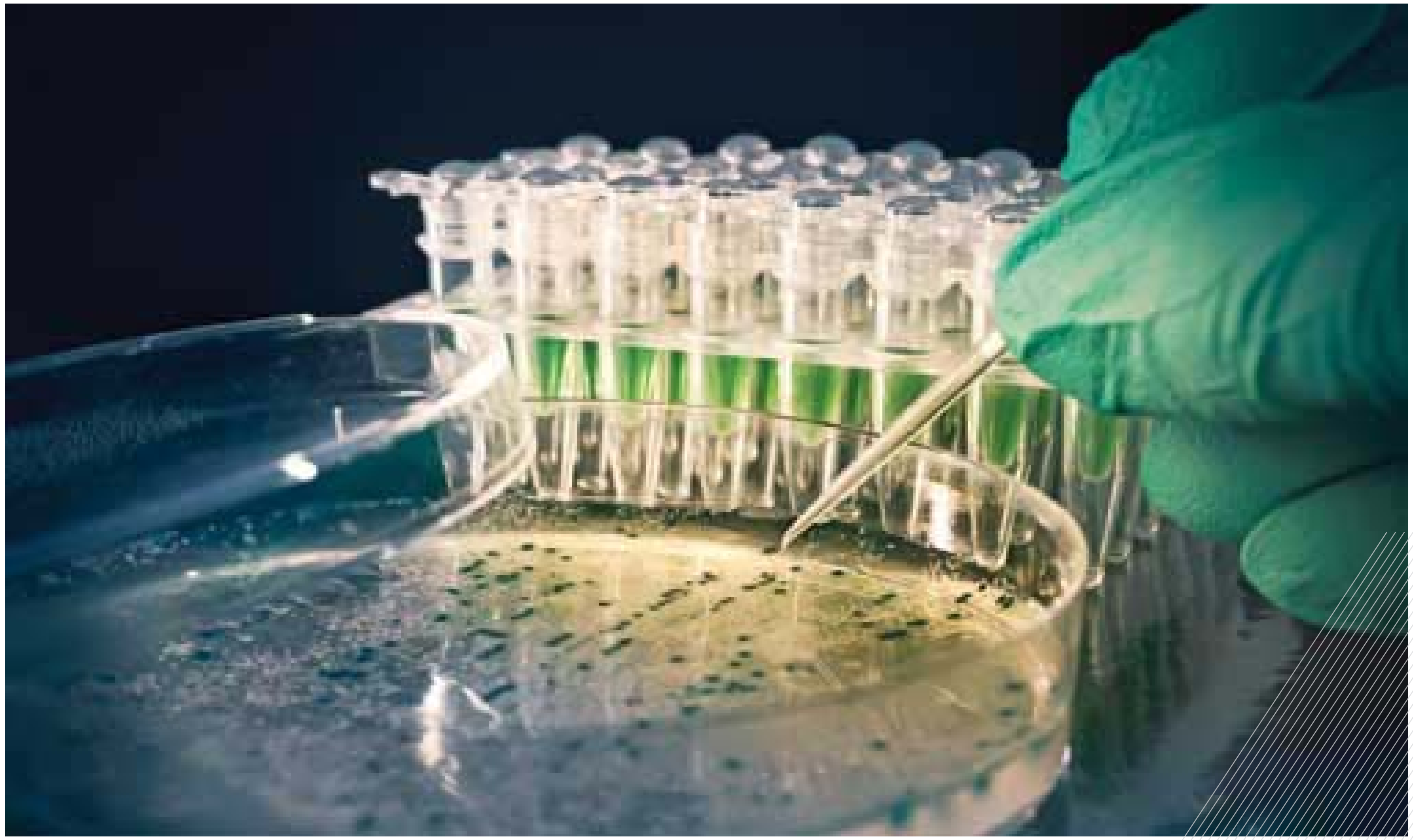


Makespace, Cambridge Pitch and Mix, and the Cambridge Mobile App Group; to investor support groups such as the Great Eastern Investment Forum and Cambridge Capital Group (Kirk and Cotton, 2012); to a range of sector and industry groups such as the Cambridge Network, Cambridge Wireless, and One Nucleus (East of England Technopole Report, 2009). In all there are just over 50 separate business and technology networks in Cambridge, though with the advent of aggregators such as meetup.com this number will continue to grow in number and diversity. This expansion does present challenges though, as increases in scale create increases in complexity (Cowley, 2012). In these circumstances, the value of the network is best unlocked as social capital is acquired.

## Summary

Of all the technology clusters in the UK, Cambridge is the most evolved, commands the most capital and is the most diverse. However, as the analysis reinforced, this evolution took considerable time to occur, and indeed it is still taking place. Whilst the diversity of innovations produced by Cambridge is unusual, there is much that can be learned and applied elsewhere. Cambridge is an ecosystem built upon the full range of elements required to succeed – entrepreneurs and investors, imbued with an enterprising culture, operating in effective networks, supported by effective local and national government policies.





# Manchester City Region – If you build it, will they come?

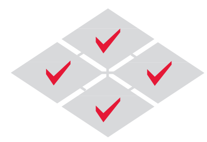
## Background

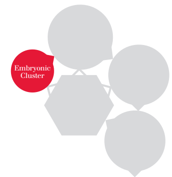
In the theoretical section of this report, we discussed the influence of Alfred Marshall and his identification of economic agglomerations in the 19th Century. His description of industrial districts was informed by what he saw when he looked at the industrial heartland of Britain, cities which were at the time global leaders and technological innovators. Manchester was the central hub in a supply chain that circled the world, drawing raw materials from cotton plantations in the United States and India, before manufacturing them into textile products to be sold around the world. Like Silicon Valley today, Manchester was also given a name which was synonymous with its output – Cottonopolis.

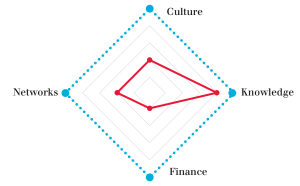
Like many of Britain's industrial cities though, Manchester found the 20th Century was far less kind; the globalisation of industry, and the modernisation and transfer of manufacturing saw a decline in the economy of Manchester causing the collapse of local industries. Though there were some flickers of life, most notably in the Trafford Park industrial district ("In London's shadow," 1998), by the turn of the 21st Century, Manchester's greatest claims to world recognition were a newly acquired Champions League trophy for the red half of Manchester, and a pulsating dance music scene.

However Manchester is certainly not short of the resources required for reinvention. Chief amongst these is the University of Manchester (UM), a world class research university with specialisations in life sciences and materials science (to be discussed later). Since the turn of the 21st Century, the Manchester City Region (MCR) has also been home to massive capital

| Quick Facts | Cluster Location: *Greater Manchester* |
|---|---|
| Key Technology Focus | Life Sciences |
| Other associated technologies | Digital, Creative and Media; Materials Sciences |
| Key point in history | 1996 - Regeneration of the city centre and Corridor Manchester prompted by IRA bombing |
| Keystone Companies/Institutions | University of Manchester; UMI3; National Graphene Centre; AstraZeneca; Manchester Science Park |
| Economic Highlights | Lifesciences employs 163,000 and generates annual GVA of £4.7bn |
| Cluster Challenge | Build a sustainable lifesciences cluster based on initial positive signs. Also maintain the initiative in global efforts to commercialise graphene. |








investments that have seen infrastructure vastly improved. Initially the IRA bombing of 1996 prompted a rebuilding and regeneration programme around Corporation Street. This was followed by further developments leading to the Commonwealth Games of 2002; and in the last decade or so, the redevelopment of the Corridor Manchester complex located to the south of the city centre, the creation of MediaCityUK in Salford which plays host to the relocated BBC and ITV, and The Sharp Project in north east of Manchester. Such significant public investment has provided MCR's business community an array of opportunities.

As to the business community itself, MCR is home to a diverse corporate base – a positive attribute given the decline in the manufacturing sector. The largest contributing sector is the finance industry which contributed £9bn in gross value added (GVA) in 2011; the introduction of MediaCityUK has massively increased the contribution of the creative and digitals industries to £2.7bn GVA (Greater Manchester Forecasting Model, 2011). However it can be reasonably argued that much of this influx is the result of cost saving moves on the part of businesses, or political and socially-motivated decisions (Sweney, 2009) rather than native resources of Manchester. Where Manchester does possess competitive advantages though, is the potential of its research base, as local government planners recognise:

> *It is important to build on existing strengths. Manchester has a strong science base and this must remain a focus, as scientific discovery and subsequent innovation are also the roots of a strong manufacturing economy. (Greater Manchester Growth Plan, 2012)*

The life sciences industry provides the second largest contribution to the MCR with £4.7bn in GVA. Given the government focus on manufacturing, and the challenges of the finance industry, it appears that the best opportunities lie in the areas where the global reputation of its scientific institutions provides the greatest competitive advantage. Consequently this report will focus on the opportunities presented by this potential, whilst identifying the opportunities for beneficial engagement with the creative and digital industries.

# Analyses

## Porterian Analysis

### *Factor Conditions*

The resources provided by the University of Manchester are considerable. As well as providing world class human resources via its applied research areas in life sciences and applications of graphene, the UM has made considerable efforts to provide routes to commercialisation via UMI3 (The University of Manchester Innovation Group) and the university's relationships with the pharmaceutical industry. Together these institutions provide high quality factor inputs in human capital, administrative and informational framework and of course its scientific and technological infrastructure. The potential of these resources is further expanded by the growth in other skills

# Manchester City Region – If you build it, will they come?

available in MCR, particularly the capacity for cross-over applications in the developing digital space. The inauguration of TechHub Manchester provides a focal point for the agglomeration of digital entrepreneurs, and the growth of formal and informal links between the centres for commercialisation at the university via UMI3 and TechHub (Rowland, 2012; Ward and Gibson, 2012) provides a path for synchronised innovation.

The final area for consideration is capital resources; in the context of MCR this is crucial. There is a demonstrable appetite for funding large scale projects through public funds – development of the Corridor Manchester, National Graphene Institute (Brumfiel, 2012), UMI3 and The Sharp Project amongst others – and there is a small but thriving private funding market in the area. However this is not yet self supporting though there is optimism that the developments at UM, especially in graphene, will draw in private capital leading to a critical mass of venture investment.

***Context for Firm Strategy***

As we have seen in Cambridge, business clusters that evolved from academic research can be highly competitive, provided the spirit of academic development is successfully transplanted into a business context. In this regard, efforts at UM, especially via UMI3 have proven successful (Dabrowska, 2012; Dempsey, 2012; Ferrie and Walker, 2012) in developing a culture of healthy competition. Also clear from strategic efforts for MCR (Greater Manchester Strategy, 2009) is a desire to develop sustainability of industry, though some care should be taken to avoid the inhibition of private investment with excessive regulation.

***Related and Supporting Industries***

As detailed earlier, MCR is home to a diverse array of industries, with life sciences the most developed cluster, its supply chains supporting the major pharmaceutical companies such as AstraZeneca that are based in the area. Developments in the field of advanced materials, specifically graphene, are still in their relative infancy, though UM's commitment at such an early stage will provide advantages as conceptual usage shifts to large-scale industrial application.

Possibly of more immediate opportunity are the other industries based in the MCR - specifically the digital and creative industries. Whilst strategic efforts aim to accelerate the growth of each of these industries separately (Greater Manchester Growth Plan, 2012), interaction between these industries will provide more interesting and disruptive innovation. Ultimately, these spillover effects between industries have a greater chance of providing MCR with its own unique approach to enterprise.

***Demand Condition***

Part of the massive capital development programme in MCR in the last decade was Corridor Manchester, a spine of advanced research hospitals which form a component of UM. Such development provides MCR with an ideal base for life sciences innovations. Also MCR plays host to major pharmaceutical companies and has ready access via national transport links to many others. This national core of sophisticated customers maintain a strong demand condition which is further enhanced by access to international markets via Manchester Airport. Whilst MCR currently plays host to fewer research hospitals (Greater Manchester Strategy, 2009) than other regions such as the South East, it is still able to access these via national transport links (though greater public health research into the north west would be preferable. As a consequence there is sufficient demand condition for the development of all life sciences.

Whilst opportunities in advanced materials are yet to affect demand conditions, and developments are largely at early concept stages for many applications, Britain has the advanced manufacturing experience and capability to provide a demand condition for these technologies. Experiences such as the widespread adoption of materials like carbon fibre in the Formula One cluster[5] are just a small example of the symbiosis that exists between industries in the UK.

[5] *To be detailed in a later chapter.*



## Dynamic Analysis

Due to the diversity of activity surrounding the University of Manchester it can be a challenge to assess its location on the Cluster Lifecycle continuum. Despite the developments in graphene to date, it is far too soon to consider this as even an Antecedent Cluster; few if any businesses are operating using this technology as it has barely begun to find commercial applications. On this basis, it should be excluded from consideration. Encouragingly, proof of concept for commercial applications should result in a rapid development of a cluster. This is partially due to public investment in the potential of graphene at an early stage, but mostly due to experience gained by the entrepreneurs and institutions commercialising UM's current research based innovations.

The dynamic analysis of the life sciences cluster is very revealing; although Manchester has a wealth of infrastructure (public expenditure on Corridor Manchester was estimated at £2bn (Greater Manchester Strategy, 2009)) and many of the institutions demanded by Porterian analysis of clusters, in reality it is still in the Embryonic Stage of development. Whilst there is no doubt there are signs of cooperative agglomeration particularly in the Corridor Manchester, which runs through the spine of UM (Dabrowska, 2012; Ferrie and Walker, 2012), at this point there does not appear to be the sort of deep links and large scale private investment required to classify the cluster as Developing.

## Comparative Model Analysis

Use of the Comparative Model to analyse Manchester provides insights which build upon those of the Dynamic Analysis. It is clear from discussions with local investors and entrepreneurs (Dempsey, 2012; Ferrie and Walker, 2012; Rowland, 2012; Ward and Gibson, 2012) that Manchester is home to a unique entrepreneurial culture, with many individual entrepreneurial subcultures. One consequence of the range of subcultures is a feeling of fragmentation – especially in the creative and media communities – as each subgroup tries to establish an identity. Part of this is driven by geography – hubs such as MediaCity in Salford, the University of Manchester, and the Sharp Project are widely dispersed. Fortunately though for the science-based entrepreneurial community their geography and institutions are concentrated, resulting in a more cohesive culture. Given the role of this proximity, the establishment of TechHub Manchester, part of the digital community just a short walk from Corridor Manchester, could prove beneficial for innovation. That said, the entrepreneurial culture in Manchester still exhibits nascent qualities lacking the critical mass of Cambridge or the shared history of Bristol[6].

When we consider the knowledge and experience in MCR, we again discover substantial latent potential, though not yet a widespread depth of experience required to build long term commercial success. The technical and research capabilities of UM leave no doubt that there is a sufficient knowledge base for the development of viable businesses in life sciences and (in time) advanced materials. Indeed, the development of close links with research units of hospitals and businesses in the area will only mean greater progress in this area. However at present the limited experience of spinouts indicates the area is still in the very early stages of development. Generations of repeated business creation and commercial development will be necessary to spread sufficient experience within this entrepreneurial community.

Given the fledgling status of commercialised research it is no surprise to find that financing opportunities in Manchester are limited – at least from private investors. Whilst there are some private investors based in the area, and efforts by UMI3 have begun to create a supply of investable businesses, there is still reliance on direct public funding, subsidies and developmental infrastructure. Given the grassroots nature of entrepreneurial growth as we have seen in Cambridge, the tendency of public funds to crowd out private investment and the necessity of public sector funding cuts (including capital projects), it will be vital for Manchester to develop a critical mass of private sector funding. To bridge this gap, local government can look to the efforts

[6] *To be detailed in a later chapter.*

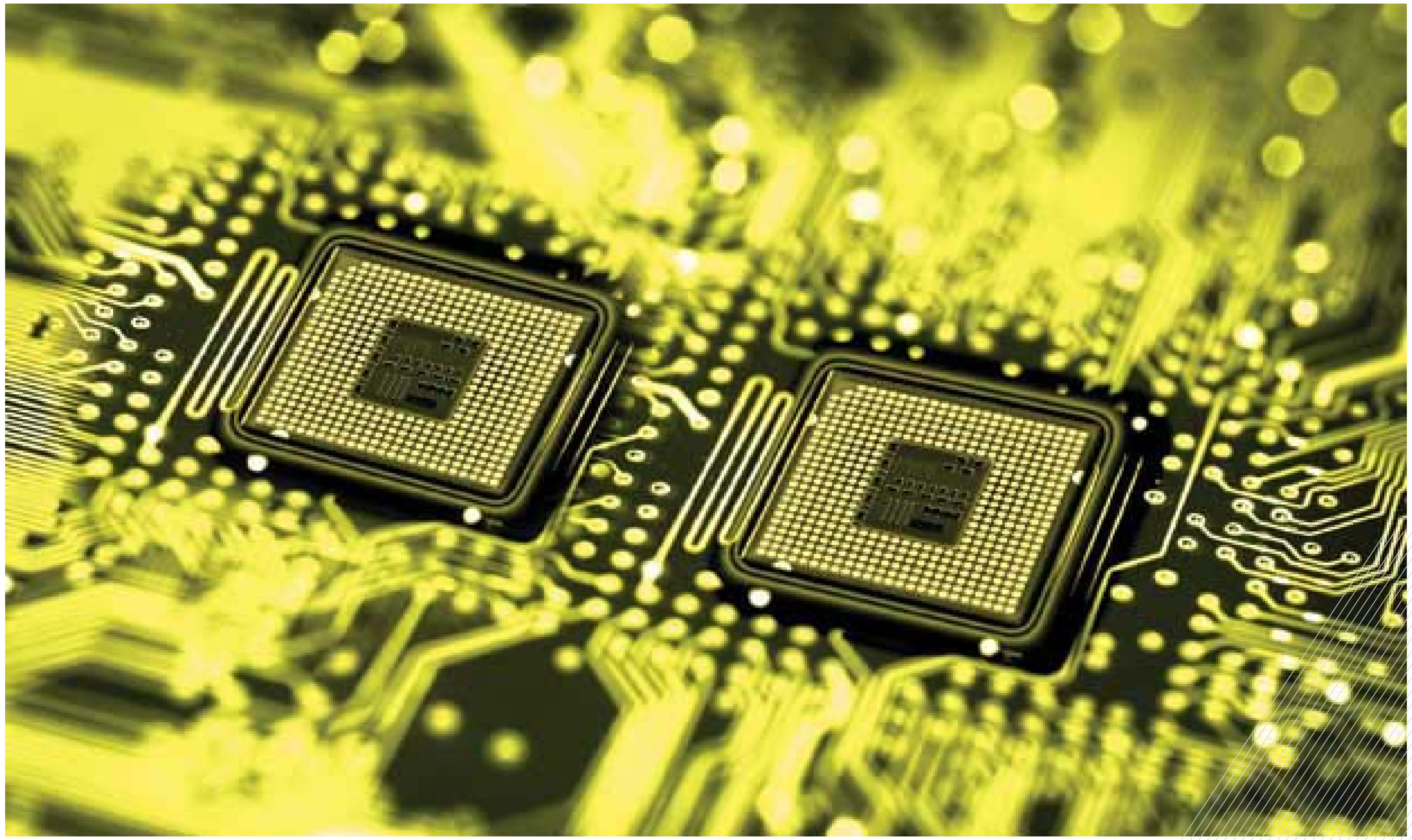
# Manchester City Region –
# If you build it, will they come?

by central government to build awareness and attract investors into London's Tech City. Manchester possesses a sufficient base of enterprise to do so, especially in life sciences, and the excitement surrounding the potential of graphene will also help build supply.

Unsurprisingly given what we have learned from examination of the Dynamic and Comparative Models, the networks in Manchester are undeveloped at this stage. This however is not to understate their vibrancy; the global focus on digital technology provides it with a great deal of impetus and the deep histories of the scientific and creative communities provide them with an energetic foundation for growth. Indeed it was the activist nature of the creative community that led to the development of the Sharp Project (Marley, 2012). What the networks lack at the moment are scale (particularly beyond Manchester itself) and interaction. Scale is vital; the ability of networks to stretch outward to other clusters is critical to their development. In contrast, one of the primary reasons for the rapid development of London's Tech City has been these network links (Clark, 2011). Similarly interaction amongst networks is vital – there exists huge potential should the networks of MCR's various industries combine as it is these links which provide the serendipity that innovation requires to occur.

## Summary

Manchester stands in contrast to Cambridge. Whereas the technology community of the latter grew from its grassroots, often in the face of successive indifferent central governments, for the last decade, the MCR has been at the centre of a concerted effort by its local authorities to jump start innovation through massive cornerstone public investments in infrastructure and institutions. Whether it succeeds or not will be vital for the future, not just of the MCR, but the Northwest of England and the whole of the UK. The technology cluster of Manchester then is an experiment, one in which all the resources are in place, but awaiting the introduction of a catalyst. Exactly what that catalyst may be is unclear at this point, though a greater quantity of private venture capital or an increase in awareness from central government and the investor community may be contenders.



# Bristol – Plenty of chips, not enough muscle?

## Background

If the story of Silicon Valley tells us anything, it may be that embryonic clusters can form as a result of an odd chain of decisions and coincidences. In the case of Silicon Valley it was the decisions of Fred Terman and Bill Shockley that did so much to lay the ground work for the future of the area (Bairstow, 1998; Saxenian, 1996). In the case of the Bristol semiconductor industry it was the decision by Silicon Valley pioneer Fairchild Semiconductor to establish a design centre in the South West precisely because there was not an existing cluster:

> *The decision of Silicon Valley company Fairchild Semiconductor to locate a design office in Bristol in 1972. Ironically, the location was chosen partly because there was no cluster present: Fairchild reasoned that it could retain engineers better by opening offices in locations where there were few similar companies around. (Marston et al., 2010)*

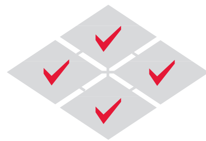
The move by Fairchild may have been the initial spark for Bristol; it could also have been the existence of other semiconductor pioneers such as Plessey (based in Swindon). Arguably it was the creation of semiconductor firm INMOS in 1977 that truly put Bristol and the South West on the global technology map. Whilst we will examine the contribution of INMOS in more depth later in this chapter, its contribution was to assume the role in Bristol that Shockley Semiconductor played in Silicon Valley. During a decade or so of innovation, barely kept in check (or indeed profitability) by management, INMOS brought in a diverse

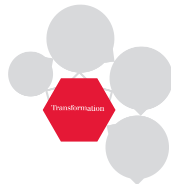


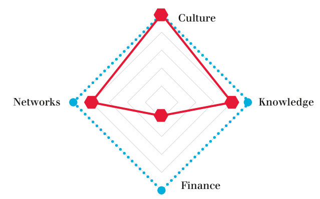


**Quick Facts** | **Cluster Location: *Bristol and South West***

| | |
|---|---|
| Key Technology Focus | Semiconductors |
| Key point in history | 1977 – Founding of INMOS |
| Keystone Companies/Institutions | SetSquare Business Accelerator (set up by Bath, Bristol, Southampton and Surrey Universities; XMOS |
| Economic Highlights | Largest semiconductor cluster in Europe; Highest rate of start-ups for Core Cities in England |
| Cluster Challenge | Attract greater levels of VC investment. |






range of talented individuals and spun out dozens of highly innovative semiconductor companies, producing a base of highly skilled engineers that continues to propagate today.

Whilst the 1980s saw a turnaround for many parts of the British economy it was a painful time for the semiconductor industry[7]. Although the creation of INMOS was in itself somewhat ill-considered (part of the famous "picking winners" industrial policies of the 1970s), the problem was compounded by a series of other associated policies which hampered the industry as it was beginning to show potential. By the mid-1980s the semiconductor industry around Bristol had become a world-leader in the development of 'transputers' a form of computer processor that allowed faster processing speeds via parallel computing at a time when circuitry capacity appeared to have reached its limit.

The first of these policies surrounded the selection of a location of a semiconductor fabrication facility (completed in 1982) to be attached to INMOS. With INMOS itself located in Bristol, logic would have dictated the facility be constructed in a location convenient to the parent company. However, with the Conservative Government of the time facing difficulties in industrial relations, the facility was instead build in Newport some 30 miles away – whilst not an enormous distance, it was sufficiently far to be out of Bristol itself and to the northwest when the cluster was stretched to the south and east. Given the nature of the type of human resources required for this work, the location of this facility did little to help employment in the Newport region and most employees chose to commute between the surrounds of Bristol to Newport rather than relocate.

The second policy decision was for the government to sell its 76% stake in the company to Thorn EMI for £192m[8] in 1984. To be fair, up to the point of the sale the government had invested £211m in INMOS (Marston et al., 2010), including funding of the fabrication facility in Newport, and INMOS had yet to become profitable. For the government of the day, looking to reduce waste, it seemed to make sense, indeed it did make sense. The problem with the sale was the selected buyer; whilst Thorn EMI was loosely considered a consumer electronics company, its specialties lay in computer games and devices like radios and televisions, which were some distance from the cutting edge of the semiconductor industry. As expected in this circumstance, Thorn EMI were unable to utilise the innovative potential of INMOS though it did serve as a cash cow. Eventually INMOS was sold on to SGS Thompson[9] , where lip service was paid to innovation, but was not supported with resources:

> *Their mandate to INMOS was: keep doing what you have been doing, we don't know enough to tell you to do anything differently. We'll keep the INMOS brand and management style and innovation style, we won't interfere, oh by the way we won't give you any investment. (Knowles, 2012)*

*[7] The aim of this report is not to provide an in-depth description of the role of semiconductors in computing or their overall economic contribution, but to look at the Bristol cluster specifically. For greater detail, it is worth reading the NESTA report Chips with Everything (Marston et al., 2010). Available at: http://www.nesta.org.uk/publications/assets/features/chips_with_everything*
*[8] A bargain considering this deal included IP for such things as the software hardwired onto the chips themselves – something in common use today*
*[9] Which was later renamed STMicroelectronics.*

# Bristol – Plenty of chips, not enough muscle?

The consequence of this situation was a cascading creation of new businesses (see Appendix 7) over the next decade coinciding with the arrival of the venture capital industry in the United Kingdom. Unexpectedly though, as we shall see this is the point where "development" in the Bristol cluster seems to stop. This is not to say that nothing happened, quite the opposite, Bristol continues to play host to many serial entrepreneurs who (as displayed in Appendix 7) continue to spin out new businesses. The challenge for Bristol is that venture investments have rarely been successful. Innovation has not been able to scale, resulting in a sort of 'entropy'. In the following sections we will seek to understand its causes better.

# Analyses

## Porterian Analysis

An analysis of Bristol using Porter's model begins to provide us with some clues as to this apparent state of cluster 'entropy':

***Factor Conditions***

Factor Conditions of the West Country tell an interesting story about the development of the cluster to date. As we have already heard, Fairchild chose the area specifically because there was nothing already there, however this is not to say that this area was without factor benefits. When Fairchild made its decision, its proximity to the international transport hubs of London, specifically Heathrow airport was very attractive as was access to the potential for scientific and technological infrastructure from universities located in Oxford, Bath, Bristol and Southampton and others. Working with industry, these universities oversaw the development of a highly skilled, highly engaged and highly entrepreneurial workforce. This human resource was encouraged to remain due to the continued existence of work opportunities and, as residents will attest, the highly appealing lifestyle available in the area.

As we have seen, the creation of INMOS would not have been possible without considerable public investment, though these were not specific to the region. Access to capital remains a problem in the cluster, despite much investment on promising technologies over the last 35 years or so, returns have rarely justified this level of investment and today investors are wary of the semiconductor industry as it is highly capital intensive.

***Context for Firm Strategy***

Whilst there is no doubt that the Bristol cluster has a wide diversity of firms, continually innovating and in competition, the sheer diversity of firms and the technologies they develop can make it difficult to resolve whether the firms are in direct competition. Similarly, the lack of significant venture investment activity over many years has reduced the number of venture and angel investors who are both willing and able (whether through lack of available capital or industry-specific knowledge) to support development in local industries. Few investors doubt the capacity for innovation and capability of the entrepreneurs in the area; however, semiconductors are generally not attractive to investors, as they are usually capital intensive and either highly specialised at one end of the industry, or highly commoditised at the other. Therefore not only is there fierce technological competition, but also fierce competition for available investment capital.

***Related and Supporting Industries***

In the semiconductor industry the two primary input resources are human capital and sources of financial capital, in these the time spent building the network in recent decades does pay dividends. Over many years, excellent connections have been built covering both these key resources. The universities, in particular Bath and Bristol, contain excellent links through relationships with key individuals such as Prof. David May and Prof. Joe McGeehan whose experience as both academics and entrepreneurs creates a strong commercial link between the universities and businesses. So whilst funding may be very challenging to acquire, the relationship networks mean that most entrepreneurs are able to access VCs themselves relatively easily (Marston et al., 2010).

***Demand Condition***

In Porter's model, localised demand is needed, and this is a struggle for this cluster. Part of the challenge lies with a general shortage of UK-based original equipment manufacturers (OEMs), a majority of whom are based out of east Asia; for example Lenovo, Samsung, Sony, HTC and the manufacturing division of Apple. In the heyday of the cluster in the 1980s, the UK was firmly in the PC manufacturing race and there was a ready demand for the innovations of INMOS and its contemporaries. This is rarely the case anymore, and certainly not at scale. The second problem is that of continued innovation developed by the firms themselves. Businesses are continually spun out to develop new semiconductor technologies that have yet to find a solid commercial application; this is supply-led innovation, and its origins are in the working practices established at INMOS (more on this later). This is not to say that these innovations do not find their way into products – current chip technologies are finding their way into many consumer devices such as digital set top boxes – but this market is relatively scattered compared to the huge volumes required in communications and computer devices manufactured overseas. In the main, there is a struggle to find commercial applications for these innovations; innovation continues, but at an ever-fragmented level.

## Dynamic Analysis

Trying to define the Bristol cluster through dynamic analysis is something of a challenge. The actions of government in the 1970s allow us to locate the period of the cluster's Antecedence, and the development of businesses such as INMOS and Plessey in the early 1980s took the cluster beyond an Embryonic stage into that of a Developing cluster. We could further argue that the sale of INMOS to Thorn EMI saw the cluster move into the Maturity phase. However it is difficult from the evidence of the interviews conducted for this report (Bartley, 2012; Knowles, 2012; May, 2012) to decide whether the cluster has moved from Maturity into Transformation or Decline as described by Aziz and Norhashim (2008). If Bristol was in Decline we would expect to see the fragmentation of the resident industry and gradual drift as businesses and entrepreneurs move elsewhere, however whilst there is evidence of this situation, there are many examples of highly engaged serial entrepreneurs and the continued development of new technologies (Knowles, 2012; May, 2012) and enterprises which show that the cluster is not completely in decline. Given the continuous development fresh businesses around new technologies and fresh approaches to the industry it would seem that the area is in a Transformative phase, however this has essentially been the case for the last two decades, which pushes the limits for credible application of this label. Credible or not though, this is precisely what seems to be occurring; a tightly bonded business community pursuing ever fragmentary aspects of semiconductor technology whilst chasing an ever smaller pool of available capital funding. The lack of clear success behind any one clear area of technological focus results in ever more Transformation. It would seem in this case the Dynamic Model is not sufficient in providing a clear enough explanation as to the status of this cluster.

## Comparative Model Analysis

If the Dynamic Model of analysis is unclear, application of the Comparative Model to the Bristol community is enlightening. With its technology focus, Bristol could claim to be Britain's answer to "Silicon Valley" – semiconductors are truly silicon technology – however the real problem for Bristol is

# Bristol – Plenty of chips, not enough muscle?

that unlike Silicon Valley, private financial capital never supplanted initial government interest. At a Cultural level there is much to compare between the two areas. Arguably the greatest gift that INMOS bestowed upon its geographical region was a highly entrepreneurial mindset amongst the engineers it produced. This gift was one of both accident and design: design because the INMOS actively sought to employ a highly diverse set of graduates; and accident because the relatively disengaged management combined with loose government funding encouraged these curious minds to take technologies in almost any direction that occurred to them. Insiders (Knowles, 2012; May, 2012) describe a collegiate environment that seeded ever more advanced technological examination (in the spirit of the famous Bell Labs), though ultimately this occurred at the expense of efficiently managed businesses. As INMOS gradually spun out these engineers, they readily created their own business and the culture spread. The comparison with Silicon Valley in this case is readily apparent.

Knowledge and Experience are again analogous with Silicon Valley. As mentioned earlier, ready access to an expanding pool of skilled engineers, combined with enough development over the decades in the local universities and a highly liveable environment have provided Bristol and its surrounds with a highly capable pool of talent. The main difference in this case though is scale – clearly the decades of success in Silicon Valley have seen it continue to expand and grow.

The main difference between Silicon Valley and Bristol lies in their different abilities to access finance. Silicon Valley grew to the point of self-sustenance primarily on the back of government military investment – both directly through research grants, and indirectly through outsourcing of major military contracts to specialist semiconductor suppliers. By the 1950s and 60s, financial critical mass had been achieved and the Valley became self-sustaining. For Bristol however, the sale of INMOS saw an abrupt end to government investment and whilst venture capital initially filled the gap in the 1990s, those initial returns were of little encouragement for existing or new VCs to increase total investment. A solid argument can also be made that the direct investment of government initially created a culture that lacked efficient financial management – innovation was not restrained by commercial reality (Knowles, 2012). Contrast this with Silicon Valley where defence projects arrived via large corporate contractors; consequently, start-up firms were required to display financial and corporate discipline in product development, something that proved vital as businesses refocused on civil markets.

The final Comparative Model area is that of networks; here Bristol once again displays its resemblance to Silicon Valley. Due to the highly skilled and technical nature of work in semiconductors, it takes considerable time to develop the requisite knowledge and capability to work in this industry and few universities are capable of providing this knowledge. Accordingly prospective graduates will be attracted to universities in Britain's southwest, and given the efficiency of business networks (there is a steady flow of entrepreneurs back and forth between business and academia) students will be readily identified and absorbed into the industry community. This familiarity also flows easily between businesses and potential investors. Help sought is readily offered and knowledge of key "hubs" (people in this case) is widely known with individuals readily accessible.

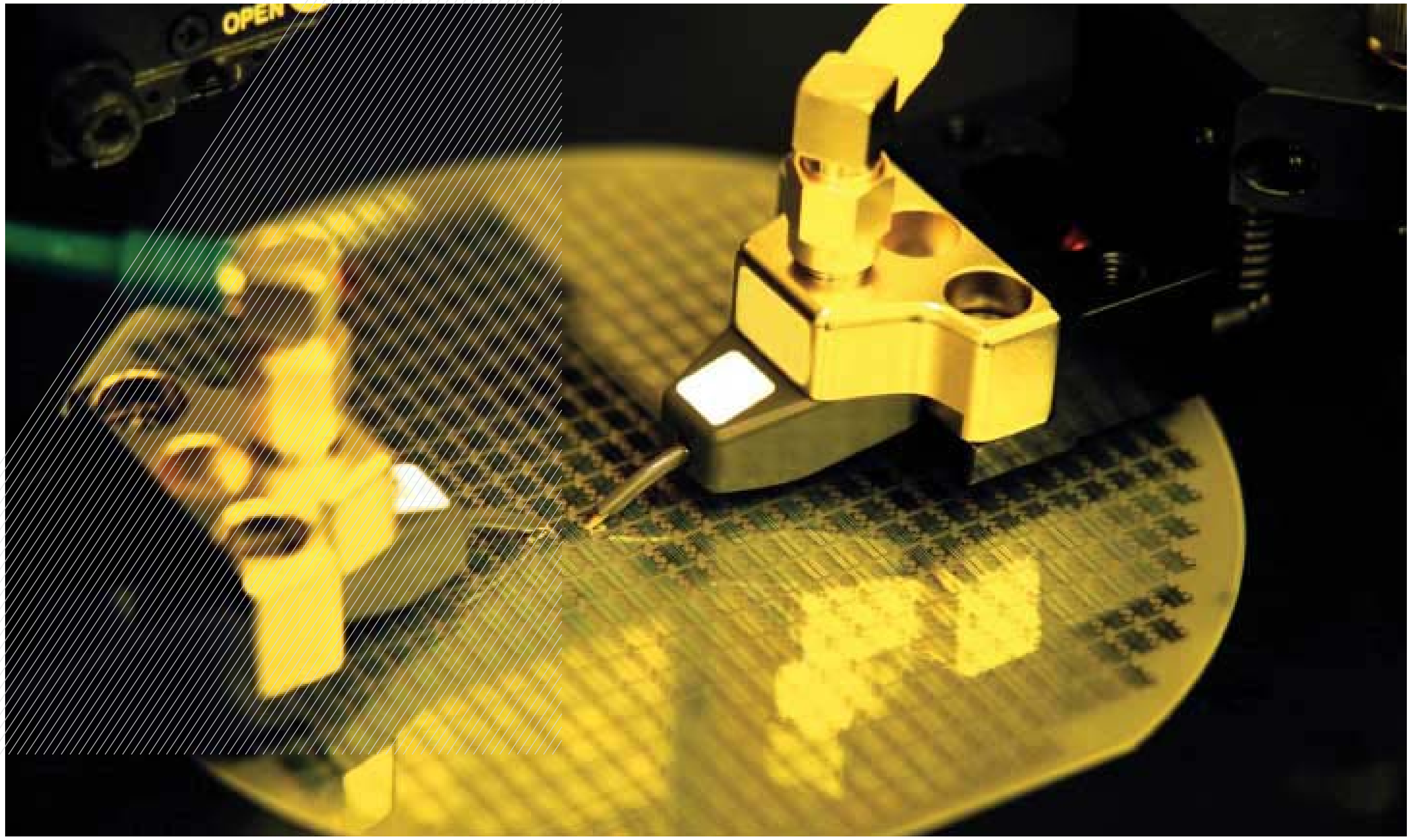
## Summary

It becomes clear through the use of the three analytical methods that the Semiconductors cluster surrounding Bristol is in a challenging state. The problems seem to be a combination of a lack of focus and a lack of finance, though which precipitates the other is arguable, this report would argue that the former has led to the latter. Whilst unrestrained entrepreneurialism





is admirable (especially given the comparative lack of it generally in the UK), it brings with it problems. An analogy that seems appropriate here is that of Apple in the late 1990s. At this time, prior to the return of Steve Jobs, Apple was a place of unrestrained innovation, this placed the company under severe financial duress, and it was near bankruptcy. With finite resources it simply wasn't possible to commercialise all its innovations; focus was required. When Jobs returned in 1997 he brought with him the discipline and credibility necessary to cut extraneous innovation programmes and focus on core products that he believed would be commercially successful without alienating his technology staff. Jobs was subsequently proven overwhelmingly correct. In this way, Bristol is in a similar stage to Apple – a highly networked collection of extraordinarily enterprising and talented individuals and businesses, competing with one another for dwindling capital resources. The question is whether a collection of businesses and entrepreneurs is capable of responding with the same sense of purpose and coordination as a single organisation.




# Formula One – An alternative cluster, based on victory

Formula One (F1) is a misunderstood sport. The common accusation levelled at this form of racing is that ‘it’s too much about the car and not enough about the driver’. This accusation shows a misinterpretation of the nature of the sport; Formula One is a team sport, a combination of driver, engineers, pit crew and machine, where the skills of the race engineers who put the car on the track are every bit as valuable those of the drivers. The history of the sport brings home this relationship; it shows how the expertise of those manufacturers over the last 60 years has created a world leading (indeed dominant) pool of expertise around high performance design and manufacturing in Britain, specifically, ”Motorsport Valley” to use its official government brand name (UKTI, 2012). Today British-based firms dominate this sport, and though they don’t fit into the typical venture capital growth model, we will see that they perform a role that is every bit as valuable to the UK economy:

> *Around 4,500 companies work in motorsport in the UK, and the sector supports 38,500 jobs, of which 25,000 are qualified engineers. The sector is also renowned for its enormous investment in R&D – equivalent to 30 per cent of its turnover, dwarfing the proportions spent by the UK pharmaceutical and IT industries. More than 15 universities in the UK now offer motorsport engineering and management degrees. (UKTI, 2012)*

### Background

Formula One, like many motorsports, traces its origins to the conclusion of World War II. It grew out of a combination of factors – a growth in the use of cars for leisure as well as utility purposes;

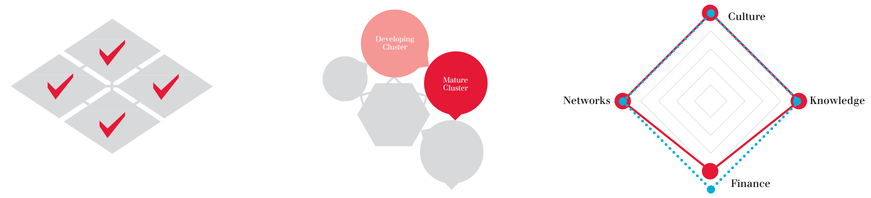




**Quick Facts** | **Cluster Location: *Midlands***

***“Motorsport Valley” – Midlands, concentrated around Silverstone Racing Circuit in Northamptonshire***

| | |
|---|---|
| Key Technology Focus | High performance automotive |
| Associated Technologies | Aerospace; advanced materials and manufacture |
| Key point in history | 1950 – Inaugural F1 Race at Silverstone |
| Keystone Companies/Institutions | Redbull Racing; McLaren F1; Mercedes GP Petronas; Williams F1; Shell Global Solutions UK; Lotus Cars; |
| Economic Highlights | Around 4,500 (UK-wide) companies supporting 38,500 jobs, of which 25,000 are qualified engineers. |
| Cluster Challenge | Maintain levels of engineering talent. |




a widespread engineering and mechanical proficiency that was a legacy of wartime necessity; and a DIY desire to make more of leisure time despite the lack of available resources (Aston, 1998). These factors were common across Europe; in Britain though, there were two crucial extra factors both would come into play as Formula One grew and matured, an abundance of disused airstrips, and the British propensity to form recreational clubs (Aston, 1998).

Evolving out of other forms of motorsports before the War, the inaugural race of the Formula One competition was held in at the Silverstone Circuit, Northamptonshire in 1950. As intuition would predict for a sport in which speed confers advantage, initially races tended to be won by the cars with more powerful engines. However as the sport matured in its first decade, things began to change. The key behind the change lies in a few crucial aspects of motor racing – straight-line speed alone will not win races; and racing tends to be conducted on excellent road surfaces, usually disused airfields. Both these aspects gave British engineers an advantage as post-War Britain had an abundance of disused airfields and severe shortages of the materials required to construct versatile and durable engines, but ready access to specific types of engines which could be repurposed. These two factors forced British garage engineers to develop racing cars which innovated beyond the engine itself to find extra speed by considering the car as a whole, one that would be fast over the whole track, not just in a straight line. When combined with the propensity of Britons to form clubs – in this case the 500cc and 750cc Clubs – this combination of innovation, competition, knowledge and network effects set the tone for decades of dominance as will be discussed later.

In the decades that followed, Formula One played host to a range of innovations: chassis design, aerodynamics, materials development, advanced engine design, and even into operational advances (Jenkins, 2010); some innovations proved ineffective or inefficient, but successful ones were quickly adopted on the track[10] and on the public roads. Throughout this period, however the key factors of interest to this discussion on clustering are the combination of intense competition, access to finance, phenomenal technical achievement and rapid dissemination of knowledge.

## Analyses

### Porterian Analysis

***Factor Conditions***

Factor conditions in Formula One are peerless – given its highly competitive nature only firms with access to the best possible resources are even able to make it to the starting line. Distribution of factor conditions can then be considered as somewhere between the excellent and highly-

[10] *Indeed many innovations like the safety system Anti-lock braking (ABS) made their way into mass-produced automobiles.*

# Formula One – An alternative cluster, based on victory

excellent. Even teams that occupy the lower areas on the grid have access to high quality resources whether they are human, infrastructural or scientific. More prestigious marques are able to draw even higher quality resources, whilst their performances on the track attract more valuable sponsorship.

***Context for Firm Strategy***

Whilst Formula One is sometimes derided as lacking competition, this actually misunderstands the nature of the sport. The competition is driven by a range of contributors – drivers, engineers, designers, the companies themselves, indeed everyone who works together to put the car over the finish line. In this context the sport is pure competition. An interesting aspect of this competition though runs somewhat counter to Porter's requirement for locally based rivals (1998). Whilst there are a large number of Formula One teams based in the Midlands of the UK (therefore certainly satisfying the locally based requirements) there are other crucial players who are located elsewhere in Europe. As we have seen from the history of Formula One, and its development especially amongst enthusiasts in Britain, arguably geography of base was less important than the opportunity to interact on a regular basis – i.e. race weekends. These race weekends provided the crucial environment for dynamic exchanges of ideas where the benchmark behind success and failure could be readily tested out on the track.

***Related and Supporting Industries***

The location of many Formula One teams in the Midlands is no coincidence, a cursory glance at a map will show that many are in close proximity to Silverstone, the home of the British Grand Prix, but more than that, the Midlands are host to a wide range of specialist motorsport suppliers (Aston, 1998). This location advantage works along the supply chain, as Silverstone has remained a fixture on the Formula One calendar for many decades, so a range of suppliers has developed in proximity to the circuit – for example the Formula One team of German manufacturer Mercedes Benz, is based in Brackley and uses engines and other systems designed in Brixworth, 20 miles away (UKTI, 2012). However, these suppliers go beyond high precision automotive, as the importance of fields such as aerodynamics and engine development mean that many aerospace suppliers contribute to the knowledge, materials and components that drive high performance racing. In these circumstances the existence of aerospace industries in areas such as Stevenage (UKTI, 2012), provided additional support.

***Demand Condition***

The specifics surrounding the Demand Condition in Formula One are interesting. In many cases the teams themselves create both supply and demand in the Midlands. Whilst top teams do not change a great deal – teams like Ferrari, McLaren and Williams have been racing under the same name for decades, there are fairly regular changes in the lower levels of the competition. In this case new teams are created by rebranding existing teams; when viewed as storehouses of talent and highly specific knowledge (much like in areas such as ICT) it is more viable to buy an old team outright and rename it, than it is to start from scratch and build expertise.

## Dynamic Analysis

There is little argument as to where Formula One is positioned when using Dynamic Analysis – it cycles between Development and Maturity via Transformation on a seemingly constant basis. If anything, it should continue to grow – its access to sponsorship money has enabled it to grow enormously in the last 30 years, despite various economic changes and legislation banning tobacco sponsorship – previously a vital form of revenue for the sport. Furthermore, the sporting competition retains enormously high barriers to entry as technical proficiency can take many years and many hundreds of millions of pounds to acquire. Even rule changes designed to reduce team expenditure have reinforced the value of businesses within the cluster – less sponsorship money forces teams to invest more carefully in expertise. Provided there is a ready audience for the sport, the cluster should thrive in the future.

## Comparative Model Analysis

The story of the rise of Formula One cluster in the UK has some interesting comparisons to our comparative model. Both Formula One and Silicon Valley developed in their respective countries following World War II; both were driven forward by highly skilled, technically expert teams working out of garages[11]; both benefitted enormously from public investment in the defence industries (Aston, 1998); both were and still are driven by ruthless competition. However, probably the greatest similarity lies in their cultural make-up. Saxenian (1996) has noted the perception that workers in Silicon Valley were engaged in something bigger than just individual firms; the same can be said of Formula One. This is not to say that there isn't a pecking order of team preferences for those involved; however, just being involved in the sport signals a level of expertise that no other motorsport (and associated industries) can provide to those participating. These two clusters then share a culture that glorifies engineers and technical capabilities, obsesses over high performance, scrutinises the performance of others and thrives on competition. This occurs to the extent that for a number of academics, the study of Formula One has become a point of references for studies into the cultures of competition:

> *F1 teams have to both develop their own innovations and imitate those of their competitors to remain competitive. It is this continual pressure to be aligned to the existing environment and to adapt to future environments that makes F1 a particularly rich context to study competitive performance and change. (Jenkins, 2010)*

As discussed earlier knowledge and experience are not just crucial to success in Formula One they are a prerequisite for participation. One of the best demonstrations of this principle was the effort required by global car giant Toyota; announcing their intention to enter the competition in 1997, they entered in 2002 following years of testing and withdrew in 2009 without ever winning a race ("Toyota Racing," 2012) (Ollivault, 2012). Knowledge and experience thus play a huge role in this cluster. In another parallel with Silicon Valley, much of the knowledge developed by firsthand experience of participants has, over the years, become integral to many institutions. Indeed the ready access of Formula One to funding combined with the intensity of competition mean that the sport has become a test-bed for the commercialisation of technologies, especially in associated fields such as aeronautical engineering and materials science:

> *More particularly, UK Formula One constructors benefitted directly from the development of carbon fibre composites, pioneered at the Royal Aircraft Establishment (RAE), Farnborough, during the 1970s. Carbon composites had replaced aluminium in all UK Formula One cars by the early 1980s. Today carbon fibre composites comprise all the chassis components, and experimental carbon fibre engines have already been built. (Aston, 1998)*

Viewing the Formula One cluster from a financial perspective requires us to step away from the typical business model. Whilst many Formula One teams are linked with or contribute directly to manufacturers, they are not traditional businesses in the sense that their intention is to convert capital to deliver sporting victory rather than converting capital to deliver more capital. However this model has parallels, in that delivering victory requires substantial capital investment in many other businesses and people. The model is also interesting as the funding of the sport has changed considerably in the last 60 years. If Silicon Valley found its expansion through the creation of the modern venture capital business model, then Formula One was a world leader in the realms of sports sponsorship as far back as the 1970s. Much like high growth firms in Silicon Valley, Formula One constructors would not get to the starting line without the capital provided by sponsorships.

As well as relying on an unusual source of finance, the comparative aspects of the Formula One cluster provide us with a crucial caveat to Porter's doctrine of locality and points to a wider

*[11] A bit of artistic license has been taken here. Whilst Formula One literally grew out of garages as did Silicon Valley pioneering firm Hewlett Packard, as Silicon Valley grew the reality was different.*

# Formula One – An alternative cluster, based on victory

definition of a network. As discussed, in the early years of the sport, garage constructors from around Europe worked independently but in Britain their propensity to club together conferred a distinct advantage, much to the irritation of Ferrari's patriarch Enzo Ferrari, who referred to them disparagingly as "garagistes":

> *With hindsight, Enzo Ferrari's pejorative remark backfired, because the "network" structure, which still exists, has been fundamental to the sustainability of advanced auto-engineering in the UK. The structure not only created competition among designers, constructors and suppliers, but also encouraged cost-effective innovation. The club structure of UK racecar engineering fostered an extraordinary degree of intellectual freedom that was probably unique to the UK. (Aston, 1998)*

But when teams gathered together to race, they were provided with their opportunity to network and 'share' innovations. The following passage provides evidence of this rapid dissemination[12] of knowledge amongst constructors:

> *Wings on F1 cars enhanced grip by generating downforce from forward motion, the opposite effect of the lift generated by an aircraft wing. Wings were quickly adopted in F1 with Lotus using front wings made from inverted helicopter blades at the Monaco Grand Prix on 26 May 1968. Both Ferrari and Brabham then introduced cars with rear aerofoils at the Belgian Grand Prix held at Spa-Francorchamps on 9 June 1968. This innovation diffused quickly throughout the teams and by 22 September 1968, at the Canadian Grand Prix held at St Jovite, every car on the grid was using some form of wing. (Jenkins, 2010)*

The network advantage conferred by the Formula One cluster, even in its dispersed form, is conclusive.

## Summary

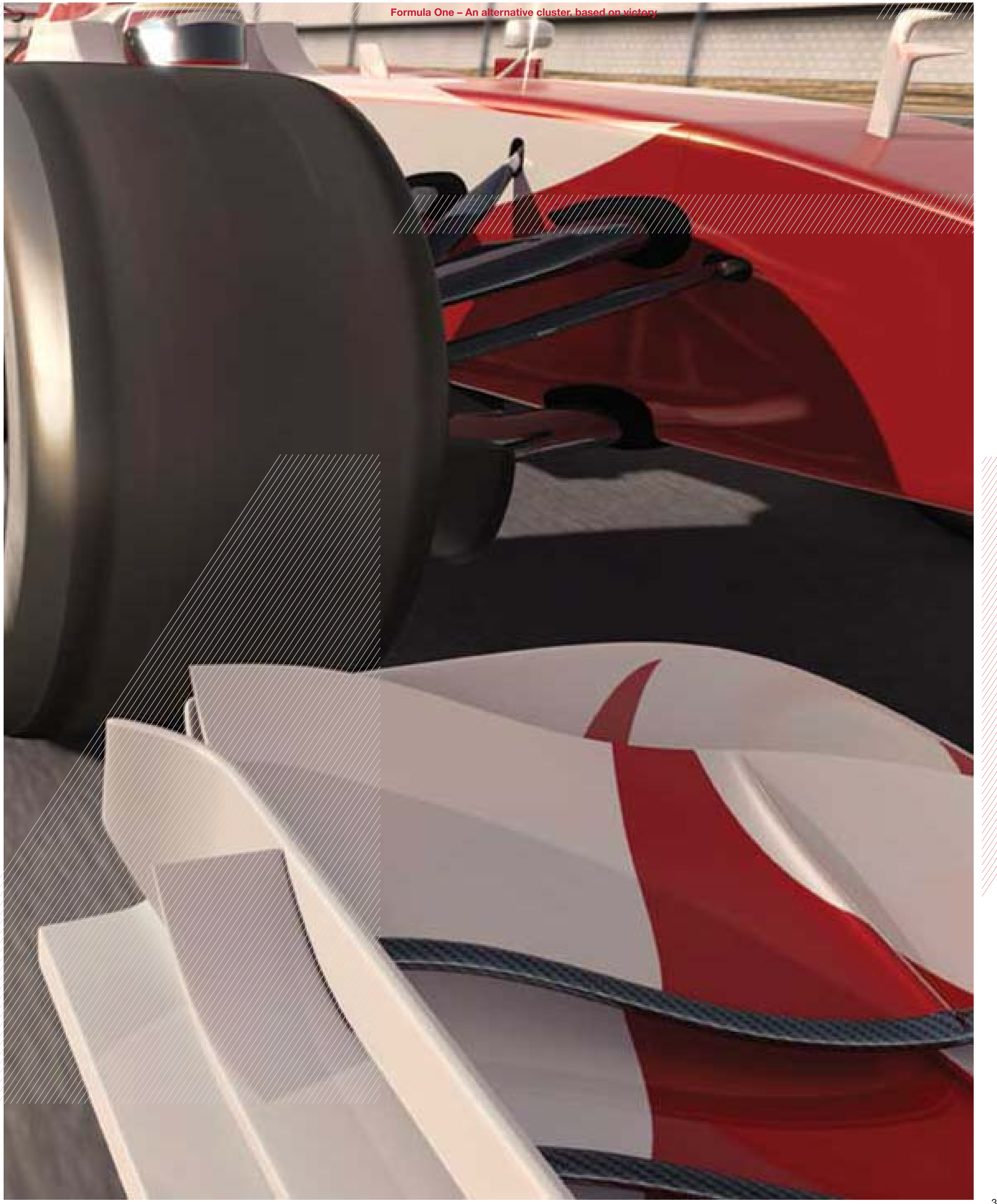
So it is clear from the growth of Formula One that British teams particularly benefitted from two different forms of network dynamic, their geographic proximity as well as the ability to meet and disseminate on race weekends. This allowed ideas and standards to spread at a more rapid rate, conferring an advantage when compared to more geographically distant teams such as Ferrari. It is no surprise, then, that over the years a greater number of teams are UK based – 8 of the 12 constructors this season and 58 of the 137 constructors in total. As a final note aside from Ferrari who hold the record for the most races won, every other team in the top ten list is or was British or British-based ("List of Formula One constructors," 2012).

Although not strictly the same form of business cluster as the others this report investigates, there is much that the Formula One cluster of the Midlands can teach those interested in developing policy to aid the development of other clusters. Not every sector will have access to the sort of sponsorship money that the sport attracts today, however the origins of the sport provide genuine enlightenment. The original spirit of innovation within tightly constrained parameters on a limited budget conferred a competitive advantage for British teams that remains today. The lessons for other innovative industries is clear – what matters are skills, culture and networks. Only once these elements are established will the injection of finances have the most impact.

[12] *Highly competitive teams will quickly see changes made by other teams that confer an advantage.*







# Aberdeen – Silicon meets Hydrocarbons

If the Formula One Cluster fails to gain attention due to its unusual nature, it can be argued that ignorance of the hydrocarbons cluster around Aberdeen is due to a combination of factors: its remoteness from London; an undeserved perception as a low-tech industry; the fact it is ideologically unfashionable; and the classic problem of falling between the gaps in the Standard Industries Classifications.

## Background

As with many clusters, Aberdeen's was created by its proximity to resources; as the North Sea oil industry thrived, so did Aberdeen. Its defunct fishing port provided the infrastructural basis for newly arrived oil companies and throughout the 1970s and 80s the town boomed. However as the early finds became depleted and new deposits became smaller and more dispersed (often deep under turbulent seas), so new techniques and machinery were required to extract from existing deposits, and to locate and extract new deposits. Yet these circumstances provided a catalytic force for innovation in local industry.

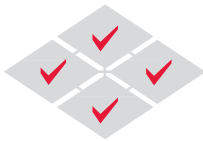
> *Creating offshore production infrastructure for the hostile North Sea forty years ago demanded huge and rapid engineering and technological innovation from UK firms. Since then, 470 offshore oil and gas installations have been built there, servicing about 5,000 wells and 10,000km of pipelines. (UKTI, 2011)*

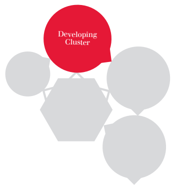
The necessity driving Aberdeen's mastery of innovation has placed it at the forefront of the technological revolutions that have driven the hydrocarbons industry. These innovations had

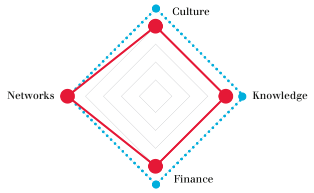




| Quick Facts | Cluster Location: *Aberdeenshire* |
|---|---|
| Key Technology Focus | Oil and Gas industry |
| Associated Technologies | High tech manufacturing and ICT |
| Key point in history | Early 1970s – Development of North Sea oilfields |
| Keystone Companies/Institutions | Halliburton; Schlumberger; BP; Shell |
| Economic Highlights | UK engineering firms have annual order books worth £15.6bn with £3.7bn of new projects each year. Up to 70% of the value of new contracts is for projects outside the UK. |
| Cluster Challenge | Maintain rates of investment and innovation to maintain global leadership position. |






many different facets as the challenges faced by the industry were often simultaneous. For example, as existing deposits began to become depleted, advances in exploration techniques were required. These advances led to high-resolution scanning techniques, which enabled new, more dispersed deposits to be discovered and mapped in ever greater detail.

Accessing and exploiting these new deposits then required advances in the machinery itself; whilst these new challenges occurred in a number of aspects of the extraction process, many innovations developed simultaneously. To tap the smaller, more dispersed deposits, innovations in drilling equipment produced drill heads which could be "steered" as they bored through the rock.

Many new deposits were discovered below far deeper seas than existing platforms and extraction techniques allowed. Initially, resulting innovations concentrated on allowing rigs to operate in deeper waters delivering advances in submarine robotics, rigs that were tethered to the sea floor, advances in the drilling process, the so-called "down-hole tools":

> *UK drilling contractors have global reach and can bring drilling ships, semisubmersible rigs and jack-up rigs to play at significant depths. Unique drilling and borehole sensor technology developed in the UK can reduce costs and maximise data capture through real-time measurement while drilling (MWD) and logging while drilling (LWD), thus optimising wellsite appraisal. (UKTI, 2011)*

However as deposits were discovered in ever deeper seas, advances allowed the operations infrastructure of the rigs to be effectively moved onto the sea floor, operating either automatically or via remote control.

Today as the world's energy needs drive oil production into more challenging environments, the skills, innovation and experience of the businesses and individuals in Aberdeen that allowed it to become a global leader will become ever more necessary providing opportunities for these businesses to become global leaders in an expanding business environment.

# Analyses

## Porterian Analysis

***Factor Conditions***

Aberdeen has a wealth of the specialised inputs required of a cluster. Over the past 40 years it has steadily built up the range of resources required to satisfy the demands of the Porterian model of high-quality inputs. Each of these elements is linked to others – starting with access to natural resources (the basis of the cluster), capital resources were deployed, physical infrastructure was developed and human resources were imported. Over time these led to the

# Aberdeen – Silicon meets Hydrocarbons

development of scientific and technological infrastructure in the form of the universities (or specific departments within existing universities across Britain), furthering the development of native human resources, informational and administrative infrastructure. Finally as the cluster formed and these elements fell into place a new form of capital resource (venture capital and private equity) arrived which not only made use of the existing resources but enabled the development of new forms of technology, enabling a new and continuing cycle of development.

***Context for Firm Strategy and Rivalry***

Aberdeen is characterised by competition; at all stages of the value chain there is incentive for an active rivalry. Start-ups and SMEs push technical boundaries with new innovations, the most promising are funded by a relative wealth of well informed venture capital and private equity firms (locals estimate at least 10 firms, unusual for an ecosystem of this size). These SMEs feed either smaller sized specialist suppliers or the much larger oilfield services firms (OFS) such as Schlumberger and Halliburton ("Oilfield services," 2012), who work with oil majors like Royal Dutch Shell and BP. All parties are represented within the geographic ecosystem of Aberdeen.

***Related and Supporting Industries***

As mentioned previously, locally based suppliers work across the cluster in Aberdeen. These suppliers provide access to a full range of products and services required of upstream oil and gas – from scanning and discovery to extraction and decommissioning.

In total the UK oil and gas supply chain is impressive, an estimated 440,000 people are employed in the entire supply chain for the UK's offshore oil and gas industry. Together the industry is estimated at $29bn annually (UKTI, 2011). As the main hub of the UK's activity in the North Sea, much of this supply chain runs through Aberdeen and on to a global customer base – the UKTI (2011) estimate that exports alone account for $9.8bn of goods and services.

***Demand Condition***

Aberdeen is host to a wealth of demanding customers. These include not only all the international oil majors - ExxonMobile, BP, Chevron, Royal Dutch Shell; major OFS companies like Schlumberger and Halliburton - local AB-based firms and also in recent years some of the biggest National Oil Companies (NOCs) such as Saudi Aramco (Saudi Arabia) and Petrobras (Brazil) have been establishing a presence (though not in production itself). The cumulative effect of this attention results in both a global presence for the area and the evolution of a highly dynamic cluster, as the next section discusses.

## Dynamic Analysis

Aberdeen is a particularly clear example of a cluster that has grown through the 6 stage dynamic cycle to find itself caught in a virtuous loop out of the forced necessity of exploiting ever more challenging oil reserves. The "Oil Rush" (Fleming, 2012) of the 1970s and 1980s pushed Aberdeen from Antecedence to Maturity at a rapid rate driven by huge influxes of capital and other resources. Interestingly this was a conscious decision taken by the government of the UK at the time who found itself in challenging economic circumstances (Hatakenaka et al., 2006) and rapid exploitation of these resources was seen as a necessity. This action seems to have depleted the easily accessible resources faster, which whilst a negative development for the UK economy forced Aberdeen out of Maturity into the Transformation phase, ultimately accelerating innovation in this cluster with greater levels of patent development that similar North Sea regional hubs (Hatakenaka et al., 2006)

## Comparative Model Analysis

Key to Aberdeen's success has been the balance of factors that drive the world's most successful technology clusters, especially those we find in our model Silicon Valley. Even a brief discussion with either entrepreneurs or investors reveals, to a remarkable degree, a business culture driven by entrepreneurialism. Businesses are regularly spun out of the larger oilfield services businesses (OFS) which sit at the "top" of the business ecosystem, whilst the universities – Robert Gordon, Edinburgh and Glasgow produce a stream of innovative patent based businesses, from technologies to operations and processes.

The origin of these businesses sheds light on the second aspect so important with our comparative model, namely technical knowledge. The classic misconception of the hydrocarbons business is that it is low tech. As Aberdeen's own history has shown, the hydrocarbons industry is constantly driven by the necessity for innovation; today the exploration and extraction of oil and gas requires incredibly advanced hardware and software. In this context the cluster in Aberdeen is awash with world class human capital that accumulates across generations of businesses; today's entrepreneur with a successful exit is likely to invest both time and money into a new start-up, or move on to become an angel or venture capital investor who vets, selects and invests in the best of a new generation of businesses.

The next aspect of the comparative model is access to finance, here Aberdeen again has numerous advantages. Seed and development funding for these start-ups arrives via a healthy market rich with knowledgeable angels and venture capitalists (VCs), themselves experienced in the industry and with deep networks across the market. This strength and depth often sees competition amongst investors including angel networks like Aurora or VCs like Energy Ventures, Lime Rock Partners, Scottish Equity Partners and new arrivals such as the Business Growth Fund (Sibson, 2012), looking to sign on high potential start-ups. Interestingly, investment opportunities exhibit the tendencies of the subsea oil and gas deposits – they require skill and experience to access but managed properly can be highly lucrative. For entrepreneurs and investors the typical path to exit is via a trade sale to one of the technology-dependent and major OFS companies like Schlumberger or Halliburton who are both acquisitive and cash-rich. Exits tend to be in the tens rather than the hundreds of millions, and whilst few companies become household names, they do generate solid returns for entrepreneurs and investors which is then redeployed into new ventures. If there is one major challenge though, it is not with equity finance, but debt finance:

> *There is quite an issue where the national problems of the banking industry have gone barrelling into our section when our commodity is hitting $100 a barrel... there's no market failure on the private equity side, but certainly a market failure on the debt side. (Fleming, 2012)*

The final aspect of the comparative model is Aberdeen's networks. Here Aberdeen benefits from being both small geographically yet a key global hub, in what is effectively a very specialised and tightly knit industry. Excellent links run like a spinal cord in all aspects of value chain – from universities and academia, through the start-ups and SMEs, taking in the investment community and finally into the OFS companies, oil majors and national oil companies around the world. This flow is constantly refreshed by the natural churn within the industry and insiders cite that the liveability of Aberdeen itself as a major driving factor behind its popularity – its residents may span the globe following business, but they return to Aberdeen and its networks, thereby ensuring their knowledge and contacts are passed on.

# Aberdeen – Silicon meets Hydrocarbons


## Summary

Despite its relative obscurity, Aberdeen is one of the most exciting technology clusters in the UK. It is an industry driver and highly competitive in an innovative industry; it is highly dynamic and remains so in what is perceived (incorrectly) as a mature industry. In the 4 key aspects of the comparative model it matches Silicon Valley in all but the scale of its exits. In this light, Aberdeen should be viewed as an example of how clusters can and should work — it is a British clustering champion. However, its position is not without its dangers. As mentioned Aberdeen has been forced into a cycle of Transformation driven by the need of technical development, but has found that each time Transformation has been required, it has led to a new Developmental phase. Therefore policies that reduce the areas desirability as either a centre of global oil and gas innovation, or are prejudicial to operating businesses of many kinds may result in the gradual decline of the area. Ironically the lack of attention to this point may be a source of Aberdeen's ability to get on with what needs doing.




# Conclusions

The preceding case studies have much to teach policymakers. First and foremost they are clear evidence (if it was actually needed) that there is a thriving technology industry beyond the M25. This report focused on these five regions, however the study could easily have expanded to include many others such as the computer games industry in Edinburgh; biotechnology in Oxford, Nottingham and Norfolk; aerospace in the Home Counties; creative sectors in Manchester and Glasgow; or developing greentech industries in the Northeast of England and Northwest of Scotland. The clusters featured in this report can each tell us something different once we understand them better.

Cambridge, by some margin the most dynamic and successful of the UK's clusters is a world leader in both lifesciences and ICT, but it is only in the last two decades that it has begun to fulfil its potential. Its first three decades saw the tireless grassroots efforts of individuals and businesses gradually building the cluster to the point that investment returns created a self supporting start-up environment. As a result today a healthy flow of capital suffuses the market, and good businesses have solid chances of receiving growth capital.

From Manchester we have an example of a cluster that has potential – there has been plenty of public investment, yet this has done little to guarantee the future of a fledgling business environment. In reality it will be the development of networks between research bodies, both public and private, businesses and investors that will guarantee the future of this cluster. This development has taken on an extra dimension of relevance with the advances in research and potential commercialisation of Graphene.

Bristol provides a mixture of lessons. Of all the UK clusters, its pedigree, its focus on semiconductors and highly networked entrepreneurial nature provide it with the most legitimate claim to be the UK's "Silicon Valley". However it also provides examples of some of the consequences of a lack of funding. Today it has all the resources a cluster needs to succeed, but lacks the serious and experienced investment that the focus on semiconductors requires to have a chance of succeeding.

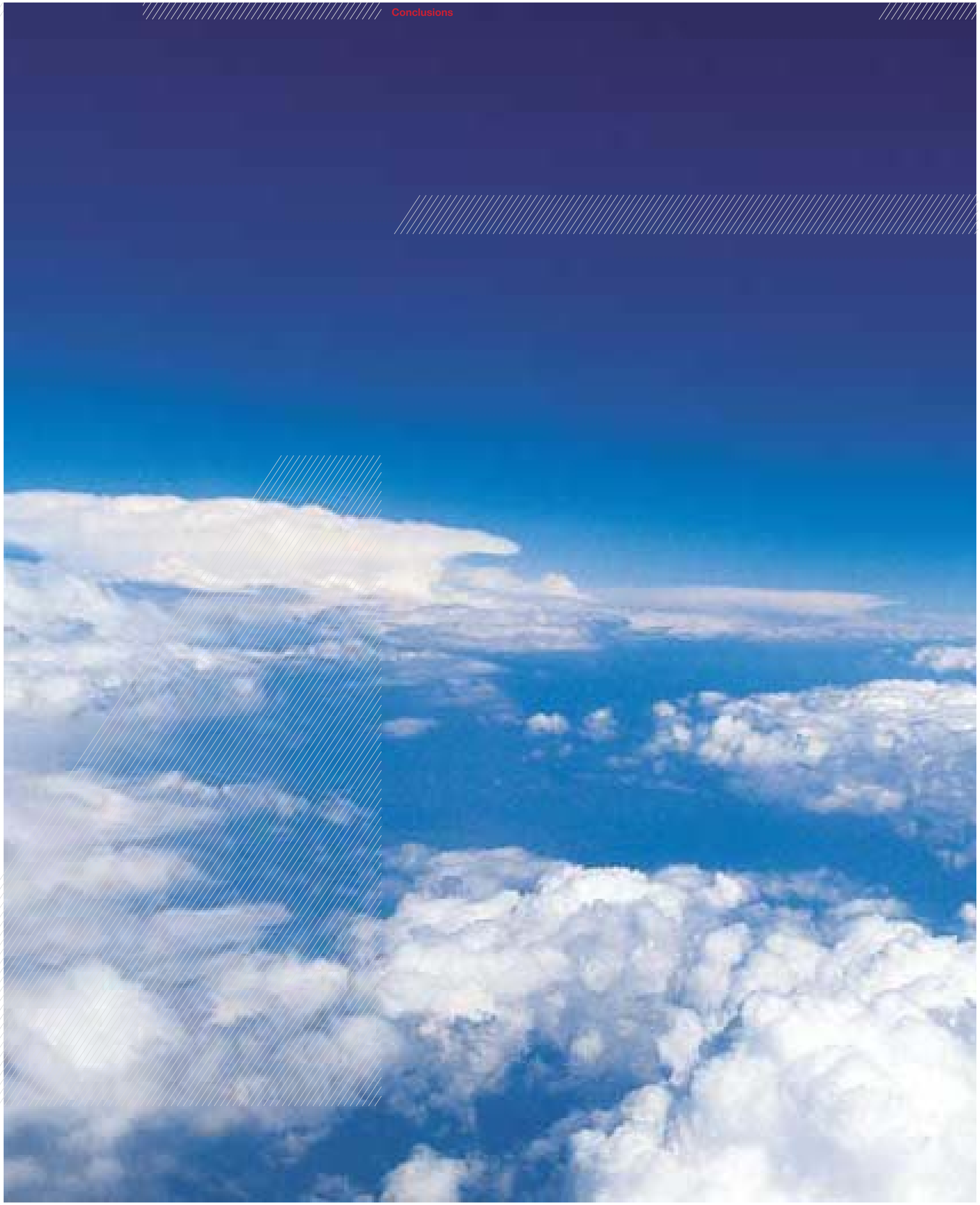
It is often said that the UK's underperformance is somehow cultural; however Formula One provides the perfect retort to this false assumption. Since 1950, Britain has been at the forefront of technological developments in the most challenging form of motorsport and today British-based teams dominate the sport mostly by weight of their highly competitive cultures and ability to raise funding for performance. It is interesting to note that the development of the "garagistes" in motor racing reflects a similar development culture of new technologies in Silicon Valley.

Finally in Aberdeen we have an indisputable example of how technology can be found in the unlikeliest of places and in industries not normally associated with innovation – a problem partly caused by its distance from London, and the vagaries of the UK Standard Industry Classifications. In such circumstances ongoing national debate over Britain's supposed inability to develop a "Silicon Valley" and the consequential efforts by government to 'rectify' a problem that doesn't exist, take on a new light. If we are better able to identify and encourage clusters, attitudes will change.

Finally, the key point the report aims to make is that whilst there is a temptation to try and create clusters from scratch, often there is no need; the UK has always been home to a variety of world leading clusters. Instead of attempting to create new ones from scratch, effort can be better directed to understand and nurture what already exists. This has always been a Tech Country.







# Recommendations

So what do these case studies mean in practical terms for policymakers? Reviewing the case studies, as well as the theoretical study that underpins the methodology, leads to recommendations falling into seven broad categories:

***Knowledge Workers***

The importance of highly trained workers in the technology based industries cannot be understated. All the clusters researched for this report rely on a steady and expanding stream of highly skilled workers. Some clusters such as Formula One, and Oil and Gas in Aberdeen are world leaders in their field and can command the very best for that reason, whereas others like Bristol and Cambridge compete on a world market for these skilled employees.

There are many ways these efforts can be assisted, and with the benefit to the overall economy in mind the following should be strongly considered:

- Greater priority should be directed towards development and training in STEM (Science, Technology, Engineering and Mathematics) graduates. The ability of the UK to compete in IP-related industries depends on this.
- Expanded immigration programmes for STEM workers. It may take many years to bring through the generations of workers required to fill the gaps, whilst it may take only a few years to lose a globally competitive position. At the moment, skilled STEM workers still want to move to the UK, so this should be embraced lest other countries with more immigrant-friendly regimes assume industry leadership[13]. It should be noted this is not just a matter of filling quotas, it is about global perception. Current immigration policies and rhetoric risk alienating workers before they consider emigrating.
- Innovation should be considered as part of a chain from graduate through to business; today's university research becomes tomorrow's new business. Investors consider a business from research through to market exit, so should policymakers.

***Funding and Finance***

When the development of an industry relies on supply of capital, it can be tempting for policymakers to flood the market with capital. However as we have seen in Cambridge and Aberdeen, the two most successful of our case studies, the most valuable and sustainable capital is privately sourced. Indeed at the early stages excessive public capital will kill or at least seriously distort a cluster (as may have been the case in Bristol). As shown with the development of Silicon Valley and indeed Aberdeen however, there is a role for public investment in technology industries provided that the investment is not direct, but comes in the form of contracts for business. In the case of Silicon Valley investment that filtered through from the various arms of the US military via larger corporations who held their suppliers to tight commercial terms. In policy terms this report would recommend:

- Private capital is a more reliable indicator of market demand and will build a more sustainable cluster. Direct public investment or supply of capital should be avoided as it will distort the market, crowd out private investors and likely destroy a cluster in the long term.
- Public investment is viable where it creates demand, such as government contracts and procurement. Investments and projects must be run under competitive commercial terms.
- Policy efforts should also be aimed at creating conditions conducive to private investment. Examples of target areas include reduced capital gains taxes and further programmes such as Seed Enterprise Investment Scheme (SEIS).

***Regulatory Policy***

Although the regulatory aspect of policy falls into a range of categories, there are two specific areas highlighted by the cluster studies. From Formula One, policymakers can learn interesting lessons from the sport's governing body, the Fédération Internationale de l'Automobile (FIA) whose regulatory interventions are ostensibly to increase safety and competition, but often result in extensive innovation by the teams. The terms of rule changes and objectives themselves are strict; how these terms are met is open to innovation. Compare this with concerns about excessive regulation (developed with the best of intentions) imposed locally on businesses in Manchester which tends to stifle innovation and increase barriers to entry for innovators.

- Regulatory policy should be developed with the ends in mind, rather than the means. For example, if the regulatory objective is "sustainability", provide businesses with a target to hit rather than the method by which to do so.

***Transport Infrastructure***

Virtually all case studies highlighted the importance of transport infrastructure. The Bristol cluster owes its existence in part to easy access to Heathrow Airport; Cambridge has quick access to London and international markets via Heathrow Airport; and Manchester has benefitted from the expansion of Manchester Airport and would benefit from easier access to other UK-based hospitals and pharmaceutical firms. Based on this it is clear that quick, reliable and cost effective links to national and international business and research partners are absolutely vital for the health of a growing cluster. In policy terms this means:

- Urgently proceed with full development of HS2 Phases 1 and 2. Develop plans to extend the western branch up to Glasgow, and the eastern branch to Edinburgh. Doing so will provide a more rapid and easy flow of business within the UK as well as reducing traffic and congestion at the UK's airports.
- To further enhance the UK's attractiveness, expedite the development of Heathrow or develop a suitable alternative international air transport hub.

In both cases the continued failure of all parties to provide leadership and plan in the future interests of the UK economy results in a loss of business confidence and acts as an inhibitor to investment.

***Industrial Policy***

Common to all officially defined clusters is their cross industry reach, this aids component businesses' efforts to disrupt orthodoxies of their respective industries. For example, Formula One is not just related to high performance manufacturing, it also crosses into materials sciences, aerospace engineering, industrial chemistry and a range of other highly technical sectors. This means that industrial policy which is based upon the Standard Industry Classification (SIC) can have unintended outcomes for cluster businesses because the SIC does not readily permit identification of industry cross-over, a key point for innovation. This has various policy consequences:

- The Department of Business, Innovation and Skills should investigate the interrelation between industry classifications as a priority, using findings as a guide to future policy development.
- Learn from the examples of the 1970s that "picking winners" in industry, also be wary of "picking industries".
- Learning from the ignorance of Aberdeen, avoid ideology that favours particular industries whilst penalising others.

***Developing Networks***

A key finding from the most successful of the clusters, Cambridge, was the need to allow grassroots movements to form, and to give them time and support to do so. This is vital for a number of reasons: it ensures that a cluster contains its own unique DNA, one based upon the resource mix native to the cluster; it also ensures that the cluster is self-managing.

*[13] The 2013 inauguration speech of President Obama has sent a clear and unambiguous message that he intends to make the United States a place of innovation that welcomes and values immigrants.*

# Recommendations

A second aspect of networks is understanding their nature. From Formula One, we learned that cluster networks are not purely based on geography, they are also based on interaction in a competitive environment.

In terms of policy, we recommend the following:

- Be wary of intervening in the management of a cluster itself, especially when it comes to "self-definition" of the cluster. Entrepreneurs are instinctively wary of government and outside influence, and intervention may alter the nature of the cluster itself.
- A key opportunity for policy involvement, is acting as a facilitator, either by removing regulatory hurdles faced at a local level (something that would have helped Cambridge greatly in its early years); or assisting in efforts to broaden and deepen business networks (something that would be helpful in Manchester at the moment).
- Embrace technological methods that bridge geographical gaps between clusters. Current examples such as Cisco's National Virtual Incubator provide an example of how technology makes such connections possible.
- The final area for policy is to work with local business networks to access specific resources, either locally (such as graduates and staff), or further afield such as international business connections, through initiatives like trade missions.

***Cultural Considerations***

The final area of policy consideration is one of culture. It is virtually impossible to "legislate" cultural change, however despite its reputation as a home of liberal thought, the UK is still very centralised in its cultural influence. As a consequence, government has the ability to direct many aspects of the nation's cultural agenda.

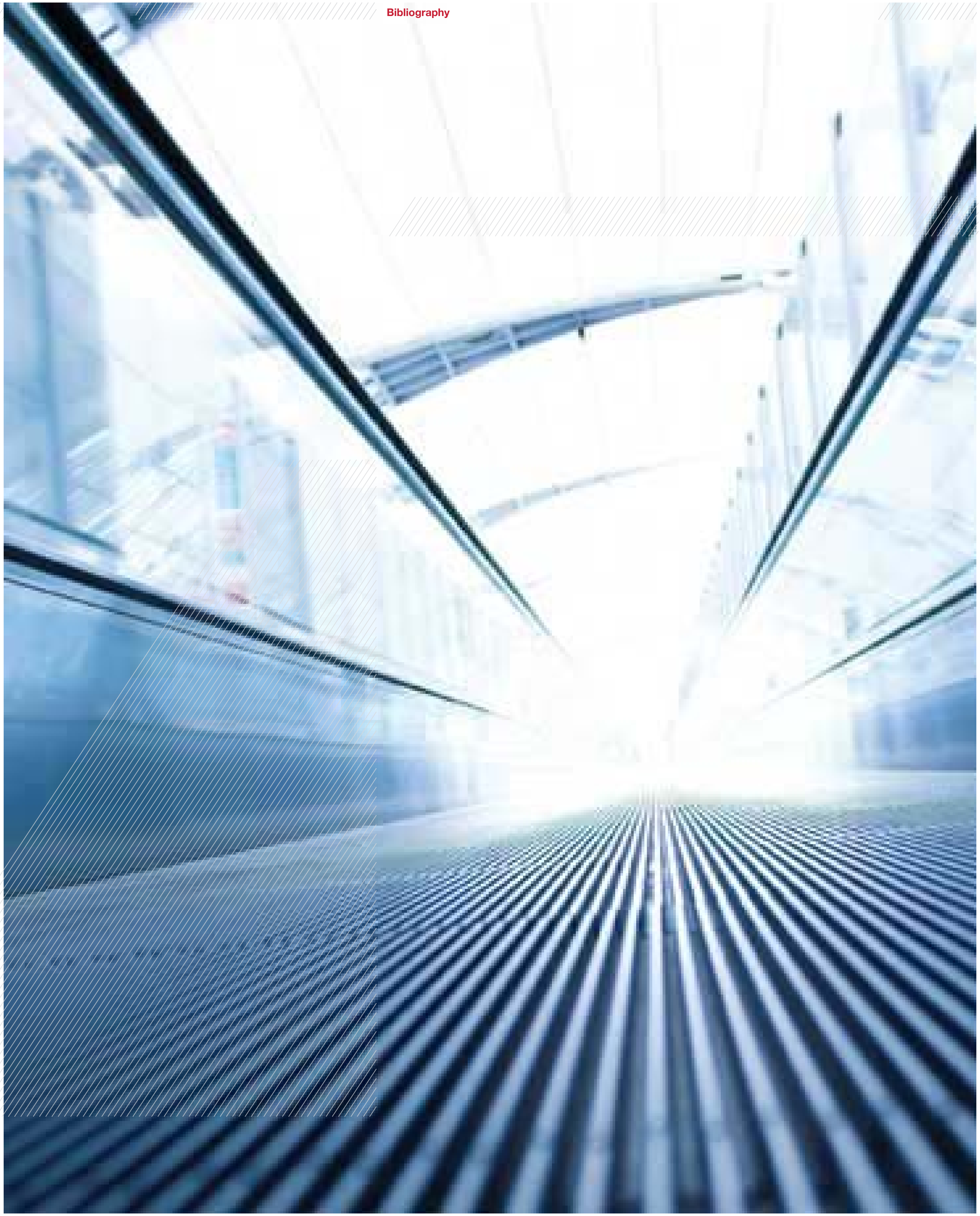
One of the most pervasive and damaging myths surrounding the debate over growth and enterprise in Britain is the supposed aversion to entrepreneurship. However all the case studies show this patently is not the case. Whether the players in the case studies had access to resources, finance or talent, all clusters were suffused with entrepreneurship and enterprise. Sometimes, as in the case of Formula One, cultural touchstones like the British tendency to form clubs, dwell in sheds and tinker with machines have metamorphosised into world-leading industries bringing enormous prestige and economic success.

A second issue (if not necessarily a myth) is the cultural hang-up over the accumulation of wealth. Whilst the business world has provided plenty of examples of how not to behave over the last decade, policymakers should avoid actions that risk inflaming scandals further, as the economic impact can be devastating.

In terms of policy making, recommendations are:

- From an early age, education should seek to encourage natural entrepreneurial curiosity in children. Interest in business should be encouraged at the earliest possible age.
- Tackle cultural hang-ups over the accumulation of wealth as a consequence of invention and research.
- Industry champions should be celebrated regardless of their industry.
- Look beyond the usual suspects (such as bearded airline entrepreneurs) to provide evidence of entrepreneurial and technological success.
- Be patient and avoid creating excessive hype. Cultural change takes generations, but cynicism is ever-present.





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# Appendices

## Appendix 1 – Methodology

Research of this nature is necessarily broad as well as selectively deep. The mixture of requirements is driven by the three components to this research:

**1. A theoretical basis for cluster analysis**
**2. General understanding of the range of UK-based agglomerations**
**3. Selection of five case studies for more in depth analysis**

***A theoretical basis of clustering***
In policy discussion, the use of the term "clustering" can be ill defined and often used incorrectly; this can confuse analysis and insight. For example, many research participants were likely to identify a gathering of businesses as a "cluster" as opposed to the technically correct term "agglomeration". As a result, actual identification of the nature of clusters becomes difficult if solely relying on a firsthand account. So crucial to this study was the establishment of a definition of clustering – what it is, what it isn't, what are its dynamics and what are its features.

Given the need to develop a multifaceted yet clear definition for comparative study, this report aims to develop a framework based on extensive reviews of both relevant literature as well as a clear understanding of comparative cluster environments. The literature review then uses existing academic and policy research, to provide grounding for the theoretical basis as well as historical research to understand the comparative cluster model.

***Understanding UK-based agglomerations***
Given that there is surprisingly little reference material on UK clusters, this section is mainly sourced through extensive interviews with a range of participants or constituents in the business environment including entrepreneurs, investors, academics and politicians; around 40 interviews in total. The aim of these interviews was to gain a greater insight into the extent of technology activity across the UK – where it happens and who is doing it – by casting the widest net possible. Many interviews followed a branching pattern with many primary interviews discussing more generalist questions before delving into business owners, entrepreneurs and academics with more specialist and practical knowledge of certain clusters or business agglomerations.

***Use of Case Studies***
Once a clear definition has been established, the report turns to its primary focus, the use of case studies to present five clusters: Cambridge, Bristol, Manchester, Aberdeen and the Formula One cluster around the Home Counties and Midlands. References for the case studies comprise both secondary sources and qualitative face-to-face interviews; both sources are able to fill gaps that may arise from the other and so enable a more holistic view than either form of source alone.
In some cases such as the Cambridge and Formula One clusters, there is a greater published history and therefore a larger wealth of existing research, so fewer firsthand interviews and less historical chronicling is required from the report. However in newer or less documented clusters, firsthand interviews took precedence as less existing research was available, both to provide a historical perspective and to facilitate further analysis.





## Appendix 2 – Discussion on Clustering

***Introduction***
First recognised as a geographic and later an economic phenomenon during the Industrial Revolution, the concepts of agglomeration and clustering have been a staple concept of economics and business strategy for well over a century now. Before and since that time Britain has played host to a range of different types of clusters in areas as diverse as manufacturing, mining, financial services, healthcare and shipping. Like all clusters, these have risen and fallen; changing, evolving or fading away as the economies that created them did the same. Elsewhere in the world, clustering has been observed in economies from Japan to Italy to the west coast of the United States and included everything from shoe making to smartphone manufacturing.

In recent decades on the back of the rise and continued dominance of Silicon Valley and the work of economist and business theorist, Professor Michael Porter, harnessing the economic power and value of clusters has become something of an article of faith in the minds of policymakers. Moreover, the drive to identify nascent clusters and even create clusters from scratch is something that pervades the ambitions of politicians of virtually every hue in most parts of the world. Britain is no different. With the current drive to rebalance the UK economy and enthusiasm for a manufacturing-led economy, her leaders are keen to identify and support, and/or help grow high-tech manufacturing and technology clusters across the country. Given the vital importance of clusters in policymaking it is worth understanding more about them.

***What is a cluster?***
Defining clustering is not a straightforward act. The study of what we know today as clustering first began in geographic studies during the Industrial Revolution. It was later given voice as an economic phenomenon called "agglomeration" by economist Alfred Marshall near the turn of the 20th Century, who defined it with simple utility as a "... concentration of specialised industries in particular localities" (Marshall, 1890). Since then, on the back of an ever-expanding quantity of literature, academics have continually looked to add their own contribution to the subject. Indeed, Aziz and Norhashim (2008) provide an enlightening summary of this expanding body of work, including the creation of a range of terminology to describe the phenomenon:

> *Economic geographers like Scott, Amin and Thrift, Harrison, Kelley, and Grant, Markusen, and Asheim also discuss the subject. They came up with concepts such as local industrial specialization, spatial economic agglomeration, and regional development to discuss the trend. Furthermore, numerous terminologies have been suggested to define the concept—"industrial districts," "new industrial spaces," "territorial production complexes," "neo-Marshallian nodes," "regional innovation milieux," "network regions," and "learning regions." However, these concepts were received with less widespread acceptance and application than when compared with those offered by business managers.*

The more overarching and most commonly accepted description of the phenomenon was developed and popularised by Professor Michael Porter (1998, 1990). His description (1998) of "clustering" comprehensively captured the range of actors and factors:

> *Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions-such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations- that provide specialized training, education, information, research, and technical support.*

# Appendices

Whilst there have been a number of critiques of his definition over the last 15 years, Porter's is the most commonly used definition amongst policymakers. Further, it is particularly useful for this report as it contains some essential elements for cluster identification and classification: competition, cooperation, spill-over effects, networks, institutional involvement, all operating within a defined geographic space.

***Why clusters matter***

Clusters are important for a number of reasons both at a local and national level. Porter's seminal work "The Competitive Advantage of Nations" (1990) discusses the economic impact of clusters at national level and beyond. In a subsequent publication, Porter also writes about their positive internal influences on competition, productivity, innovation and new business formation (Porter, 1998). Saxenian (1996) also examines clusters in relation to their ability to derive global competitive advantages at regional and international level. Pisano and Shih (2009) highlight the cluster's role in what they term the "industrial commons", a shared manufacturing and knowledge base vital for national economic development. At the local level, Moretti and Thulin (2012) discuss their importance for building local economies; and clustering is cited by Nathan et al. (2012), NESTA (2010) and Westlake et al. (2010) as a factor behind the growth and success of cities. For an analysis of the purely economic impact, Spencer et al. (2010) provide a detailed quantitative analysis of a range of clusters identified in Canada, as they state:

> *Specifically, it was found that, with some notable exceptions, the clustering of economic activities has a clear positive impact at the industry level. The evidence shows that when industries are located in an urban region with a critical mass of related industries, they tend to have both higher incomes and rates of growth compared with when they are situated in non-clustered settings. Additionally, it was found that the overall proportion of clustering within a city-region is positively associated with average income levels and employment growth. (Spencer et al., 2010)*

Nevertheless, Spencer et al also caution that unsurprisingly this effect is not felt when industries are connected in a declining area.

It is therefore reasonable to conclude that policymakers have a reasonable case for supporting the development of clusters where they occur for the range of economic benefits they bring. However, as challenging as it can be to define and unearth clusters, once identified they present a new range of problems.

## The Challenges of Clusters

***Clusters cannot be created, but can be destroyed***

Clusters present a unique challenge to policymakers. On the one hand, if you find yourself host to one, they provide enormous economic benefit, but on the other hand they are capricious and usually impervious to creation. Indeed, efforts to do so regularly fail (O'Mara, 2010)(Starobin, 2011), but this hasn't stopped many governments from trying. For decades, the regenerative successes of Silicon Valley have seen delegations from all over the world (Becker, 2000) travel to California to visit its corporate parks, meet the entrepreneurs and take in the surrounds of Stanford University. They then return home and try to replicate what they've observed, whilst failing to realise that the success of Silicon Valley lies not in the physical artefacts (Schein, 2004) of Silicon Valley but the patina of culture, entrepreneurialism, finance and knowledge that have accumulated over half a century of enterprise and activity. Mere replication is no guarantee of success, and indeed just getting the mix wrong can result in decline as demonstrated by Saxenian (1996). Clusters then are grown, not created, the best advice for policymakers is to focus on economic policy that encourages businesses and investment and avoids direct tinkering (Aziz and Norhashim, 2008).





At this point it should be noted that there are many examples of thriving agglomerations and embryonic clusters (Aziz and Norhashim, 2008) that originated from direct public support, usually from local councils. However, there is likelihood that this is a result of the success of localism identified by Moretti and Thulin (2012), as well as beneficial terms offered to firms. The real challenge, however, still remains in the ability to scale these up to become regional and internationally competitive clusters.

***Clusters restrict as well as promote growth***

A second problem of clusters, one particularly relevant when considering the challenge of embryonic clusters, is their very ability to nurture – to a point. The benefits of grouping with a small handful of complementary firms are usually preferable to going it alone. Shared access to resources and business opportunities can keep firms running for an almost indefinite period of time. Understandably this is excellent for the small, lifestyle businesses that every community needs. As Dahl and Sorenson (2010) discuss, this can provide a number of benefits:

> *A nascent entrepreneur living in the region, for example, might want a particular product and, being unable to find it, decide to produce it himself. Or, he could become aware of an opportunity from a friend. Regardless of the source, locals almost certainly have a better sense of the economic opportunities around them. Moreover, once the initial idea hits them, they can "test" the local market cheaply by talking about it with friends..*

This situation allows for a relatively easy life, which provides the satisfaction derived from spending time with family and friends (Dahl and Sorenson, 2010). However as a consequence there is little impetus or capacity for growth. Indeed the dynamic competitive clusters so sought after by policymakers with an eye to export markets are the very antithesis of those described as beneficial by Dahl and Sorenson.

Therefore application of this model to high growth firms (or firms with ambitions of high growth) is a problem. In such an embryonic cluster, there is little likelihood of development beyond a certain point; local resources wouldn't allow it and there is little incentive to do so. Embryonic clusters are often based around a limited amount of resources, or where resources have been "artificially" introduced (such as local government support), they also lack the variety of allies and competitors required to allow firms to evolve and improve their businesses. Occasionally, firms which outgrow their home cluster will attempt to maintain growth by moving to a larger cluster however doing so results in a significant loss to the embryonic cluster and adds business risk to the firm itself. The longer the firm waits to make this move, the greater the impact upon its former home and larger the stakes presented by moving.

It is also worth noting at this point the characteristic rapid drop off of beneficial spillovers as distance from the cluster increases (Porter, 1990) – therefore businesses that do not sit within the cluster will be unlikely to share its benefits.

***Clusters are highly competitive***

Further challenges arise for policy-makers when clusters are considered from the perspective of firms, as Michael Porter did with his Diamond Model (Porter, 1990) (See Fig. 5). At this point clustering becomes a cut-throat competition for survival; at virtually every stage of the supply chain, competition is fierce. Resources and customers are more likely to be found in a cluster, but intense competition means survival is not guaranteed. What is good for the cluster ecosystem is not necessarily good for its component firms.

# Appendices

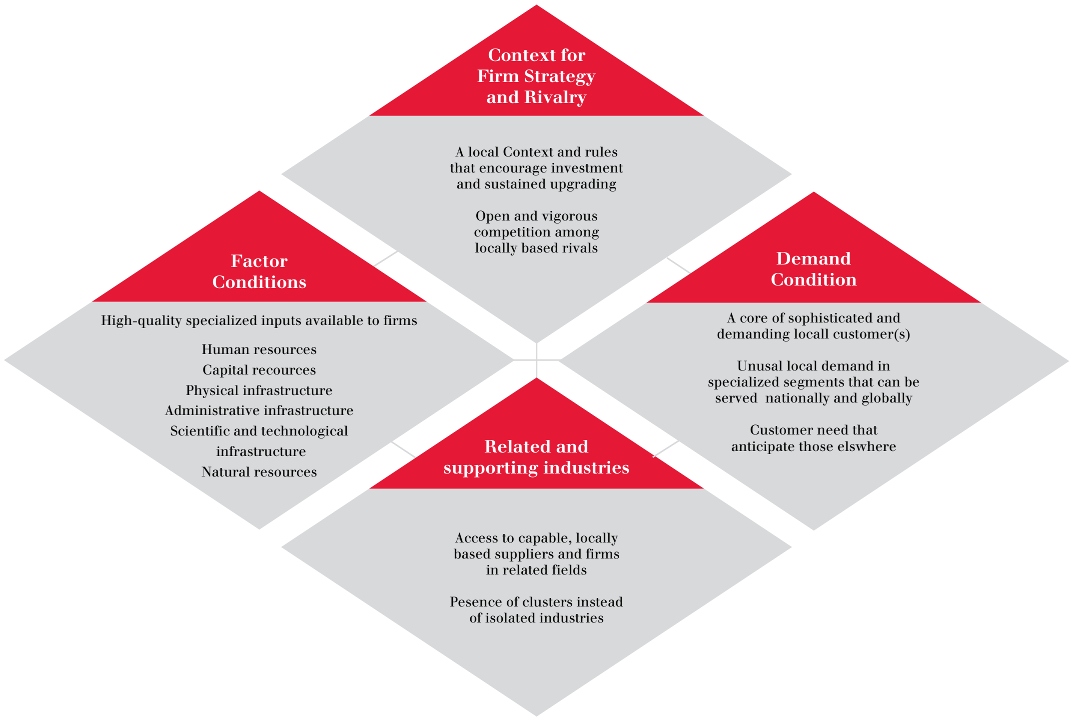



*Figure 5 – Porter's Diamond Model*

For the individual firm, survival comes from the ability to acquire and make more efficient use of resources and build social capital, whilst forming alliances which will aid in their efforts to survive. Firms that are more successful in this pursuit will survive and succeed in a cluster. Indeed as both Porter (1990) and Saxenian (1996) note, in this highly Darwinian environment, clusters which exhibit strong and diverse competition at the firm level will naturally produce more resilient and capable firms. Consequently then, such firms will be more likely to survive and thrive elsewhere. This is one of the primary reasons thriving clusters are so valuable to national economies, locally successful firms with a proven ability to survive stand a better chance in a global market.

***Clusters are not a single industry***

As Porter's description advises, clusters often contain a range of differing though complementary industries. This seemingly obvious statement, though, throws up a series of challenges for policymakers.

Firstly and most basically, it leads to challenges in identification of clusters, as application of statistical analysis via the UK Standard Industry Classification (UK SIC 2007) is insufficient as whilst this methodology will identify obvious industries such as ICT and Biosciences it may completely miss relationships between other complementary industries[14]. Additionally, clusters may be missed entirely if the cluster is based on a mixture of industries which are innovative yet fall into classifications that appear "low tech"[15].

The second challenge of complementary yet different industries arises through the application of industrial policy designed with the best of intentions to benefit one industry or the other, often

[14] *The shipyards of Glasgow lead to the clustering of other industries such as cotton manufacturers and glass and table-wear crucial to fit out passenger ships.*

[15] *Examples such as Agriculture, Oil and Gas, and Chemicals suffer from this misidentification.*





produces unintended consequences in other industries (Pisano and Shih, 2009). The current policy focus on exports and manufacturing in Britain is laudable though care should be taken not to destroy value in the service industries so valuable for many clusters; few policymakers need reminding of the disastrous impact of the "picking winners" approach in the 1970s.

***Clusters are not static***

Given the focus on the development and growth of clusters, it may seem a truism to state that they are dynamic. Nevertheless, this aspect is sometimes ignored, primarily because the focus on growth tends to blind policymakers to the fact that clusters can also mature, shrink and fade away. Indeed much of the academic critique on Porter's Diamond model has been directed at its inability to assess the dynamic nature of clusters. Therefore it is unsurprising that much of the research that followed Porter has sought to build on his framework to incorporate a more dynamic view with emphasis on understanding the lifecycle of clusters. Whilst there are many models for this development/dynamism, the six stage model discussed by Aziz and Norhashim (2008) has the benefit of being highly practical in its nature.

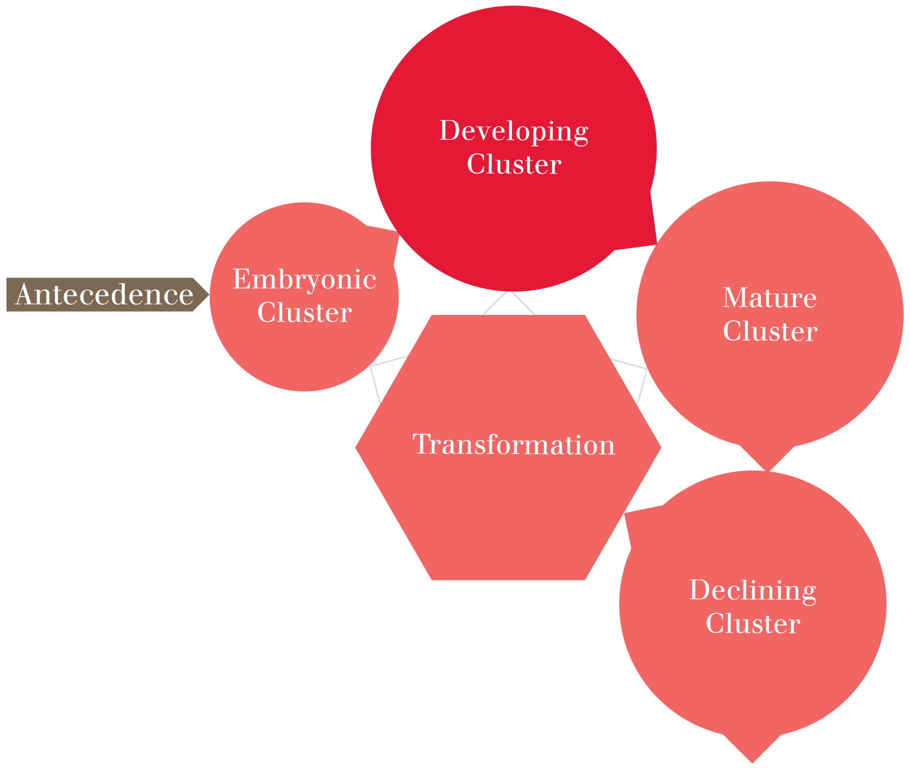



*Figure 6 – 6 Stage Cluster Lifecycle Model, Aziz and Norhashim (2008)*

Covering the phases Antecedence, Embryonic Cluster, Developing Cluster, Mature Cluster, and Declining Cluster/Transformation, the Aziz and Norhashim model (see Fig. 6) provides recognition of the crucial early and late phases of the cluster lifecycle which in many ways are the most significant for policymakers. This point is vital as many of the problems in policy making occur at this stage. Whilst identification and growth are given primary attention, understanding the lifecycle of clusters indicates that managing decline as well as growth should be the primary objectives.

# Appendices

## Appendix 3 – Modelling of clusters

Whilst this report subscribes to the belief that policymakers should avoid trying to 'recreate' Silicon Valley, we do believe that this cluster does provide a benefit by serving as a model for clustering, provided the correct parameters are assessed. If used in this way it can complement the dimensions developed by Porter with his Diamond Model, and Aziz and Norhashim with their 6 Stage Model. An explanation of this process follows.

***Why model?***
In many pursuits, the key to a successful outcome is the ability to visualise that success. The rationale that success will be easier to achieve if the outcome is known beforehand is compelling; if the process is tracked from start to finish, milestones, problems and issues can be identified.

In the case of technology clusters we are fortunate to have an excellent template available to study, Silicon Valley. Whilst this report is far from the first to use Silicon Valley as a model, we hope to avoid the common pitfalls, and the misguided tendency of governments to replicate the outward appearance of the region. These pitfalls are usually a result of policy designed to create the next Google or Facebook; instead this report aims to look at what forces create these businesses in the first place and so focus on the following aspects of Silicon Valley:

- Its continued success is built on the exploration and mastery of high-technology deep-knowledge industries;
- Its success is based on continuous iteration, enabling it to keep pace with (and often lead) the advance of new technologies;
- Through the close integration of innovation and private finance, it has become self-sustaining, requiring government only to avoid inadvertently damaging it through legislation, rather than having to provide direct financial support;
- It has become a global centre of gravity, drawing the best minds from around the world to build upon its own success;
- It has developed and nurtured a culture that values innovation and risk not solely for the purposes of financial gain, but also for the sake of technological advancement and in some cases a quasi-philanthropic desire to improve the community through business;
- The successes, developments and platform innovations of businesses in the area have reshaped not only the US but that of the entire global economy.

As such this report does not view the infrastructure, industries and businesses of Silicon Valley as the model; rather it sees internal norms and external impact as objectives in themselves. It was these technical innovations, supported by motivated investment stretching back over half a century that were a benchmark. As Clark (2011) states, these waves of innovation propelled the area forward and provided the impetus and expertise required to be at the forefront of the next wave of development (detailed in Appendix 4). As with any iterative process, each new wave of development was founded upon knowledge gained and wealth created by previous waves. It is worth considering the key factors which generated these waves as they provide Silicon Valley with the advantages it retains today.

***Culture***
A common misconception portrays Silicon Valley as a story simply of technology and business; rather it is also a story of people and culture. It is important to bear in mind that few developments were made with a clear "goal" in mind, the process was evolutionary and because of the dynamic nature of clustering, the outcome was and remains uncertain. Therefore, policymakers should not look back and attribute any actions as expecting an end goal. What is clear in the story of the cluster is that crucial interventions by certain individuals at each stage not only drove the process of development forward, but created and then embedded the values and assumptions into the region's culture.





Fred Terman in the pre-Silicon Valley period displayed elements of a plan, however as Clark (2011) shows, his primary intention was to retain talent near Stanford, and in doing so he created the institutions that laid down a fertile environment for others to follow. His connections with the US federal government meant military funding was available as new and untried technologies were researched, but it was his pugnacious determination and persistence that made this possible.

William Shockley brought the 'Traitorous Eight'[16] to Palo Alto, reputedly because it was close to his mother (Murray, 2010)(Bairstow, 1998), and unwittingly provided the stimulus for the Eight to seek strike out on their own (Saxenian, 1996)(Bairstow, 1998) backed by the visionary financial backing of Arthur Rock. As the alumni of Fairchild Semiconductor dispersed to create more than 60 new semiconductors, integrated circuit and computing businesses in the 1960s they took with them not only their technical knowledge but also an entrepreneurial DNA (Schlender, 2005)(Hambrecht, 1984) that was based on individualism, competition, experimentation, calculated risk taking and the acceptance of failure as a part of advancement. Whereas in many other locations – not just outside the US but also within – such uncertainty may be feared, in Silicon Valley it is lauded even in the face of a disaster like the Dotcom crash:

> *The valley also recycles its most important resource – people. Observers are quick to lampoon the callow folly of the fallen dot-comers, but they overlook the experience gained by these pioneers. An entire generation of twenty- and thirty-somethings just rocketed through an accelerated business cycle. They got in, shot up, crashed down and now they are out, and their careers still lie more before than behind them. Few are rushing to embrace the security of the corporate establishment. Rather, they are busy starting over. (Saffo, 2002)*

This DNA is the collection of values and assumptions (Schein, 2004) that underpinned the future of the region and can be found in the entrepreneurs behind every Silicon Valley venture in the last 50 years. Indeed it can be extended further still, Saxenian (1996) cites examples that suggest that at stages the culture of working "for" Silicon Valley itself was more powerful than loyalty to individual employers.

***Knowledge and Experience***
Reviewing the evolution of Silicon Valley it is tempting if that to view the success of the area as one of mastery of technological development, implying that if that sort of technical expertise can be studied and implanted then the area's success can be replicated. The success of Silicon Valley though is an excellent expression of the importance of Resource Based Theory (Wernerfelt, 1984). The Theory - defined important resources as Valuable, Rare, Inimitable and Non-substitutable – was something Silicon Valley's various participants knew intuitively. From the creation of Fairchild Semiconductor onwards, individual firms continuously innovated, spread their knowledge and used it as a basis for further innovation. Silicon Valley pulled off a neat trick in remaining highly competitive whilst openly sharing this information (Saxenian, 1996). When looked at in totality, the region of Silicon Valley contained valuable and rare knowledge, which grew with its continuous innovation. As Porter (1990)(1998) discusses, this is how economic clustering builds competitive advantage, not just for the firms but for the region.

This regional specialisation of knowledge and experience is further enhanced by the continuous cycle of regeneration of firms as well as dispersion of expertise through movement of employees. This was common from the subsequent development of the Traitorous Eight (See Appendix 5) and is still very much present in the current generation of firms (See Appendix 6). Such movement is woven into the fabric of the region and creates a powerful flow of both human and social capital, dispersing both codified and implicit knowledge practises.

*[16] A somewhat melodramatic nickname given to a group of engineers who Shockley brought to work with him at Fairchild. The group included such Silicon Valley luminaries as Gordon Moore (co-founder of Intel), Eugene Kleiner (co-founder of Kleiner Perkins Caufield & Byers) and Robert Noyce (co-founder of Intel).*

# Appendices

The cumulative value of this knowledge and experience of Silicon Valley is something that no shortage of governments around the world seeking to replicate (O'Mara, 2010) (Starobin, 2011). However, whilst replication of artefacts is helpful, it will not bring success without understanding the values and assumptions (Schein, 2004) embedded in the human capital of the region such as those described in the previous section on Culture. A similar failing is to try and supplant the existing resource based advantages of the 'next' Silicon Valley. It is in these indigenous resources, enhanced by global collective insights that create opportunities, and it is here that the sustainable strategic advantage lies.

***Finance***

Whilst the knowledge base and cultural proclivities of Silicon Valley provided the desire and capability to succeed, it was money that made it happen (Warner, 1998). That money was provided by the financing practises written into the deal structured by Arthur Rock for the creation of Fairchild Semiconductor. In 1960, two years after its establishment, Fairchild Camera and Instrument exercised an option written into the original contract and bought Fairchild Semiconductor. The "Traitorous Eight" were well rewarded for their shares in the business. Eventually they took with them their knowledge and personal wealth and set about starting their own new businesses – including Intel (in 1968). Recognition of the importance of stock options was crucial: both as a key method of attracting and incentivising staff, and in the distribution of wealth upon exit. This process of infusion of wealth was so successful that by 1972 the alumni of Fairchild Semiconductor were responsible for the creation of at least 60 semiconductor businesses and at least two venture capital firms – Kleiner Perkins and Capital Management Services (later renamed Sequoia Capital). These firms were established fully aware that the success of the next generation of businesses can only be delivered by those with both the experience and the money to commercialise their ideas:

> *All this is because the partners prefer to be seen not as financiers, a term they disdain, but as company builders who work closely with the entrepreneurs they fund. Even though KP has raised some $650 million in capital in the past four years and clocked annual returns well in excess of anything most Wall Street money managers could sustain, the partners insist that making money is not the essence of what they do. (Warner, 1998)*

Crucially, it was not just the provision of finance for the company, though this undoubtedly contributed to the success of the individual firm, it was also the creation of a 'stocks and options' culture and practice that infused itself into the values of the firm, and subsequently the region. Whilst it created wealth for its investors and entrepreneurs, importantly it also created wealth for those with expertise who became involved in the young firms. Each new generation of firms was created by the last, some used their wealth to start new firms (see Appendix 5), some provided funding to entrepreneurs and some started firms that refined the funding model.

This combination of entrepreneurial and financial vision formed a template, that created a chain of businesses (some more successful than others), allied with a networked 'collective memory' that started with Fairchild Semiconductor (Bairstow, 1998) and it is no surprise to see that this pattern of interwoven companies is reflected today (see Appendix 6).

***Networks and Clustering***

In Appendix 4, the chronology of Silicon Valley views innovation metaphorically as a wave. In the case of Silicon Valley, networks act as the ocean, transmitting the energy of the wave, bringing together the resources of culture, knowledge and finance. Effective networks contribute at all levels in the successful development of high growth entrepreneurial businesses – from access to key talent at the formation of the venture (Arora et al., 2008); to sourcing of initial angel funding (Steier and Greenwood, 2000); to sourcing VC funding and accessing the value of networks of portfolio companies (Gompers and Lerner, 2001)(Lashinsky et al., 2004); finally through to gaining favourable terms at IPO, with examples such as Google ably demonstrating the power of networks (Robicheaux and Herrington, 2007).





Further increasing the power of the networks of Silicon Valley to drive interaction are the roles of economic clusters (Visser, 2009)(Wonglimpiyarat, 2006). Although focused on the clustering of Italian ceramics producers, Porter's Diamond model can be easily applied to the businesses of Silicon Valley. The complex webs of social and human capital expressed in Appendix 5 eventually evolved. Similar interactions between the firms and individuals of today (Appendix 6) show how these networks are still dispersing knowledge and expertise throughout the cluster of firms.

***4D Comparative Model***

Combining all these aspects together, we can form them into a framework to illustrate performance. The diagram below shows how this would work with a hypothetical cluster "X"; in this case Silicon Valley, represented by the dotted blue line acts as the archetypal comparator, whilst scores for Cluster X are plotted in red. For example in the hypothetical cluster described in Fig. 7: the Culture dimension rates as four; Knowledge is two; Finance is three; Networks are three. This is compared to Silicon Valley which rates a five on each dimension. Currently values are assigned by estimate though the benefit of this framework means that as further research results are included, the Comparative model for each cluster can be refined, to the point that clusters may be compared against their previous selves as well as to other geographies.

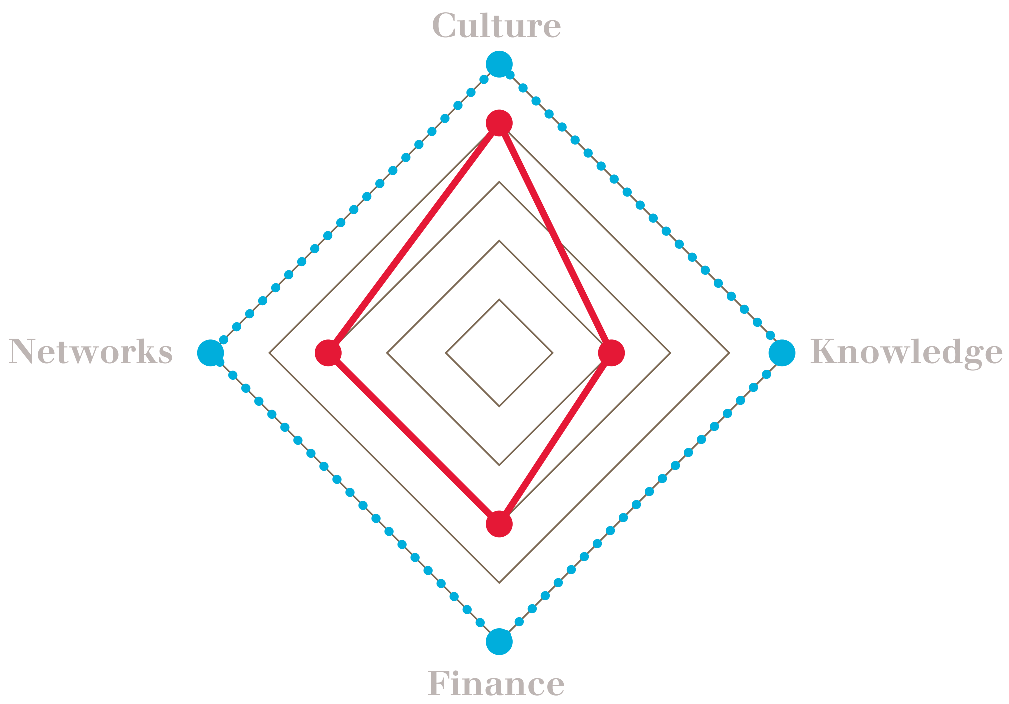



*Figure 7 – 4D Comparative Model*

***Analysis framework based on synthesising models***

This Comparative Model based on Silicon Valley, then, serves a purpose for this report as its application allows us a more rounded perspective of both Porter's Diamond Model and Aziz and Norhashim's Six Stage Model of the dynamics of clusters. By synthesising these models – Diamond Model, Dynamic Model and Comparative Model – into a single framework we are able to develop a holistic view when analysing the clusters in our case studies.

# Appendices

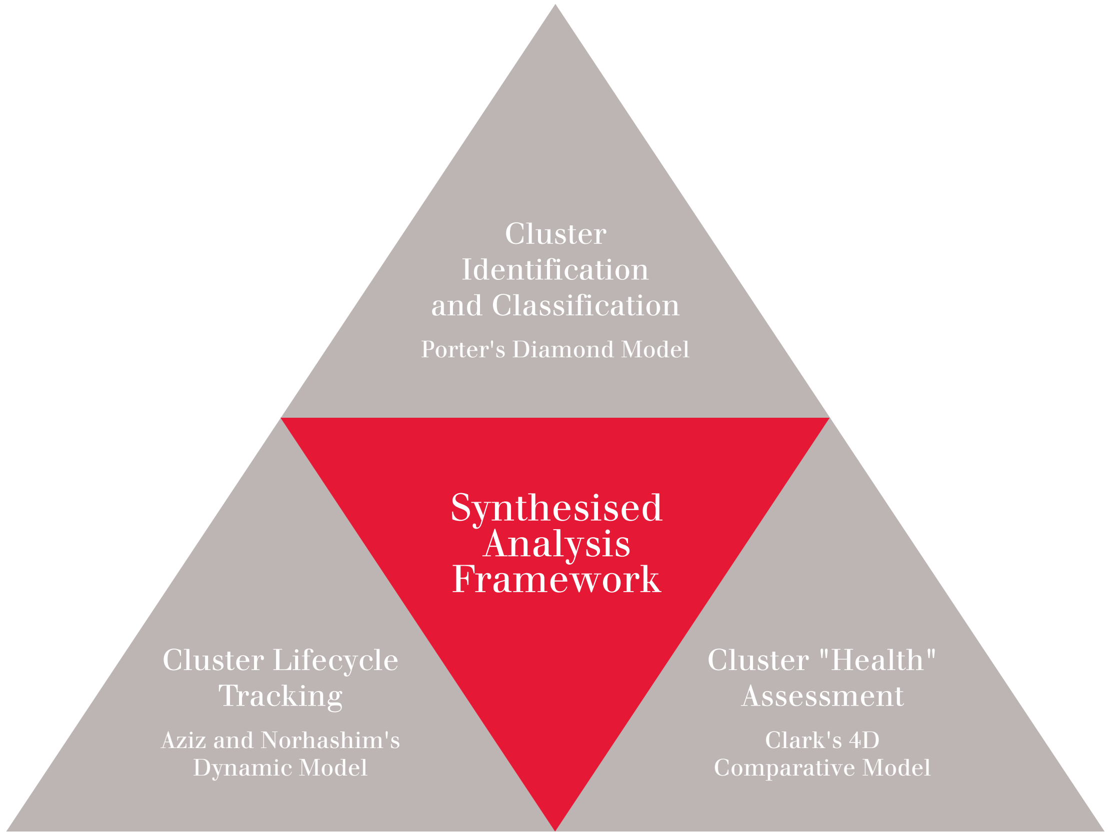



*Figure 8 – Synthesised Analysis Framework*

Porter's Diamond Model enables us to identify clusters and their nature amidst a sea of agglomerations. Using Aziz and Norhashim's Dynamic Model we are able to assess the development stage of the subject clusters. Finally, by using the Comparative Model we are able to track key indicators of cluster health comparison to an idealised example. This diagnostic toolkit allows for the development of a highly detailed understanding of a subject cluster, ultimately allowing policymakers to operate with a more detailed understanding of the subject cluster. Having developed this analysis framework we then use it to review case studies of five candidate clusters from around the UK. These candidate clusters represent a variety of industries and geographies and have followed different paths to where they find themselves today. Each cluster exhibits a range of strengths and weaknesses, and which through the use of the Synthesised Analysis Framework this report hopes to develop greater understanding, and ultimately inspire recommendations for policy development. Further it is hoped that by demonstrating the efficacy of this approach, it can be applied to help develop insights into other clusters and agglomerations elsewhere.





# Appendix 4 – History of Silicon Valley

***Introduction***

Silicon Valley's success is due to a series of technical innovations supported by motivated investment stretching back over half a century. These innovations, expressed in this paper metaphorically as Waves, propelled the area forward and provided the impetus and expertise required to be at the forefront of the next Wave of development. As with any iterative process, each new Wave of development was founded upon knowledge gained and wealth created by previous Waves.

To gain an understanding of the history of developmental Waves that lead to the Silicon Valley as we see it today, this paper will first use of a chronological narrative to examine the cluster.

***Wave 1 – Valves – Pre-Silicon***

Prior to World War II, what we know today as Silicon Valley was typical of much of Northern California at the time – expanses of farmland sweeping eastwards from San Francisco, at the time an economic hub of the eastern Pacific Ocean ("20th Century Industries," n.d.). The region's economy at the time centred on successful primary industries such as agriculture and mining, whilst institutions like the naval base at NAS Sunnyfield, and Stanford University and UC Berkeley were in place there was little to suggest the role the area would play in the next 60 years of technological development.

By the 1930s Stanford was producing a steady stream of highly qualified technical graduates, however at that time the power of the established high-tech cluster in New Jersey surrounding businesses like Bell Labs drew graduates to the East Coast. Indeed the departure to the Northeast of Santa Clara's only native high-tech business, Federal Telegraph Company in the early 1930s (Adams, 2004) should have spelled the end of any technological aspirations that may have existed.

This brain drain galled Fred Terman, professor of electrical engineering at Stanford, in the first of a series of interventions that changed the fortunes of this unassuming corner of the United States. He convinced two graduates, Bill Hewlett and David Packard to establish their new electronics testing equipment locally and remain in the area. The successful retention of Hewlett Packard along with Terman and Stanford's involvement in US military projects during and after World War II provided the basis of a series of actions between the early 1940s and late 1960s designed to create an outreach link between Stanford and local high-tech businesses (Bairstow, 1998).

***Wave 2 – Semiconductors – Shockley and the 'Traitorous Eight'***

Whilst Terman's ultimate objective, connecting Stanford and high-tech businesses, may not have been fully realised, by the late 1950s his actions had nurtured a small but vibrant network of new high-tech businesses, including IBM, clustered in the vicinity of the university at Palo Alto. It was into this incubator that in 1957 Nobel laureate Physicist William Shockley established his visionary semi-conductor company, bringing with him a team of leading engineers and scientists attracted by his visionary reputation. However whilst Shockley was a genius, his management style proved poisonous for his team who became restive and looked to take their skills elsewhere. Eventually they found the support and guidance of Arthur Rock, an investment banking analyst who specialised in the electronics industry. It was Rock who suggested they establish their own business and who eventually secured funding through Fairchild Camera and Instrument with an innovative venture funding plan; Fairchild Semiconductor was created. As the story was told in Fortune Magazine:

> *Rock didn't know it at the time, but he had hit upon a completely new approach to company building – as well as an almost magical formula for accelerating the development of new technologies and creating immense personal wealth. In a single stroke, Rock had created the DNA for what would become Silicon Valley: venture capital, stock options, and a company that would itself spawn a little startup called Intel. It was all there in that one deal. (Schlender, 2005)*

### *Wave 3 – Integrated Circuits – Growth in the Valley*

The creation of Fairchild Semiconductor in 1957 took place within a period of rapid experimentation, iteration and development in the region. In 1958 the integrated circuit was created by Jack Kilby at Texas Instruments and only a year later Fairchild Semiconductor developed the planar process enabling integrated circuits to be manufactured on a commercial scale. This development set in motion a sequence of iterative improvements that saw the integrated circuit become the powerhouse behind the new science of computing[17]. As the hardware became more powerful, simultaneous experimentation allowed other developers to experiment with what would become known as software. With much of this development centred around the San Jose/Palo Alto/ Mountain View region, northern California was fast becoming the centre of a new world of development. In little over 30 years, Terman's vision had become a reality – Stanford had become the centre of a cluster of innovation and development, powered by the minds developed in Stanford and funded by the local businesses.

### *Wave 4 – Hardware – Personal computing takes shape*

If the 1960s were the period of development for the basic components of computing, the 1970s saw them come together to create the basic forms we use today; three companies led the hardware development: Intel in micro-processing; Xerox in user interface; and IBM in database and storage.

#### *Intel*

Born from the founders of Fairchild Semiconductors, Intel had established itself in the 1960s as a leader in integrated circuits, and micro-processors. A series of innovations allowed them to commercialise their successes in development – the 4004 a commercially available microprocessor in 1971; the 8008 in 1972, the 8080 in 1974. As Moore's Law[18] would suggest, each iteration was more powerful and functional than the last. The computer "brain" was becoming ever more powerful.

#### *Xerox*

Having developed laser printing in the 1960s, Xerox established their Palo Alto Research Centre (PARC) in 1970. Research at PARC saw a list of developments we recognise today – Ethernet in 1973; workstation with mouse in 1974; Graphical User Interface (the precursor to Microsoft's Windows) 1975; commercial computer with mouse 1981.

#### *IBM*

In parallel with Xerox and Intel, IBM was focused on the database and storage functions. Whilst IBM itself had a global spread, developments from businesses on the West Coast included – the floppy disk in 1971; SQL (a database management programme) in 1974; relational database systems in 1974.

Collectively these developments saw the development of computers as ever more powerful business machines, however they would have remained business-focused without actions of Ed Roberts a resident of New Mexico who in 1975 created the MITS Altair 8800 releasing it to hobbyists through mail order. The Altair 8800 was based on a cloned processor reverse-engineered from the Intel 8080 by Advanced Micro Devices. With a starting price of $439, the Altair 8800 was vastly more affordable than the $10,000 Intel business equivalent. This affordability brought into play the early adopters and enthusiasts like Paul Allen and Bill Gates of Microsoft and Steve Jobs and Steve Wozniak of Apple – new empires were born in garages. MITS effectively democratised the computer and home computing was born.

*[17] Gordon Moore's famous "Law" was first identified in 1965*

*[18] Named after Intel founder Gordon Moore, "Moore's Law" states that the number of transistors that can be placed on an integrated circuit doubles approximately every 2 years, effectively doubling the computing power of the circuit.*





### *Wave 5 – Software – The emergence of Microsoft*

The 1970s saw the creation of Microsoft and Apple in 1975 and 1976 respectively. Apple, formed by Steve Wozniak and Steve Jobs focused their development on the computers as a complete system – considering hardware and software together; whereas Microsoft focused on software. This difference in approach would take their businesses in vastly different directions over the coming decade, yet whilst both benefited, it was software-focused Microsoft who came to dominate. Their first operating system, BASIC was developed for the Altair 8800; however, they effectively cornered the market when they combined with IBM in 1981 using their operating system MS DOS.

This decision to focus on software proved prescient as in 1983 Compaq released an IBM PC Clone. For IBM the introduction of cheap clones was a threat to their market dominance, for Microsoft, it presented an opportunity to entrench their market dominance. So as the PC market fragmented with the introduction of cheap Japanese semiconductors in the mid-80s, the spread of PCs into the mass market meant the only clear winner was Microsoft.

### *Wave 6 – The World Wide Web – Commerce comes to the Internet*

The concept of what we now know as the Internet is not new. The concept of a distributed network capable of surviving nuclear attack was proposed by Paul Baran in 1962, and by 1969 the forerunner to the Internet, the ARPANET (Advanced Research Projects Agency Network) was inaugurated with four nodes (three of these in Californian universities[19]) with the aid of US Defence Department funding. The ARPANET grew rapidly throughout the 1970s to the point that by 1980 it had almost 430,000 users exchanging 100 million emails annually. During the 1980s much of the basic infrastructure (servers, cabling etc) of the Internet was established however; without a means to make the system user-friendly to a wider audience, the Internet remained the domain of universities and specialist groups.

This changed due to the efforts of Tim Berners-Lee at CERN in 1990-91. Berners-Lee's development, the World Wide Web (WWW), was a collection of protocols that sat on top the infrastructure of linked servers on the Internet enabling information to be created in pages. Because each of these pages contained a unique address (the URL) they were easily searched and accessible through the use of a web browser; the first browser, known as Mosaic (later Netscape) was developed by Marc Andreessen in 1993. The "access from anywhere" functionality was seen within the academic world as opening the possibility of connecting the world of knowledge:

> *The World-Wide Web was developed to be a pool of human knowledge, and human culture, which would allow collaborators in remote sites to share their ideas and all aspects of a common project. (Wardrip-Fruin and Montfort, 2003)*

For entrepreneurs however, the possibility to reach a global audience with a minimum of infrastructure provided completely different opportunities; opportunities that seemingly made many existing business models obsolete. The first opportunity (and battle) revolved around managing the ever-growing web – browsers like Microsoft Internet Explorer and Netscape; along with search engines like Yahoo and Excite. It was the pre-profit IPO of Netscape in 1995 that announced the commercial scale of the World Wide Web revolution, and was the spark that lit the fuse of a new financial boom. The next opportunity adapted traditional businesses in a new way – e-tailing and online advertising were born. As more entrepreneurs awoke to the potential of the Web, a multitude of new businesses emerged, most funded by an associated boom in the venture capital market keen to replicate the success of Netscape and its backers. In this new environment of high expectation and low capital costs, the funding cycle rapidly increased as businesses burned through cash in a phenomenal growth phase. One example of this growth was Amazon; the "online bookstore" was established in 1994 by Jeff Bezos with $40,000 of angel investment, and by May 1997 sold at IPO with a market capitalisation of $438m (Galante and Kawamoto, 1997). The story was similar in the search engine market as Yahoo and Excite were also sold at IPO delivering massive returns for investors.

*[16] These were UCLA, Stanford Research Institute and UC Santa Barbara. The fourth node was at the University of Utah.*

### *Wave 7 – Search Matures and Web 2.0 takes off – Post crash regeneration*

The bursting of the Dotcom Bubble in 2001-02 is seen in popular conception as a sort of 'bonfire of the vanities', and in many ways it was; too many businesses had received funding without the business models to justify the capital injections.

> *America's 371 publicly traded Internet companies have grown to the point that they are collectively valued at $1.3 trillion, which amounts to about 8% of the entire U.S. stock market. (Willoughby, 2000)*

To the general public, the uppity start-ups got their comeuppance and greedy investors had their fingers burned. However the common conception of the story dwells too much on the hubristic tendencies of those involved, and misses the real benefit of the crash – its Darwinian outcome. The crash saw a freeze in the availability of venture capital – businesses with unsustainable burn rates collapsed and died (Willoughby, 2000), however businesses which were showing promise usually held on and indeed some thrived as high-quality talent became available as other businesses collapsed. The best example of these successes was Google, which having won the "search war" proceeded to make the business profitable in the depths of the crash; it generated over $19m of revenue in 2000, $85m in 2001, and $439m in 2002. It turned its first profit in 2001 at $7m, and followed that up in 2002 with over $100m (Robison, 2008). The dotcom shakeout had run its course towards the end of 2003; Google maintained profits exceeding $100m on the back of nearly $1.5bn in revenues (Robison, 2008). With 97% of these revenues provided by internet advertising – Google had proven that the internet advertising model could work. When Google went public in 2004, it was valued at US$25bn (Robicheaux and Herrington, 2007), a market capitalisation that made it more valuable than either Ford or General Motors (Robison, 2008).

The year 2004 also saw, if not the birth[20], then the concept of Web 2.0 begin to take hold of the community of developers in Silicon Valley. Web 2.0 was the collective term for the socialisation of the World Wide Web, taking it beyond static pages, bringing collectivity and an interactive mindset, and ultimately delivering Sir Tim Berners Lee's vision of a more human web to life. Effectively Web 2.0 turned the web from a library to something more like a public square or a village green. Social networks like MySpace (founded in 2003) captured the spirit of Web 2.0. However 2004 will be remembered as the year Facebook was created in a Harvard dorm room before relocating to Palo Alto, and the year social networks took hold.

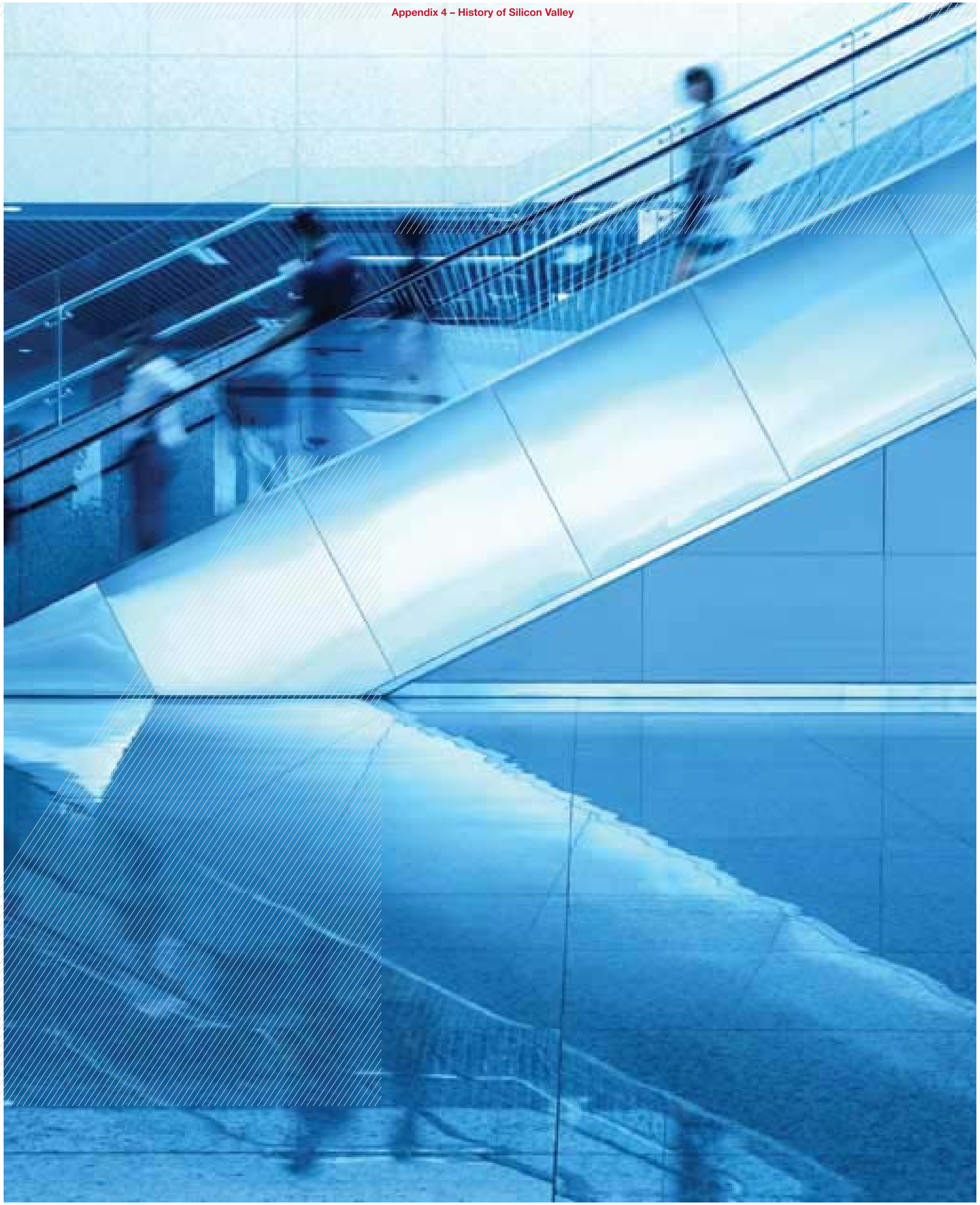
### *Wave 8 – Smart devices and the return of hardware*

Silicon Valley was built on developments in hardware, but for most of the 1990s it seemed that hardware development would be consigned to the margins of activity in Silicon Valley. Apple continued to focus on hardware but for most of the decade it seemed in a terminal decline, still innovating but losing money and in grave risk of bankruptcy. It seemed as interest in the web advanced apace, hardware was something Silicon Valley would let go.

The roots of Silicon Valley's hardware renaissance, however, lay in the return of Steve Jobs, a man who retained the respect, and indeed the reverence of the company's key engineering and creative staff. In 1997, Jobs returned to a near-bankrupt Apple and set about a brutal reformation of the company – retaining the innovation, refocusing on consumer users, but cutting the waste. The first evidence of his labour was a new range of consumer-focused products – the candy-coloured iMac range – which landed on the beige PC market like a multicoloured explosion, virtually redefining itself and the market in the process. Following this up with a succession of innovative consumer products, Apple won itself both a highly devoted consumer base and hegemony of the newly re-emergent hardware market. In each case – new generations of iMacs and iBooks, iPod (2001) and iPhone (2007) – Apple took on incumbents and redefined the market into its own terms. Each product brought with it a combination of relentless consumer focus and excellence of product, each building brand equity, each creating or popularising its product category, and each adding to anticipation of the launch of the next product. So it was in April 2010 when Apple launched the iPad, it created a category from scratch, and consumers and the market followed. Thanks to Apple, hardware was once again big in the Valley.

[20] *The term was first conceived in 1999.*





# Appendix 5 – Fairchild's Offspring


*Figure 9 – Fairchild's Offspring. Source: Business Week, August 25, 1997. P. 84*



# Appendix 6 – Interconnected Tech Companies Today

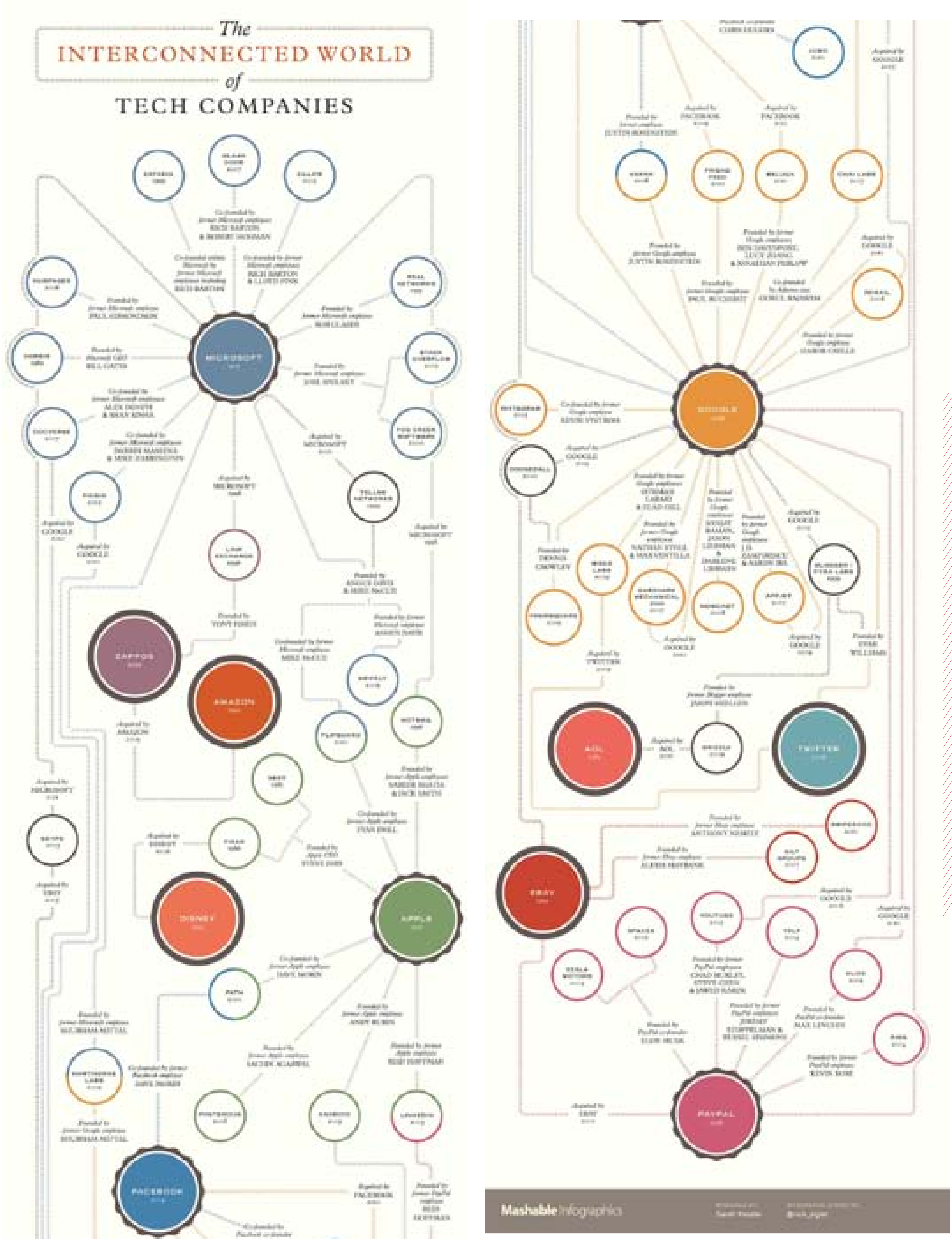



*Figure 10 – The Interconnected World of Tech Companies. Source: Mashable Infographics (http://mashable.com/2011/07/19/tech-companies-infographic/)*

# Appendix 7 – Semiconductor Companies of the South West

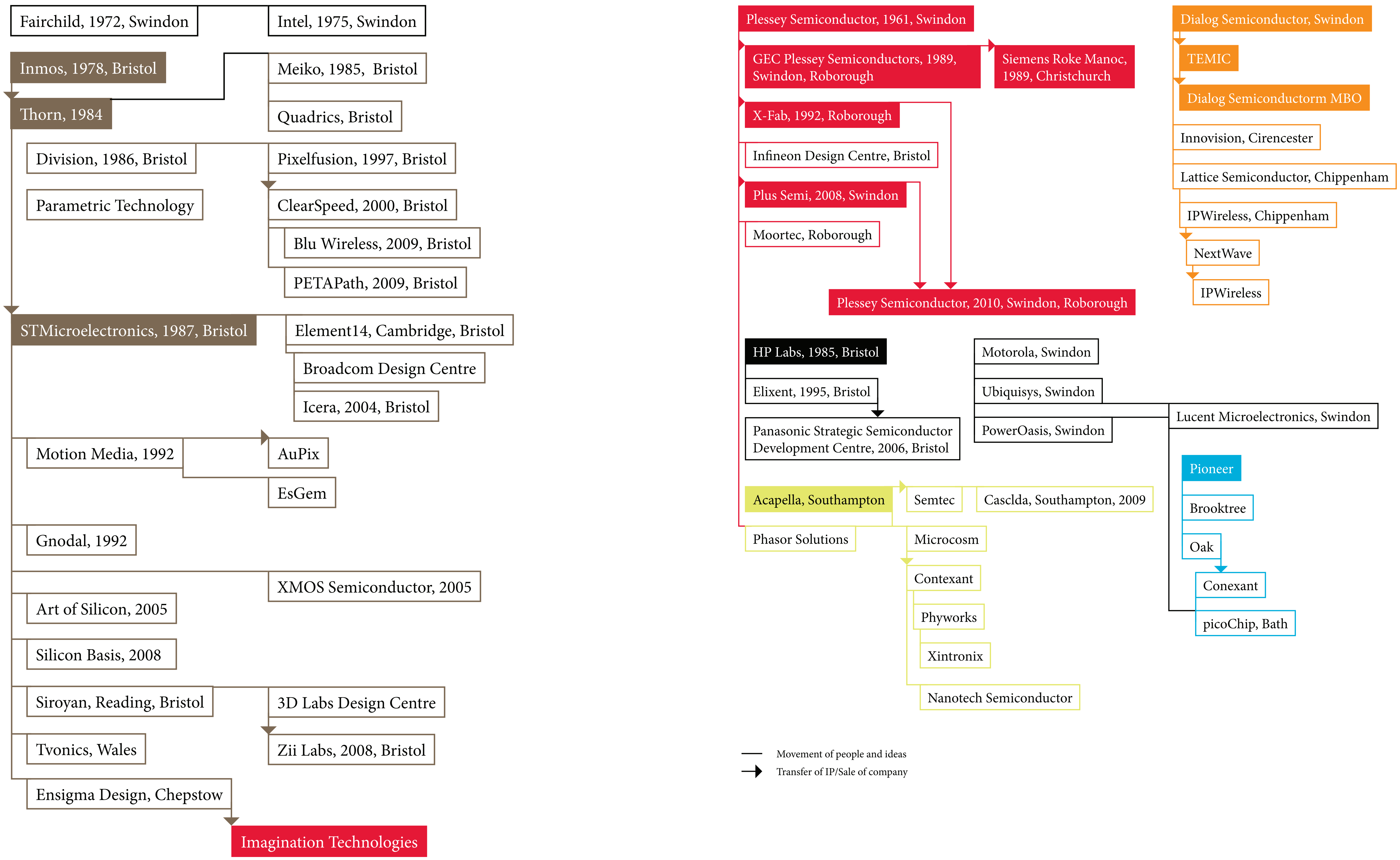



*Figure 11 – Family Tree of Semiconductor Firms in the South West. Source NESTA “Chips with Everything”, p. 12-13.*

# Appendix 8 – UK Cluster Maps

## Tech Britain


*Figure 12 – Tech Britain Cluster Map. Source: http://techbritain.com/*

Tech Britain is an online resource that highlights the people, companies, finance and spaces that comprise each of the United Kingdom's tech clusters. The over arching aim is to provide a balanced perspective of the United Kingdom and its startup ecosystems.

## Cambridge Cluster Map


*Figure 13 – Cambridge Cluster Map. Source: http://www.camclustermap.com/map/badge/businessweekly*

Cambridge Cluster Map is a free-to-access online service brought into being by Cambridge University and leading figures from the area's technology community, in the form of the Cambridge 2 You initiative. The Map is designed to open the Cambridge technology cluster to the world. Through visualisations, reports and directories the Map paints a vivid picture of the business community that has grown up over 40 years.