TECHNOLOGY-BASED FIRMS IN SCOTLAND

A Report for Scottish Enterprise

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EXECUTVE SUMMARY

1. Introduction

1.1. This study examines the nature of growth of technology-based firms (TBFs) in Scotland. This study was commissioned to provide a more detailed insight into Scottish TBFs in general and high growth-TBFs in particular.

1.2. A common assumption amongst policy-makers has been that high growth firms (HGFs) are dominated by TBFs. Indeed, the rationale for the considerable sums of money spent on innovation support in its various forms is premised on the assumption that this will lead to the emergence of HGFs. However, this assumption is challenged both by our recent study of HGFs in Scotland undertaken on behalf of Scottish Enterprise and by the wider literature. The reality is that the representation of technology based firms in the population of HGFs is broadly on a par with their proportion in the economy – and some studies suggest that they may even be under-represented. This clearly begs the question whether this is the case in the Scottish context and what is the performance of these firms in Scotland?

2. Literature Review

2.1. The literature on high growth technology firms is significantly smaller than that on high growth firms in general. However, it is clear that technology-based firms account for a minority of high growth firms and certainly no more than their overall share of economic activity. Indeed, the majority of high tech firms do not appear to seek rapid growth – although in this respect they are no different to firms in other sectors. This undermines 'barriers to growth' arguments often advanced by policy makers when trying to promote these types of firms which suggests that many firms will grow when these barriers are overcome. Key barriers to growth appear to be threefold: (i) over-emphasis on R&D-led technology and lack of commercial orientation; (ii) the financial strains associated with product life cycles; and (iii) the challenges of 'crossing the chasm' from the specialist early adopter market to the mass market.

2.2. There is no consensus in the literature on the characteristics of high growth, high-tech firms. However, factors which would appear to be at least loosely associated with high growth high tech firms are as follows: (i) high levels of human capital amongst the founding entrepreneurs, industry-relevant experience, strong opportunity-driven motivation, high levels of entrepreneurial orientation and ambition; (ii) a large varied senior management team, venture capital-backing and a strong export orientation; (iii) firms which have 'product-as-service' business models, offering solutions rather than single products, with a strong sales and marketing focus and strong customer end-user engagement.

2.3 There appear to be two key factors which are common in successful TBFs: first, founders of high tech firms have specialist technical and commercial knowledge which they have developed as employees, hence will emerge from existing technology organisations; second, the founders will typically locate their businesses in locations where they already living and working. In combination these features, in turn, mean that high growth, high tech firms will tend to be more geographically concentrated to a much greater extent than is the case with high growth firms in general (Mason and Brown, 2010).

3. Definitions

3.1. There is no ideal method for defining 'high tech' firms. Despite its limitations, this study defines high tech firms using an industry classification . The definition adopted includes both high-tech manufacturing and high-tech services and is based on Standard Industrial Classification (SIC) categories. This combination of rigour, derived by using measurable criteria, plus an element of subjectivity, has considerable appeal. It also allows for the definition to be modified to take account of local circumstances in terms of industrial structure. For our Scottish definition, it is appropriate to include the energy sector in the definition of high technology industries. A full list of the SIC codes used can be found in Table 2.1 on page 13.

4. Analysis of ONS data

4.1. The first stage of the research assessed ONS data which is held by the Business Structures Database (BSD). The data from the ONS should be a reliable source of information on business growth owing to the fact that it draws on the official register of all businesses operating in Scotland from the Inter-departmental Business Register (IDBR). This is the data source which NESTA have used for its analysis of HGFs across the UK (NESTA, 2009; 2011).

4.2. Scotland has a very slightly higher proportion of HGFs in its business base than the UK average and the second highest regional proportion after Greater London. However, Scottish HGFs are not as prolific job creators as their counterparts elsewhere in the UK. Most HGFs are relatively small and over 10 years old. They are located in a variety of sectors and technology sectors do no account for a disproportionate share.

4.3. Scotland's proportion of all high tech firms in its business base is the second lowest amongst UK regions. However, the proportion of high-tech enterprises obtaining high growth status (18.4 percent – or 188 firms) is in line with the UK average. Across the UK as a whole, the proportion of high tech firms which achieve high growth is greater than non-high tech firms. This is particularly the case for Scotland. Therefore, contrary to what seems to have been reported previously in the academic literature, incidence rates of HGFs are detectably higher in a number of hi-tech and knowledge intensive services.

4.4. Finally, high tech-HGFs in Scotland tend to be smaller than the overall population of HGFs, and there are relatively few larger firms. They are also younger, although the proportion of high growth-high tech firms over 10 years old is higher than that for the proportion of HGFs as a whole.

5. Analysis of FAME data

5.1. One of the limitations of the IDBR dataset held by the ONS is that the individual companies are anonymous, hence it is not clear what companies are, and are not, included. Specifically, it includes companies that while registered and headquartered in Scotland are, in fact, subsidiaries of non-Scottish-owned companies. The FAME database – which is based on company accounts that are submitted to Companies House - overcomes this anonymity problem. The downside is that only two million companies are included in FAME in a detailed format, biasing the database to larger companies. However, from our point of view this is not particularly disadvantageous as it gives us a profile of technology companies that have achieved growth at some point in their life. We will refer to these as *significant Scottish technology companies*.

5.2. This analysis gives a further perspective on technology companies as a whole in Scotland. First, the majority are subsidiaries of non-Scottish companies, in some cases reflecting acquisition. Just 30% are Scottish owned and headquartered. Second, they exhibit considerable diversity in terms of age, size and sector. Only 20% are less than 20 years old. Many are long-established engineering companies with a tradition of innovation. Technology companies vary in size from under £1m turnover to over £1,000m turnover, but concentrated in the under £50m range. Finally, and perhaps the most significant finding, is the significance of the energy sector, particularly oil and gas, both as a direct source of technology businesses and also as a major market for technology firms in other sectors.

6. Interview Findings

6.1. The third stage of the research involved face-to-face and telephone interviews with senior managers (usually the CEO) of 19 technology-based firms. These firms were identified using the business database FAME. The majority of these firms were either experiencing or had experienced a period of high growth.

6.2. The companies exhibit considerable diversity in terms of their age, size and the nature of their business, with many far removed from the 'white coats' stereotype of a technology business. They are predominantly small and medium sized businesses, with less than £10m in sales and less than 50 employees. Most are engaged in B2B activities. A variety of

business models are in evidence. Most have overseas sales and a significant proportion derive most or all of their sales from exports. Several of the larger companies have international operations which reduces their Scottish footprint.

6.3. Companies are competing largely on the basis of their technical and domain knowledge, capabilities and offerings. Both IP and formalised R&D activity were less common than might have been expected.

6.4. Universities are of minor importance in terms of company source. Just one could be classified as a genuine university spin-out and it no longer has any links with the institution. Two other companies emerged from failed university ventures and only one has strong research links with a local university.

6.5. Most companies have been growing, many quite fast, but some were hit hard by the financial crisis and are only now resuming growth. The majority are anticipating further growth, albeit at varying rates. However, some are at, or anticipate hitting, growth ceilings which in some cases arise from financial constraints. Hardware-related information technology companies are more likely to encounter growth constraints than software companies.

6.6. The main growth constraints that were reported are recruitment, accessing both debt and equity finance (especially by smaller firms) and distance from major markets (especially by hardware companies). The companies were based in Scotland because that was where their founder was living. However, there were few significant advantages of a Scottish location, except for companies selling into the North Sea oil and gas sector. The distance from customers, restricted airline routes and lack of domestic markets were seen as the biggest disadvantages.

6.7. Many of the companies had been approached by potential buyers and several owner-managers seemed likely to sell in the foreseeable future. This raises important questions about the pros and cons to the Scottish economy about the process of business acquisition,

7.0 Summary and Policy Implications

7.1 Scotland performs well in relation the rest of the UK in terms of the presence of highgrowth businesses. However, Scotland performs less well in terms of high growth, high-tech firms. The primary reason for this most probably owes to the fact that Scotland's proportion of high tech firms in its business base is the second lowest amongst UK regions. As a consequence, the overall proportion of its high tech businesses that are high growth is low.

7.2 However, the proportion of high tech firms in the UK which achieve high growth is greater than non-high tech firms. This is particularly the case for Scotland. Therefore, contrary what has been reported previously, the incidence levels of HGFs are higher in a number of hi-tech and knowledge intensive services than the overall population of businesses. On the face of it, this would appear to justify the emphasis which policy-makers give to technology-based firms as a source of HGFs.

7.3 High tech-high growth firms in Scotland tend to be smaller than the overall population of HGFs, and there are relatively few large firms. They are also younger, although the proportion of high growth-high tech firms over 10 years old is higher than that for the proportion of HGFs as a whole. This suggests that high tech firms take time to mature before they can become 'growth-oriented' businesses. The research also revealed that the oil and gas industry plays a vital and disproportionate role in fuelling the growth of Scottish high tech HGFs.

7.4 The qualitative element of the research revealed that many of the smaller HGF high tech firms encounter growth constraints in relation to recruitment, access to both debt and equity finance, and distance from major markets. One of the responses is to sell to a larger international company. And, indeed, many Scottish high-tech firms become acquired in recent years. Therefore, the issue of corporate acquisition and its impact on the Scottish economy seems worthy of further empirical investigation.

7.5 The research raises a number of interesting and challenging policy issues. Issues such as the nature of support to TBFs, the role of public procurement for developing TBFs, the role of inorganic growth within their growth strategies are all aspects associated with these firms which merit further investigation. From the perspective of this study, it was found that companies of scale play a strategic role in developing TBFs in Scotland, notably as a source of market pull and important supply for emerging companies. Policy makers therefore need to give consideration to how the major firms in the Scottish economy might be encouraged and supported to play a more strategic role in the economy both as incubators and investors in TBFs.

1. INTRODUCTION

There is considerable empirical evidence to support the proposition that only a small proportion of firms, create the majority of jobs in any cohort of new businesses (Kirchhoff, 1994; Storey, 1992; 1994; Anyadike-Danes et al, 2009; Henrekson and Johansson, 2010; Stangler, 2010). One of the first people to discover this phenomenon was the economist David Birch who christened these highly dynamic and rapidly growing firms as 'gazelles' (Brich, 1987). A recent overview of the literature examining gazelles concluded that "a few rapidly growing firms generate a disproportionately large share of all new net jobs compared with non-high-growth firms. This is a clear-cut result" (Henrekson and Johansson, 2010, p. 240). Other attributes of high growth firms (HGFs) include above average levels of productivity growth (Mason et al, 2009), high levels of innovation (Coad, 2009; Mason et al, 2009), strong levels of export-orientation (Parsley and Halabishy, 2008) and a high level of internationalisation (Mason and Brown, 2010a). Moreover, not only do HGFs create jobs directly, they also have important spill-over effects that are beneficial to the growth of other firms in the same locality (Mason et al, 2009) and industrial cluster (Brown, 2011; Stam et al, 2009). For these reasons it is now increasingly argued that governments should focus on the promotion of high growth firms rather than start-ups (Shane, 2008; 2009).

Previous research on HGFs in Scotland (Mason and Brown, 2010) found that they are extremely heterogeneous in terms of their age, size, ownership and industry sector. Few fitted the strict gazelles definition which refers to *young* high growth firms that are less than five years old (OECD, 2008). The vast majority are over 10 years old, some significantly older. Moreover, they are by no means all new start-ups. Many have been 'pre-incubated' in established organisations and become independent enterprises as a result of a management buyout (MBO). Serial entrepreneurs are also significant as founders of high growth firms. Growth is often 'stepped', particularly where it is achieved by acquisition, an important mechanism for high growth.

In terms of their activities, most HGFs sell to other businesses, not to consumers. They are UK and globally-oriented with only a minority selling exclusively within the Scottish market. They have business models which are based around building long-term relationships with customers which generate recurring revenue rather than one-off transactions and their business proposition is as much based around selling knowledge as it is selling tangible products and services. Partnering is at the core of the business model of many of HGFs, but takes a variety of different forms and levels of formalisation. HGFs have a variety of core competences but the most common ones are associated with the quality of their employees, innovative products and services and technical, market and customer knowledge.

HGFs tend to be located in Scotland because this is where their founders live. However, most are weakly embedded in Scotland with few business ties and, because of their UK or global market orientation together will low levels of local manufacturing, their Scottish footprint is often limited to their HQ. Their limited embeddedness in Scotland is illustrated by the lack of research and recruitment links to local universities. A number of HGFs have had had financial support from government with early stage financial support and support for overseas market

entry have been the most significant types. Government also has had important, often critical, indirect effects on HGFs, creating markets (through privatisation and deregulation) and expanding markets (regulation, public sector tendering and climate change policy).

In contrast to the original study on HGFs in Scotland, the main focus of this research is specifically on the growth of technology-based firms (or TBFs). TBFs are seen as key growth catalysts in the economy and fundamental drivers of innovation and new technological development. These highly dynamic firms are also viewed as a key source of dynamism in modern economies by creating new markets and displacing less productive incumbents (Schumpeter, 1987). Indeed, since the second half of the twentieth century, high technology industry was thought to be one of the 'greatest engines fostering economic growth in the global economy' (Frankel, 2012, p.724). Plus, this focus has been particularly strong in Europe owing to the fact that it lags behind the US in terms of the number of these rapidly growing technology-based firms (Biosca, 2010).

In recent years, one of the key assumptions, particularly amongst policy-makers, has been that HGFs are dominated by technology-based firms (TBFs) (Coad and Reid, 2012). Indeed, the rationale for the considerable sums of money spent on innovation support in its various forms has been premised on the assumption that this will lead the emergence of technology based HGFs (OECD, 2010). However, this assumption has been challenged both by our own study of HGFs in Scotland (Mason and Brown, 2010) and by the wider literature (e.g. Acs et al, 2008; Henrekson and Johansson, 2010). The reality is that the representation of technology based firms in the population of HGFs is roughly on a par with their proportion in the economy. Plus, very little as yet is known about the incidence of HGFs within the population of TBFs (Brown et al, 2012). This clearly begs the following questions: what role is played by TBFs within the overall population of Scottish HGFs and what is the proportion of TBFs which achieve high growth?

1.2 RESESARCH OBJECTIVES

During the last twenty five years the development of TBFs has been a central policy objective within Scotland. Organisations such as the OECD and economic development agencies have for some time placed great store on creating and supporting technology-based enterprises in the hope that they grow and become major contributors to economic growth and wealth creation. In Scotland, over the last twenty years the Scottish Government and Scottish Enterprise have developed a highly sophisticated suite of policy interventions to support TBFs. Support includes assistance with funding to develop technology, entrepreneurial support and access to funding. However, there is little in-depth research on the challenges TBFs face, their drivers of growth and the contribution they make to economic development in Scotland - and how these firms grow differently from non-high-tech firms.

Recent research undertaken by Scottish Enterprise suggests that relatively few high growth businesses are high-technology firms in Scotland (Mason and Brown, 2010). Potential reasons include:

- the immature or nascent nature of many TBFs (too young to achieve high growth);
- a lack of a proper market focus (i.e. 'technology-push rather than 'market-pull');
- a lack of strong ambitious leadership and management ambition, or weak management capabilities;
- lack of appropriate funding; &
- acquisitions by larger firms.

However, the varying importance and interplay between these different factors is not yet fully established. In light of this evidence gap, more research is needed to examine the nature of growth within TBFs so that policy makers such as Scottish Enterprise can better understand the key growth constraints and conditions affecting the ability of these firms to grow. The main objective of this research exercise is to enable Scottish Enterprise to better understand the nature and determinants of growth within Scottish high technology businesses and identify appropriate policy responses. In order to provide a comprehensive assessment the following issues will be examined in greater depth within this report:

- Define what is meant by a TBF and provide a clear taxonomy of different variants of these enterprises;
- Estimate where possible the aggregate number of TBFs in Scotland and outline their sectoral composition;
- By examining a sample of these firms, establish their key demographic characteristics in terms of sector, employment, average turnover, degree of internationalisation, levels of innovation and , geographical location;
- Examine the founding origins, governance structures and leadership styles and how this affects their subsequent growth potential;
- Assess the different growth processes and growth strategies within these firms;
- Assess how many TBFs are high growth firms;
- Examine the nature and determinants of growth within TBFs and how this varies across different types (e.g. corporate spin-offs, university spin-outs and corporate ventures);
- Explore how foreign acquisition of indigenous TBFs affects their growth and development;
- Assess the main barriers to growth evident within TBFs such as technological development, leadership and management skills, absorption capacity constraints, management capacity, funding, sales and marketing and degree of customer focus/end user engagement etc;
- Articulate the economic contribution these firms make to the Scottish economy both directly and indirectly;
- Provide policy recommendations for Scottish Enterprise and stakeholder organisations to help promote the growth and development of TBFs in Scotland.

1.2 RESEARCH METHODOLOGY

The research reported in this paper is based on an extensive, multi-method programme of research on HGFs within Scotland conducted between January 2011 to April 2012. We have adopted a mixed methods approach comprising quantitative elements based on firm databases and a qualitative interview-based study. Recent assessments of mixed methods studies have found them be a useful methodology for undertaking business-related, entrepreneurship research (Molina-Azorin, et al, forthcoming). The work included the following components:

- An analysis of the Inter Departmental Business Register (IDBR)-based Business Demography dataset;
- An analysis of technology-based firms on the FAME data base; &
- A mixture of face-to-face and telephone interviews with a sample of high growth technology based firms.

The work involved a major collaboration between two universities (Strathclyde and Aston) and Scottish Enterprise. Aston University undertook the analysis of the ONS Business Structures Database (see section 4) and the University of Strathclyde collaborated with Scottish Enterprise on all the other aspects of the research including: the literature review, sectoral definitions, FAME analysis, company interviews and final report writing.

The report begins with an outline of what is meant by a 'high technology firm' and how such firms can be defined. It then undertakes an extensive review of the literature on TBFs to set the context and raise some lines of enquiry to be followed up in the empirical work. . The following chapters report on the findings from each of these lines of enquiry. The final chapter discusses the conclusions from the work and highlights some policy implications which arise from the study.

2.0 DEFINING HIGH TECHNOLOGY FIRMS

It is critical at the outset to define what is meant by high technology and how 'high tech' firms can be identified. This is not a straightforward task and there is little consensus about the precise characteristics that such firms should possess. Most studies adopt a similar approach, defining high technology industries on the basis of particular characteristics, notably R&D spend, employment in scientific occupations and patents. For example, the OECD use R&D intensity as the main measurement criteria (OECD, 1997). However, the use of different criteria has resulted in a wide range of definitions and lists of high tech industries over the years.

A pioneering approach in the UK was undertaken by Butchart (1987) which identified specific four digit categories in the 1980 Standard Industrial Classification (SIC) as being high technology. This list was subsequently converted into the equivalent categories in the 1992 SIC. However, this definition is now rather outdated. An alternative definition has been produced by OECD (Hatzichronoglou, 1997) but this is limited to manufacturing. Eurostat data includes both high tech manufacturing and high tech services. The USA has several definitions of high tech. However, these various approaches all ultimately require judgement on what constitutes a 'high' level of the particular characteristics used in the definition – for example, what constitutes a 'high' level of R&D intensity? Moreover, even at the most detailed level of disaggregation SIC categories can be very broad. Moreover, most emerging industries are initially captured in the 'not elsewhere categorised' groupings. And, of course, industries change over time in terms of their technological characteristics.

An industry-based definition of high tech industry also has operational difficulties when applied at the firm and establishment levels. Specifically an industry definition assumes homogeneity within the industry whereas in reality firms are likely to display considerable variability in the extent to which they are high tech. A further problem is that the criteria used in defining high tech are weighted towards large firms, whereas R&D expenditure and technology occupations are often under-recorded in small firms. Another problem is that such definitions emphasise product technology rather than process technology. But, of course, many lower technology products are made using sophisticated process technology and many high tech products are made using low levels of process technologies. A further complicating factor is the spatial division of labour, or corporate geographies, of businesses whereby firms may undertake their high tech functions and activities in separate establishments and locations to those of their lower tech activities. This problem was manifest in Scotland (and other peripheral regions) in the 1970s and 1980s with multinational companies, particularly in the electronics sector, establishing branch plants which focused on more mature products and used routine production methods (Brown and Mason 2012). Although such plants were classified as high tech from an industry basis they were less likely to meet such a definition using a firm-based classification.

The alternative approach is one that is based on firm or establishment characteristics. However, this is impractical. First, this would require a huge amount of firm/establishment level information, which simply does not exist. Second it would be highly subjective. For

example, the Sunday Times Fast Track defines a high tech company as one "whose business growth and success is dependent on the development of one or more technologies." This begs various questions: for example, what is 'dependent' and what is a 'technology'.

Despite the drawbacks highlighted above, this study defines high tech firms using an industry definition. One that does have considerable appeal is the definition used by Glasson et al (2006) in their study of high tech industry in Oxfordshire which is based on an extended Butchart definition. The definition includes both high-tech manufacturing and high-tech services, in largely based on SIC categories but also includes a range of non-SIC-based activities (Appendix 1). This combination of rigour, derived by using measurable criteria, plus an element of subjectivity, has considerable appeal. It also allows for the definition to be 'tweaked' to take account of local circumstances. The inclusion of 'Motor sport and automotive engineering/design activities' is particularly appropriate in Oxfordshire which is the focus of the motor sport cluster in the UK (Henry and Pinch, 2001) but is less appropriate in Scotland.

For a Scottish definition it was appropriate to make some adjustments to take into consideration the nature of the economy in Scotland. A full listing of the SIC codes adopted are outlined below 3. The main inclusions to the original definition by Glasson et al (2006), are outlined below:

- Extraction of crude petroleum (SIC 11.2) and ancillary services (11.2). This will capture the majority of TBFs in the oil and gas industry.
- Under Electronic publishing, reproduction of computer media (22.33) has been added to capture computer games activities
- New SIC codes for life sciences have been added that correspond with the Scottish Government definition of the sector (24.4, 33.1)
- Replaced automated machinery and robotics (no specific 1992 category) with machinery and equipment not classified elsewhere (SIC 29 all). This will include a lot of capital equipment, pumps, valves, air-conditioning equipment etc. This also includes renewable industry companies and a number of other high tech manufacturing companies. SIC 29 also includes defence-related manufacturing (e.g. 29.6).
- In the electrical equipment category SIC 31.40 has been added which covers primary cells and batteries.
- The manufacture of transport equipment (34.10) and parts and accessories (34.3) have been added.
- The SIC codes for manufacture of games and toys (36.5), which includes domestic electronic games.
- Security and related activities has been added, that includes monitoring by mechanical or electrical devices (74.60/2)

Table 2.1. HIGH TECH SECTORS BY STANDARD INDUSTRIAL CLASSIFICATION (BASED ON SIC 2003)

High-Tech Manufacturing Activities	
11.1, 11.2	Energy
22.1, 22.3	Electronic publishing
24.4, 33.1	Life Sciences
25.24, 26.15, 26.82	Composites and other advanced materials
28.52	Precision Engineering and precision components
29 (all)	Machinery and Equipment not classified elsewhere
30.01, 30.02	Computer equipment & office machinery
31.1, 31.2, 31.4, 31.62	Electrical equipment
32.1, 32.2, 32.3	Electronic equipment & components
33.1, 33.2, 33.3, 33.4	Medical & surgical equipment
34.10, 34.3	Transport Equipment
35.3	Aerospace & related activities
36.5	Manufacture of Games and Toys
High-Tech Service Activities	
64.2	Telecommunications
72.2	Software development & consultancy
72.6	Web/internet services
72.1, 72.3, 72.4, 72.5, 72.6	Other computer
73.1	R&D (natural sciences & engineering)
74.2	Architectural & engineering activities
74.3	Technical testing & analysis
74.60/2	Security and related activities

3. TECHNOLOGY-BASED HIGH GROWTH FIRMS: A LITERATURE REVIEW

3.1 INTRODUCTION

High growth firms (HGFs) are now widely accepted to be a key driver of economic development in advanced countries (OECD, 2010). Based on a review of prior studies Henrekson and Johansson (2010) found that a small number of rapidly growing firms generate a disproportionately large share of all net new jobs. In the UK in the period 2002-2008 HGFs represented about 6% of the total number of businesses (NESTA, 2009). They have been responsible for around half of the net job creation by firms with 10 or more employees in this period. The majority of HGFs tended to be small (less than 50 employees) but well established (over five years old) (Anyadike-Danes at el, 2009). Updating this research to cover the recession found that the number of HGFs was very similar to both the 2002-2005 and 2005-2008 periods and that, as before, they generated more than half of all new jobs created by firms with 10 or more employees (NESTA 2011). This suggests that HGFs are equally significant in periods of economic growth and recession.

A study of HGFs in Scotland, undertaken on behalf of Scottish Enterprise confirmed their importance in aggregate terms to the Scottish economy (Mason and Brown, 2010; Brown and Mason, 2010). In-depth investigation of a sample of HGFs highlighted their heterogeneity in terms of age, size, sector and origins. They were typically knowledge-based, innovative, strongly customer-oriented and had distinctive business models. Most were internationally-oriented with a strong physical presence in foreign countries. However, for the most part they were not deeply embedded in Scotland in terms of their production and links to suppliers. They were located in Scotland because that was where their founders were living.

One of the most surprising conclusions from the various studies of HGFs that have been undertaken in recent years is that they are not overrepresented in high-technology sectors. As Henrekson and Johansson (2010, p. 240) observe, HGFs "exist in all industries. If anything, they appear to be overrepresented in services." The recent NESTA study (Biosca et al, 2010, p. 8) similarly observes that HGFs "are distributed across the economy, from mining to banking." They further note that while HGFs in high-technology sectors are not unimportant, such firms "are only one part of an overall growth picture that depends just as heavily on businesses that innovate in other ways: new services, new business models, and new processes are often just as important to growth businesses as new technology." Nor is there conclusive evidence of a strong link between R&D expenditure, innovation and high growth (OECD, 2010). Here again, the Scottish study mirrors these conclusions. Although innovation was a characteristic of most of these firms, by no means all HGFs were in high technology sectors (Mason and Brown, 2010). The limited overlap between HGFs and TBFs is an extremely important conclusion. It challenges the assumption amongst the policy-making community that supporting high technology sectors will generate HGFs. Indeed, one of the key conclusions from the Scottish study was that policy-makers may be over-emphasising the role of TBFs as a source of HGFs (Mason and Brown, 2010; 2011).

More importantly, given the amount of financial support that is directed to TBFs, to high tech clusters and to the commercialisation of university and public sector research, this raises the question why this support has not generated more high growth-TBFs? This introductory section of the report reviews the literature on HGFs and high technology sectors in order to set the context and to identify appropriate research questions. It is structured as follows. We begin in Section 2.2 with a brief examination of the theory of firm growth and how this relates specifically to high technology firms. In Section 2.3 we look at the evidence on the success of TBFs and whether these businesses grow rapidly. In Section 2.4 we examine the empirical research surrounding the key growth characteristics of TBFs. We then go on in Section 2.5 to review the literature on the obstacles to growth confronting TBFs. In the final section, we draw together some conclusions from our literature review and identify the main themes to be addressed in the empirical work.

3.2 THEORIES OF FIRM GROWTH

We start with a review of theories of firm growth. This provides a framework for making sense of empirical studies of firm growth (Garnsey et al, 2006). One of the earliest and most important conceptual contributions to this debate was made by the economist Edith Penrose (1959). In her seminal contribution *The Theory of the Growth of the Firm*, Penrose challenged the dominant neo-classical view of the time which primarily viewed firms as a 'black box' comprised of supply and demand functions. Using a case study of the Hercules Powder Company, Penrose (1960) suggested that traditional economic theories were inadequate at explaining the intricate complexities of the growth within real life firms. In contrast, Penrose viewed firms as bundles of human and non-human resources. In her view, 'growth is governed by a creative and dynamic interaction between a firm's productive resources and its market opportunities' (1960, p.1). She claimed that there are two main drivers of firm growth: internal and external factors. However, the former were the most important because external factors, such as the ability to raise capital, were often shaped in certain ways by the firm's internal capabilities.

With her insightful analysis Penrose highlighted the importance of internal resources in determining the growth of the firm because expansion requires planning and the deployment of managerial resources. The pioneering nature of this work, led increasing levels of interest from various academic fields in the factors fuelling the growth of firms. Interestingly, it was business and management researchers rather than Penrose's fellow economists who most eagerly embraced her theoretical ideas and began to empirically investigate the key determinants which drive the growth of firms (Coad, 2009; Pitelis, 2007). The Penrosean perspective on firm growth was instrumental in the development of resource-based view (RBV) of the firm which was developed during the early 1990s (Barney, 1990). Research by Barney (1990) and Alvarez and Barney (2000) classified resources into four main categories:

1. Physical capital resources: including geographic location, premises, capital equipment, technology and access to raw materials.

2. Human capital resources: including training, experience, judgement, intelligence, relationships and insights of individuals.

3. Organisational capital resources: including the firm's structure and systems, informal relations among groups within the firm and between the firm and the environment.

4. Entrepreneurial capabilities: including learning, knowledge, creativity and leadership.

The RBV view of firm quickly became the accepted orthodoxy within the management and entrepreneurship literature. However, there were some who took issue with certain elements of this theory. One focus for criticism was the belief by the RBV that certain resources merely 'exist'. Considerations of how resources are developed, how they are integrated within the firm and how they are released have been under-explored within this perspective. Another criticism of RBV has focused on the static nature of the theory, particularly the factors which give rise to the creation of certain resources, especially in certain dynamic markets (Eisenhardt and Martin, 2000).

These criticisms led to the development of an alternative perspective based around the 'dynamic capabilities' of firms (Teece et al, 1997). This approach 'emphasizes the development of management capabilities, and difficult to imitate combinations of organizational, functional and technological skills' (Teece et al, 1997, p. 510). The main strength of this perspective is that it draws on a number of sources of a firm's competitive advantage. It therefore integrates and draws upon a multidisciplinary research agenda in such areas as the management of R&D, product and process development, technology transfer, intellectual property, manufacturing, human resources and organizational learning. In recognition of the fact that firms increasingly confront rapid technological change, the dynamic capabilities view stresses how firms exploit 'existing internal and external firm specific competences to address changing environments' (Teece et al, 1997, p. 510). This point seems particularly relevant in helping to explain the importance of the external environment for firm growth and the rapidly changing environment which confronts TBFs.

While these theoretical concepts provide some interesting insights into firm growth they seem quite broad brush mechanisms for helping us fully understand rapid growth within TBFs. The RBV has been a key way of illustrating how a firm's resources help shape the growth of the firm. However it says little about how firms go about marshalling these resources. A dynamic capabilities perspective offers a more nuanced way of unpicking the various individual components of firm growth and stresses the importance of rapid technological change, however it says little about the most important factors underpinning growth of successful firms. Neither does it say much about the factors explaining the decline and eventual demise of some firms.

3.3. DO TECHNOLOGY-BASED FIRMS GROW RAPIDLY?

In tandem with mounting theoretical interest in firm growth, from the 1970s onwards researchers began to take a strong interest in the growth of firms particularly in high

technology sectors of the economy (Little, 1977; Mowery and Rosenburg, 1989). The emergence of new transformative sectors such as the microelectronics industry was considered to be a key driver fuelling increasing levels of academic interest in high-tech industries and their powerful role in promoting and shaping economic development within advanced economies (Dicken, 2003).

At the same time, research during the 1970s began to point towards the strong role played by small firms in the economic growth process. The early work of David Birch in particular was important in promoting widespread interest in the role played by small firms and new business starts. In his famous report *The Job Generation Process*, David Birch (1979) pointed out that giant corporations were no longer the main sources of job creation in the US and that the majority of new jobs were created by small firms. The combination of these two themes – high tech and small firms - resulted in an upsurge of policy maker interest in the potential role for new high technology based firms (or NTBFs), especially in terms of the new employment opportunities these firms could potentially produce.[1] The level of interest was particularly strong during the 1980s in economies which were undergoing severe structural changes (Almus and Nerlinger, 1999). As a consequence, the widespread perception which gained prominence during the late 1970s was 'that new and small technology-based firms are central to the creation of future wealth and employment ….' (Tether, 1997, p. 91). Innovative and technology-based new and small firms have therefore been the focus of rapid growth expectations from policy-makers around the world.

Recent research study conducted in the US certainly seems to support this focus (Eckhardt and Shane, 2011). This study used a database of 201 industries over a 15 year period (1983-1997) to examine why some industries host more new high growth firms than others. The research discovered that over half (52%) of new high-growth firms are located in just ten industries. The study also discovered that increases in the proportion of employment of scientists and engineers in industries is positively associated with counts of fast-growing new firms. The findings strongly suggest that technological innovation is an important determinant of high growth entrepreneurial opportunity. The findings from this study contrast markedly with recent research on HGFs in the UK (Anyadike-Danes et al, 2009; Mason et al, 2009; Mason and Brown, 2010). These studies, in common with the bulk of research in this field (see Henrekson and Johansson, 2010), all found considerable diversity in terms of the sectoral distribution of HGFs. This may suggest that the US economy is markedly different from European economies (Biosca et al, 2011). Alternatively, it may call into question the choice of the Inc 500 database as the study's main data source. Its reliance on firms submitting themselves for inclusion on these listings may over-represent technology-based firms which are trying to raise their profile to obtain further rounds of venture capital funding.

[1] Although the term NTBF was first coined by the Arthur Little Group (Little, 1977) using a very vague definition of firms less than 25 years old, in this paper the term NTBF is taken to refer to young firms (less than five years old) operating in 'high technology' sectors.

Indeed, there appears a lack of definitive empirical evidence - especially from a European context- to justify a policy focus on technology-based new and small firms (Storey and Tether, 1998). One of the problems with research in this area is a lack of longitudinal analysis which specifically focuses on the survival of technology-based firms. In their review of the empirical evidence base during the 1990s, Storey and Tether (1998) conclude that the direct and indirect employment generation effects from NTBFs are *mixed*. They claim that two key conclusions can be drawn from previous studies:

- Compared with start-ups in general, NTBFs exhibit faster average employment growth rates.
- The absolute growth in employment of NTBFs is modest. For example, in none of the studies examined did the average employment of the firms which survived for 10 years exceed their employment at start-up by more than 20 employees.

One of the earliest studies examining the growth trajectories of high technology firms was longitudinal research undertaken in San Francisco between 1969 and 1976 (Cooper and Bruno, 1977). This study discovered that the failure rate of TBFs was lower than that for non-technical based firms and that their growth level was higher. It also found that the level of acquisition of TBFs was high. However, only a small proportion of firms grew rapidly (only 12 percent achieved a turnover of more than $5milion). The study also found that the level of acquisition of TBfs was high. A follow-up study (Bruno et al, 1992) noted the rising discontinuance rate over time, due both to failure and acquisition, and the small proportion of firms (18%) which remained independent after 20 years.

A UK study of high-technology firms found that the survival rate in the 1986 to 1992 period was lower than that recorded by businesses in general (Westhead and Cowling, 1995). This study also revealed that mean absolute employment growth in their sample of TBFs was markedly higher than that recorded in a group of surviving independent firms in more 'conventional' sectors. Interestingly, from a regional perspective, firms located in less economically prosperous northern and assisted areas in Britain recorded lower levels of employment growth (Westhead and Cowling, 1995). This would suggest that the role played by TBFs and NTBFs varies geographically and that additional support for firms in peripheral regions may be needed (Westhead and Cowling, 1995). The authors also claim that policies to encourage all firms to grow risks being ineffective, and instead, policies must be tailored to support existing TBFs which already have demonstrated the inclination and ability to grow in employment size.

Within much of the research literature there is a strong presumption that growth was a central objective for these types of business. However, in an important contribution to the debate surrounding the role played by TBFs in economic growth, Tether (1997) discovered that a small number of firms are responsible for providing the bulk of the new employment. Contrary to the 'barriers to growth' perspective that argues that these firms would grow if certain barriers were overcome by firms, such as finance or management expertise, Tether claims that there is a large amount of diversity within the population of TBFs and that 'the large majority of these firms do not seek rapid growth' (Tether, 1997, p. 92). In particular, firms vary considerably in

terms of their competencies and interpretation of market needs and opportunities (Tether, 1997). From his empirical research he claims that the vast majority of innovative TBFs which survive become established, niche-market, technology-based SMEs, rather than grow into large firms.

Using evidence from Cambridge, Garnsey and Heffernan (2005) similarly report that substantial growth is unusual. More significantly, they observe two further common features: firms often fail to sustain their early growth; and second, interruptions to growth, and even growth reversals, even amongst firms with a largely successful growth record. They explain this in terms of a combination of both internal and external factors. From an internal perspective firms often lack the resources to withstand setbacks. The pace of growth may outstrip the synchronisation of specialised resources and the time, competence and knowledge of the management team. The external environment in an emerging industry is likely to be volatile. Given how common growth setbacks are, this "underlines the need to view new firm growth as an unfolding process in which the future cannot be extrapolated from the past" (Garnsey and Heffernan, 2005, p. 695). This, in turn, needs longitudinal studies over a period of time to properly track the growth of firms.

In summary, the empirical evidence base on the growth potential of new and young technology-based firms is mixed. It suggests that these firms generally exhibit faster growth rates than business start-ups as a whole. They also have a higher survival rate. Recent research also shows that the employment multipliers from high-tech firms are much higher than those found in more traditional sectors such as manufacturing (Moretti and Thulin, 2012). However, the average rate of direct employment creation amongst TBFs has been modest. In general, the average rate of direct employment creation has been much less than ten new jobs per firm per year (Tether, 1997). An important finding from a policy perspective is the fact that the majority of these firms (as with most firms in general, see Henrekson and Johansson, 2010) do not seek rapid growth which undermines the 'barriers to growth' arguments often advanced by policy makers.

3.4 BARRIERS TO THE GROWTH OF TECHNOLOGY BASED FIRMS

The emphasis in the UK and European literature on TBFs and university spin-offs is on the limited growth that such firms achieve. For example, a significant theme running through Oakey's work in the 1980s and 1990s was that TBFs in the UK exhibited an unimpressive growth performance. TBFs in the US grew much more significantly in aggregate (Storey and Tether, 1998). Moreover, in the UK, and more generally across Europe, there is an absence of extremely fast growing firms that is found in the USA (Storey and Tether, 1998).

Much of the literature attributes the limited growth of TBFs to the lack of access to finance, especially venture capital which, in turn, is attributed to the short-termism and lack of risk appetite amongst investors. However, this can be interpreted as a convenient excuse to cover up for the failure to generate revenue or demonstrate customer demand (Planys, 2008). Others have focused on the characteristics of the founders of high tech firms, notably their

prior employment experience which is typically in research organisations and their lack of commercial experience. We discuss this further in the next section.

However, Oakey and Mukhtar (1999) argue that the product life cycle imposes particular strains on hjgh tech firms throughout their existence. In most cases a substantial amount of product development work has to be performed before any income is derived from income from sales. The product launch is likely to be at a time of maximum financial stress, when R&D costs have been incurred, marketing needs to be funded and no income has been achieved. Firms are vulnerable in the event that product development takes longer than anticipated. Moreover, as firms are likely to be able to develop one product at a time these periods of financial stress will recur as research and development expenditure for the next product occurs at times when profits from the current product are declining. Should the sales of a product be lower than anticipated and thus unable to cover the costs of the R&D, the survival of the firm is at risk. These characteristics, in turn, make them too high risk for many funders.

Geoffrey Moore (1991) has a rather different take on the effect of the product life cycle on the ability of TBFs to grow. This model distinguishes several different types of customer:

- Innovators are passionate about technology and so pursue new technology products aggressively even before they have been formally marketed.
- Early adopters, like innovators, also buy new products because of their benefits.
- The early majority are comfortable with the technology but wait until they see other people using the products before buying themselves.
- The late majority are not comfortable with the technology and so wait to purchase once it has become an established standard and support is available.
- Finally, the laggards are not interested in the technology and would only buy such a product if it is embedded in another product.

The early and late majority each constitute about one-third of the market, so are key to a firm's growth and profitability. However, whereas the basic product model assumes that over time firms can move seamlessly between these different customer segments, Moore argues that there are discontinuities, particularly between early adopters and the early majority which can create a significant barrier to growth. Early adopters are buying to get a significant advantage over their competitors. They expect a radical discontinuity between the old and the new, but being the first customers are prepared to bear with the inevitable bugs and glitches that accompany any innovation just coming to market. The early adopters on the other hand are buying for a productivity improvement. They want technology to enhance, not overthrow established ways of doing business. Above all, they do not want to debug someone else's product. By the time they buy it they want it to work properly and integrate appropriately with their existing technology. However, "crossing the chasm" to the mainstream market requires both a significant increase in the scale of operation and change in the principles and practices of managing finances, organisation and product development.

An alternative perspective – for example, voiced in a paper by Planys (2010), a Scottish-based technology consultancy – is that the majority of TBFs adopt a technology-push approach. Often led by academics with very limited industrial and commercial experience, they are very distant from sales and few can articulate the nature of their offer in the form a value proposition for the target customer. They struggle to differentiate between individual project opportunities and scaleable market opportunities. They have little in the way of market information – often because they are engaged in leading edge activity that requires the creation of a market. However, they have little or no sales and marketing resource. Sales people, if employed, tend to be misused. These businesses are likely to have public support to develop their products and receive advice from public sector. They are over-focused on IP protection. Their major objective is to attract funding. Planys argues that this diagnosis applies to Scotland's early stage technology businesses, which they describe (p. 10) as being "exceptionally under-developed in the crucially important commercial areas and are significantly under-investing in their commercial capabilities."

They highlight two main causes. First, assistance with sales and marketing is often not part of the portfolio of public support sector support. Interventions are primarily focused on technical developments, IP protection and access to funding. To the extent that sales and marketing support are provided it is in the form of grants for trade shows. Second, investment is focused on the early stage verification of technology – priming the pump for larger investments or early acquisitions. In other words, the Scottish investment environment is effectively a transaction mechanism for getting Scottish research that has been publicly-funded into the global market, rather than a driver for developing indigenous businesses. Planys argue that the emphasis is on technology, IP generation and transactions rather than on company building. Sales and marketing does not fit in this model. The key beneficiaries are the investors who reap the benefits of publicly funded research, IP protection and co-investment. This lack of focus, understanding and investment in sales and marketing functions, Planys suggests, has various consequences: uninformed initial specifications of the product/service; lack of awareness and demand in the target customer base; expensive re-development after initial market engagement; and lack of sales revenue to demonstrate market acceptance. This, in turn, "condemns many technology start-ups to the short-life of stunted growth and unfulfilled expectations" (Planys, 2008, p. 15).

Bhidé (2008) offers another perspective which argues that only some types of TBFs are likely to grow. Moreover, these are not the ones most heavily involved in R&D. His argument is that firms which are engaged in making basic science, engineering or technology advances are unattractive to venture capital firms for a number of reasons. Their time scale is too long for investors who need exit within five to seven years, they have to create markets in order to grow and their prospects are too uncertain. It is therefore too difficult for VCs to evaluate. VCs prefer to invest in firms that are exploiting high level know-how that has already been developed by a lab or inventor – what he calls 'mid-level knowledge' - where there is clear evidence (at least to the expert eye) of large potential demand and where rapid expansion is both possible and offers substantial payoffs in terms of competitive advantage.

University Spin-Off Companies (USOs)

University spin-offs (USOs) are an important sub-set of technology-based firms. For example, in life sciences 34% of start-ups between 2005 and 2009 were university spin-outs (Crocker, 2010). It is argued that USOs not only face the difficulties associated with NTBFs in general but also face some additional specific obstacles, notably, the lack of commercial skills of academic entrepreneurs and the conflicting objectives of the key stakeholders, notably the university, the academic entrepreneur, the management team and investors in the business (Vohora et al, 2004). The challenges experienced by university spin-off companies in growing have been explored by Vohora et al (2004). They argue that USOs grow in a non-linear way, moving from one development phase to another. These discrete development phases are separated by various 'critical junctures' which have to be overcome if the firm is to progress. These phases are as follows:

- Research phase – the prior academic research undertaken by the founding team over a number of years prior to start-up
- Opportunity framing stage – recognising an opportunity and taking the formative steps to creating a USO.
- The pre-organisation phase – having committed to commercially exploiting the opportunity, the management team starts to develop and implement strategic plans. This includes the establishment of credibility and the acquisition of the necessary resource to start the business.
- Reorientation phase – this involves the attempt to offer something of value to customers. The information and knowledge that is acquired from interactions with customers, competitors, suppliers and potential investors leads to changes in the approach of the business.
- Sustainable returns phase – the USO attains sustainable returns. This is likely to involve a weakening of the links with the university, for example, moving off campus, recruitment of professional managers. However, at least one of the academic investors is likely to continue as technical adviser while remaining at the university.

Vohera et all argue that for the USO to develop its full potential and become an established firm generating sustainable returns it must successfully overcome the various critical junctures which separate these various phases. These critical junctures are:

Opportunity identification. The academics have to be able to identify a solution to a market need. The problem here is that while possessing significant technological know-how, academics typically have insufficient knowledge of how to serve markets and unrealistic expectations of the profits that can be derived from the technologies they have developed. Academic entrepreneurs often lack the necessary human capital and prior business experience to conceptualise how a technological discovery can be best applied to meet real human need. A business will not succeed unless this critical juncture is overcome.

Entrepreneurial commitment. Intention precedes action (to start a new business) and entrepreneurial commitment is necessary for a potential entrepreneurial venture to be taken forward from a vision to a business. This involves the academic entrepreneur taking various actions which involve making significant commitments – such as hiring a manager and disengaging from the university in some way. Academics who are uncomfortable with the commercial world, lack faith in their own abilities to cope in a commercial world, lack social networks to identify commercial staff and have an inability to delegate can prevent this critical juncture from being overcome. University cultures, structures and (lack of) policies may discourage the various actors (academic entrepreneur, hired managers, investors) from becoming sufficiently committed to take the business forward.

Credibility. The entrepreneur has to be able to gain access to and acquire an initial stock of resources that are necessary for the business to function. Finance, particularly seed finance, is critical. However, a lack of credibility constrains the entrepreneur's ability to access and acquire key resources. Meanwhile, achieving credibility with external actors (e.g. potential investors, potential managers) are hampered by the intangible assets of the USO (e.g. patents) and the founding entrepreneur's lack of a commercial track record. Certain ties to the university might be seen by investors as a liability.

Sustainable returns. Achieving sustainable returns after the business has begun to commercially exploit its technological assets requires the ability to continuously re-configure existing resources, capabilities and social capital with the new information, knowledge and resources that is obtained from engagement with the market. This involves addressing resource weaknesses, inadequate capabilities and social liabilities and turning them into strengths. For example, informal structures need to be reconfigured into formal structures and routines.

The study of Scottish USOs by Targeting Innovation (2008) identified a number of common features of successful firms.

Management. Perhaps contrary to expectations, in a large proportion of the most successful spin-outs the initial management team was able to take the company from start-up to maturity. Moreover, by no means all had prior commercial experience although they all had at least once experienced commercial manager.

Markets and Customers. Most successful companies diverged radically from their original plan. Relatively few successful companies have developed a business based on their original product or service idea. They often ended up selling different products to a different set of customers than they had intended, usually out of necessity. This reflects that most technologies have a very wide range of potential applications and it can be difficult to work out which is the best market.

Finance. About 30% of USOs in Scotland received some form of private investment. However, only a few had been able to raise the funds needed to create a substantial company. The less successful companies have had to struggle as best they can with an irregular sequence of small,

sub-optimal investments. Some companies have been able to generate early revenues and so grow without significant external investment, but such firms typically do not get beyond ten employees.

So what has been the growth performance of USOs? On the whole the evidence suggests that these firms have not grown to the level expected by policy makers (Harrison and Leitch, 2010). As long ago as the early 1990s, studies of university spin-offs in Sweden highlighted their limited growth (e.g. Olofsson and Wahlbin, 1993). A recent review of the growth of USOs concluded that "the vast majority of university spin-off companies are small technology based firms set up to exploit limited portfolios of technological/intellectual assets, and with limited growth aspirations or potential" (Harrison and Leitch, 2010, p. 15). In their view, the belief that transferring technology from universities to the market via spin-off companies "is based on the atypical experience in … Silicon Valley and the Route 128 area" (Harrison and Leitch, 2010, p. 7). This is confirmed in a study of university spinoffs in Scotland by Targeting Innovation (2008). It noted that there have been around 200 spin-outs from Scottish universities, mostly since 1997. Of these, 30 percent are no longer trading (which is probably a lower failure rate than for small business in general), 55 percent employ less than 10 people and just 15 percent employ more than 50 people. Of the latter, which number 17, just six have developed to become substantial businesses, all of which have raised business angel or venture capital funding and five took more than ten years to realise their potential.

3.5.1 CHARACTERISTICS OF GROWTH-ORIENTED TBFS

This discussion of barriers to growth raises the question of what is distinctive about those firms that do exhibit growth. In recent years there has been a growing literature on high growth firms. Indeed, one recent review of these studies identified 34 empirical studies (Dodds and Hamilton, 2005). However, the overwhelming majority of these studies do not specifically examine technology-based firms.

According to observers, broadly speaking, the main determinants of small business growth fall into four main categories (Dodds and Hamilton, 2007):

1. Characteristics of the entrepreneur;
2. Characteristics of the firm;
3. Management strategies;
4. Environmental/industry specific factors.

Using this classification system we can review the literature of the nature of growth in TBFs and NTBFs.

3.5.1 Characteristics of the Entrepreneur

Level of human capital

One of the issues which has been most investigated is the level of human capital that the founders of new high tech firms possess. Clearly, the knowledge and skills of the entrepreneur will play a significant part in shaping the growth of a firm, especially given the complex nature of innovation processes within NTBFs and TBFs more generally. For example, longitudinal research undertaken in Britain between 1986 to 1992 found that a correlation between high-tech firm size and the graduate level education of entrepreneurs (Westhead and Cowling, 1995). Elsewhere, research on NTBFs in the former West Germany between 1989 and 1996 found that positive growth effects were derived from the human capital of the founder(s) (Almus and Nerlinger (1999). This holds especially for entrepreneurs from technical disciplines whereas general business knowledge was found to play a less important role. With respect to non-innovative young firms, a comparably lower influence of the human capital of the founder(s) can be assumed (Almus and Nerlinger, 1999).

More recent research on a sample of 439 Italian high-tech start-ups also confirms that human capital has a direct positive effect on firm growth (Columbo and Grilli, 2005). Corroborating the findings from Almus and Nerlinger (1999), this work shows that firms founded by individuals with selected human capital characteristics - specifically university-level education and prior work experience in technical functions - can leverage the distinctive capabilities and knowledge to grow more than other firms (Columbo and Grilli, 2005).

However, while strongly connecting firm growth to human capital, the problem with some of these quantitative studies is that they fail to show precisely how human capital and skills enable an entrepreneur to navigate a company towards a high growth trajectory.

Experience of Founders

Cooper and Bruno (1977) also discovered that high growth TBFs were more likely to have been started by individuals from larger corporate backgrounds whose new ventures were in cognate technological areas. Later research by one of the authors confirmed that entrepreneurs in technical, growth-oriented firms tend to emerge from related 'incubator' organisations (Cooper, 1985). Interestingly, the latter study found that existing businesses rather than universities or research institutes were the primary generators of growth-oriented TBFs (Cooper, 1985). The understanding of the origins of high tech entrepreneurs was extended by Harrison et al (2004) in a study of high tech entrepreneurs in Ottawa. Their study makes two important observations. First, entrepreneurs are not 'local'. Rather, they are attracted to technology clusters, or incipient clusters, by a range of magnet organisations (talent attractors). Second, entrepreneurs draw on their experience and the networks established during their entire career, working in different organisations and places, and not just on those resulting from their immediate past employment. This challenges the concept of an 'incubator' organisation as being too simplistic. These factors (the importance of non-local entrepreneurs

attracted by magnet organisations, and multiple sources of employment) is confirmed in studies of the Cambridge cluster (Keeble, et al, 1999). They are also consistent with more recent research which suggests that the probability of becoming an entrepreneur increases with the number of different professions and industries an individual has previously worked in (Astebro and Thompson, 2011).

Research on the growth experiences of different types of entrepreneurs in Scotland, not all of whom are in high-tech businesses, also confirms the benefit of a multiplicity of business experiences (Westhead et al, 2005). Three types of entrepreneurs were examined: novice entrepreneurs, serial entrepreneurs (those beginning new businesses having sold an existing business) and portfolio entrepreneurs (those with multiple business ongoing interests). Drawing on data on 354 private firms in Scotland this research discovered that portfolio entrepreneurs have more diverse experiences, and more resources, than serial or novice entrepreneurs. The authors of the study conclude that, on average, portfolio entrepreneurs appear to generate more attractive growth prospects than other entrepreneurs. This is because portfolio entrepreneurs are more likely to be motivated by wealth generation and display higher levels of growth in the businesses they own than the other categories of entrepreneurs. Interestingly, the research found that the top four percent of the fastest growing firms owned by portfolio entrepreneurs generated over half of gross new jobs created by portfolio entrepreneur firms (Westhead et al, 2005), confirming the disproportionate role a small number of firms play in the job creation process from entrepreneurship.

Entrepreneurial Motivation

Recent research has revealed that starting a business to exploit a business opportunity (as opposed to starting a business out of necessity such as those made unemployed) is an important driver of business growth ambitions for technology entrepreneurs (Verheul and Mil, 2008). Similarly, opportunity-driven entrepreneurs, such as those who leave a job to start a new venture, are more likely than necessity entrepreneurs to expect that their ventures create more than 20 jobs within five years (Reynolds et al, 2002). The level of ambition seems to be connected to the level human capital of the entrepreneur. For example, it has been found that individuals with a higher household income and greater levels of supervisory skills exhibit a greater desire to grow their firm (Cassar, 2006).

Consistent with economic motives, the importance that the individual entrepreneur places on financial success was also found to be a key determinant explaining the growth preferences, the intended size of the venture and the actual growth achieved (Cassar, 2007). In other words, those driven by making substantial material gains from a business tend to grow their business more than those who may view a business as a lifestyle or career break option. The weak growth encountered by university spin-outs is often attributed to the fact academics view business as a life-style option rather than an opportunity to make substantial financial returns (Harrison and Leitch, 2010).

Entrepreneurial Orientation

Over the last thirty years there has been a sizeable amount of research conducted on entrepreneurial orientation (EO) and the role this plays in shaping the dynamism of entrepreneurs and businesses (see Covin and Wales, 2011). According to Covin and Wales, EO refers to the organisational decision-making proclivity generating entrepreneurial activities. The history of EO research can be traced to the work of Mintzberg (1973) who conceived EO as a managerial disposition characterised by an active search for new opportunities through which strong growth might be achieved. According to Lumpkin and Dess (1996, p.136-137) EO has the following dimensions: 'a propensity to act autonomously, a willingness to innovate and take risks, and a tendency to be aggressive toward competitors and proactive relative to marketplace opportunities' These types of characteristics seem to feature strongly in firms with high levels of EO compared to less entrepreneurial entrepreneurs or firms.

As a consequence of this research a number of different measurement approaches were produced to measure the extent of EO within a firm (Covin and Wales, 2011). In Table 1 one of the earliest attempts at measuring and assessing EO within firms is outlined. This work has been developed and applied to all types of businesses and not merely TBFs which limits the usefulness of these approaches somewhat. This type of methodology enables researchers to tease out the levels of entrepreneurial orientation within firms based on the entrepreneur's outlook and behavioural characteristics. The findings of a meta-analysis of 51 studies (comprising more than 14,000 companies) of EO found that there is a strong link between EO and business performance (Rauch et al, 2009). This would suggest that companies with strong levels of EO (as defined above) do achieve superior growth performance.

Table 1: A Composite Measurement of Entrepreneurial Orientation

- If an entrepreneurial firm is operationally defined as 'one that engages in product market innovation, undertakes somewhat risky ventures, and is first to come up with 'proactive' innovations, beating competitors to the punch' then my firm is an entrepreneurial firm.
- If the firm characteristically exhibits high levels of risk taking, innovativeness and proactiveness.
- If the firm often takes calculated risks by pursuing innovative initiatives before potential rivals recognize the opportunities at which our initiatives are targeted.
- Whether risk taking, innovativeness, and proactiveness are equally inherent to the firm's overall business orientation.
- Whether the innovative initiatives pursued/funded by my firm are often somewhat risky and industry leading (i.e. chosen in advance of other firms' potentially similar initiatives).
- Whether the firm concurrently manifests risk taking, innovativeness and proactiveness.
- Whether the firm often pre-empts its rivals by being an early leader with innovations

whose success
- In general, whether the firm is on the cutting edge when it comes to exploiting entrepreneurial opportunities because of our desire and demonstrated ability to embrace novel (and often risky) innovative initiatives ahead of its rivals.

Source: Miller (1983)

Growth Ambition

In contrast to the large volume of research which has been conducted on entrepreneurial orientation, there has been relatively little research specifically on the importance of entrepreneurial growth ambition. At present there have been no systematic attempts within the academic literature at capturing data on growth ambition levels within companies and how this affects company growth. Little in the way of official surveys are currently undertaken which explicitly attempt to elicit information on this important indicator of business growth. Notwithstanding this, however, certain proxies exist to assess current levels of entrepreneurial ambition in Scotland. For example, data collected by the Global Entrepreneurship Monitor (GEM) asks start-up entrepreneurs and owner/managers for their current and 'expected' jobs in five years. Due to its widespread coverage this enables us to compare growth aspirations in Scotland and other parts of the UK. From this evidence there is very little overall divergence between job creation ambition levels between Scotland and other parts of the UK. On the other hand, Johnson and Conway (1977) question the ability of small business owners to predict their future employment. Their evidence is that "very small firms tend to systematically over-estimate their prospects" (p 385).

Based on GEM data, Scotland can be differentiated from the rest of the UK in two important respects:

- First, Scotland comes out top for the number of respondents who expect to generate no new employment from their business in the next five years (19%);
- Second, compared to England (11%) and Wales (11%), respondents in Scotland (6%) and Northern Ireland (7%) are much less optimistic about creating sizeable businesses within five years (i.e. enterprises with 250 plus employees).

There also appears to be quite significant variations in ambition levels between different types of firms. For example, there appears to be evidence that some young firms have very limited growth ambitions and tend to be more focused on firm survival rather than growth (Freel, 1998). A recent evaluation of the SMART innovation programme in Scotland appears to confirm this assertion (PACEC, 2009). The evaluation discovered that 81% of successful SMART applicants wanted to either 'grow moderately' or 'stay the same size'. Only 19% of the firms actually wanted to grow rapidly.

Dynamic leadership is a key factor driving successful businesses in Scotland (Mason and Brown, 2010). Leadership is different from, but complementary to, management. Kotter (2001) identifies three key roles of leadership. First, leadership is concerned with coping with change, in contrast to the role of management which is to cope with complexity. Second, leadership is

about articulating the vision of the organisation in ways that are relevant to the various stakeholders in the organisation. An third, leadership is about motivating people. Leadership is therefore crucial to help overcome the major challenges confronting rapidly growing businesses. In particular, the study found that strong leadership and personal ambition were central elements propelling the growth of these high growth businesses.

In summary, while relatively little is known about the overall levels (and key determinants) of ambition in companies, it appears that strong levels of entrepreneurial ambition may be important for enabling businesses to take the necessary steps towards actually growing a business (Mason and Brown, 2010). However, more evidence is needed before this relationship can be properly validated.

3.5.2 Characteristics of the Firm

Size of Management Teams

The vast majority of research into the size of the founding teams across all types of businesses has produced compelling results showing that larger teams have an advantage (Dobbs and Hamilton, 2007). Indeed, team-based ventures account for a disproportionately greater number of rapidly growing firms (Kamm et al, 1990). In many ways, this finding seems to be quite logical and corresponds with the view that larger teams have more financial resources, greater levels of human capital to draw upon and larger networks than a single individual entrepreneur. Moreover, team based start-ups need to pursue bigger opportunities if the business is to financially support multiple owners.

Of course, the management team of a business – especially a growing business – is unlikely to remain static over time. It is often argued that a pre-requisite for growth is the removal, or sideways move, of the lead entrepreneur and replacement with a professional manager. This action may be undertaken by venture capitalists. Indeed, it has been suggested that the default position of VCs is that founder-CEO will need to be replaced (Pollock, et al, 2009). However, research suggests a more nuanced conclusion, with founder replacement being linked to levels of sector uncertainty, the VC's own relevant industry experience and the characteristics of the founder-CEO (Pollock, et al, 2009). However, the proposition that founder-managed firms perform less well than professionally managed firms was not supported by Willard et al (1992) – although this study was not confined to high tech firms. As firms evolve, boards of directors may also be important in guiding their strategic direction. Zahara et al (2009) suggest that boards enhance the absorptive capacity of science-based firms that are moving beyond their initial stages of development. Technology intensive firms need to learn new skills and to assimilate and exploit new sources of knowledge. Therefore, effective boards can sometimes substitute for poor absorptive capacity within young TBFs (Colombo, 2010).

VC Backed Firms

There is considerable evidence of a positive relationship between growth and venture capital funding. Venture capital investment speeds the development of companies, enabling them to transform ideas quickly into marketable products and become industry leaders through first mover advantages (Zhang, 2007). Venture capital-backed companies aim at more radical innovations, are significantly faster in introducing their products to the market and pursue more aggressive market strategies than other start-ups (Hellmann and Puri, 2002). This, in turn, means they are younger when they achieve an IPO compared with companies that were not venture capital backed, and they sustain their success for much longer after their IPO (Gompers and Lerner, 2001). A study of VC-backed start-ups in Israel also found that they had superior performance than non VC-backed firms (Avnimelech et al, 2008).

There are two important qualifications this conclusion. First, venture capitalists are highly selective in the types of firms that they will invest in. Specifically, they seek to invest in businesses that have the potential to generate a large return on their investments in a five to seven year time frame through an initial public offering (IPO) or sale of their investee business to a corporate buyer. VCs therefore invest in management teams that are capable of rapidly building an enterprise, and in businesses that have a durable competitive advantage, where rapid expansion has significant payoffs, and which operate in markets that already have sizeable sales in conjunction with a large number of potential users who have not yet become customers (Bhidé, 2008). Thus, the superior performance of VC-backed companies may purely be down to the fact that they have been subject to intensive pre-screening and in-depth due diligence which ensures that the most capable ones receive investment, rather than to the 'added value' that VCs provide to their portfolio of companies (Avnimelech et al, 2008). However, in an important paper, Peneder (2010) finds that venture capital-backed firms grow significantly faster than other firms and further demonstrates that the positive impact of venture capital investment on growth remains after controlling for the selection effect.

Second, VC investing focuses on maximizing the returns to the fund, not in maximizing the returns from every investment. While VCs invest on the basis of expecting every investment to be successful, the reality is that the success of the fund depends on having one or two very successful performers, whereas the other investments will either perform moderately or will fail. Thus, those VC-backed companies that achieve high growth are only a minority of all VC-backed companies.

A further problem with many of these studies is the use of cross-sectional rather than longitudinal data sources means we lack the insight to see how these firms perform over a longer period of time. According to Colombo et al (2010), recent studies using time series data tend to show a correlation between VC backing and stronger sales and employment growth in high tech start-ups (see Bertoni et al, 2008).

Export orientation

There appears to be some evidence that the internationalisation process occurs differently according to firm type. One study which compared both technology-intensive and traditional

firms in three different regions in the UK discovered that there were sizeable differences in the internationalisation processes (Bell et al, 2004). Traditional firms view the internationalisation process from a much more cautious and incremental perspective. In contrast, knowledge-intensive firms are far more open to rapid international expansion with internationalisation often occurring concurrently with domestic expansion. Moreover, technology firms have a stronger commitment to international markets in terms of their international entry mechanisms. In this instance technology-based firms may adopt a much more aggressive approach to internationalisation which involves rapid and deep engagement in international markets and simultaneous domestic and overseas expansion (Bell et al, 2004).

The concept of 'born global' has now become closely identified with high tech firms (Bell et al, 2004). While there can be difficulties distinguishing between knowledge-intensive and traditional firms, this basic dichotomy helps to make distinctions between the business internationalisation processes of each type (see Table 2). Rapid internationalisation has to be viewed as a holistic process rather than a linear or incremental approach as typically depicted by those advocating a staged approach to business internationalisation (Jones, 1999).

Owing to the nature of most high technology industries, there is a strong assumption that their growth will primarily arise through the penetration of international markets. Indeed, research

Table 2: Different Internationalisation Strategies by firm type

	Knowledge-Intensive Firms	***Traditional Firms***
Motivation	Proactive Evidence of strategic thinking and planning Niche offerings/small home market International from inception Active search Committed management	Reactive Adverse domestic market conditions Unsolicited/enquiries orders Reluctant management Cost of new production processes 'force' export initiation
Patterns	Concurrent Near simultaneous domestic and export expansion (in some cases exporting precedes domestic market entry) Lead markets Strong evidence of networks	Incremental Domestic expansion first 'Psychic' markets Limited evidence of networks
Pace	Rapid Fast internationalisation (large number of export markets) Many markets at once New product development of 'global offerings	Gradual Slow internationalisation (small number of export markets) Single market at a time Adaptation of existing offering

Method of Distribution/Market Entry	Flexible Use of agents or distributors, but also evidence of integration within client's channels, use of licensing, joint ventures, overseas production, etc.	Conventional Use of agents/distributors or wholesalers Direct to customers
Subsequent Internationalisation	Structured Evidence of a planned approach to international expansion Expansion of networks	Ad hoc Evidence of continued reactive behaviour to export opportunities Unrelated to new customers

Source: Bell et al (2004)

shows that there is a strong connection between business internationalisation and rapid firm growth within high-tech start ups (Burgel et al, 2000). In their comparative study of more than 600 high tech start ups in the UK and Germany, Burgel et al (2000) discovered that firms with overseas customers had faster sales growth than those who only sold domestically. This relationship was strong: 'the effect of internationalisation on sales growth was quite remarkable in its size' (Burgel et al, p. 6). However, the study did not find that sales growth had an impact on the overall growth of these firms in terms of employment. More recent research undertaken by BIS (2010) also confirms that business internationalisation is strongly associated with rapid firm growth.

Business Models

Business models are a critical component in competitiveness, yet are not given the importance they deserve. In essence, a business model is the method of doing business to generate revenue. The business model describes how a company makes money by specifying where it is positioned in the value chain[2]. The academic literature on high technology firms makes a distinction between two different types of business models: 'hard' and 'soft' (Connell and Probert, 2010). Companies with 'hard' business models are those who develop a physical product or service offering (e.g. a new piece of technology, equipment or software). Companies with soft business models are science or technology based 'whose business model is to provide R&D based services (e.g. technical consulting, contract R&D) and which draws on its expertise and/or proprietary technologies to provide bespoke offerings for a range of customers and applications' (Connell and Probert, 2010: 3). Many 'soft' companies fall into the traditional descriptions of support, or ancillary, companies rather than the core part of an industry.

[2] See Mason and Brown, 2011, for examples from their study of HGFs in Scotland)

There is evidence that some companies follow a strategy in which they start as 'soft' to generate cash which subsequently enables then to 'flip' to become 'hard'. Connell and Probert (2010) provide evidence of this feature in an investigation of 52 soft companies in Cambridgeshire. They found that a number of the older successful 'hard' technology firms in the region had emerged from 'soft' companies. For example, Cambridge Processing, which was the precursor to Acorn Computers and ARM Plc, initially followed the 'soft' model of providing specialist business services to customers. These soft companies built distinctive customer-focused business models to overcome the heavy capital demands of developing proprietary technology. By using 'bootstrapping' financing (money from family, friends etc) these firms were able to remain 'in greater control of their destiny' and stay 'locally based for many years' (Connell and Probert, 2010: 2). By working with multiple clients in the same technological areas, and driven by their market needs, these firms gradually developed a unique knowledge base around which to create their own IP.

This study by Connell and Probert (2010) revealed that 'soft' companies employed 3,500 people. As well as this direct employment contribution, these firms also help to germinate 'hard' companies. They also act as an important source of complementary expertise for other local 'hard' companies in the form of technological and productivity spillovers with their local clients. The authors claim that the 'soft' company business model brings various benefits to firms at different stages of their development:

- **As a start-up model**: it requires limited capital investment or equipment; easy to manage; access to a wide range of clients.
- **As a growth model**: it allows a gradual build up of capabilities and market understanding; facilitates progressively larger projects as resources increase; permits more or less self-funded growth.
- **As a platform for transition into product**: provides mechanisms for on-going intelligence gathering about emerging customer needs; can turn modest investments in IP into additional revenue streams (e.g. via 'orphan' IP obtained from clients)
- **As a mechanism for exploring applications of platform technologies**: enables different commercial applications of science or engineering breakthroughs to be explored with a variety of different customers; helps address the problems associated with funding lengthy development timeframes.

While very insightful, more work is needed to better understand the transition from soft to hard companies. It is also important to note that some firms move from the hard category to provide softer elements as a 'solution provider'.

3.5.3. Management Strategies of TBFs

Strategic Configurations

Having looked at various individual and firm-level characteristics underpinning the growth of TBFs we now move on to examine the role of business strategy in the growth process. Clearly, not all TBFs firms will adopt the same strategies when trying to achieve growth. To date, there has been no specific studies comparing the exact differences in managerial strategies between TBFs which grow rapidly from those that are less successful. However, previous research has examined the management strategies of growing and non-growing firms across all sectors (Hansen and Hamilton, 2011). This work identified certain factors that were present in growing small firms that were absent in non-growers. Four factors were in evidence in the growing businesses: opportunistic perceptions of the external environment; controlled ambition of the owner-manager to grow; a business culture of innovation and flexibility; and use of extensive private business networks, including portfolio entrepreneurship.

Looking specifically at high tech firms, there is some evidence on the strategic differences between those that are successful and less successful. For example, Meyer and Roberts (1986) studied the effectiveness of new product strategies in ten small TBFs. They found that high performing firms avoid excessive technological diversity in their product lines and instead concentrated on 'leveraging' existing technologies when introducing new products. Similarly, a study of high tech firms in Belgium found that high performance levels were typically associated with features such as 'marketing offensiveness' (proactive marketing approaches), 'technological offensiveness' (such as heavy R&D and levels of new product development) and the extent of product specialisation (Vanden Abeele and Christiaens, 1986).

Another study attempted to map the strategic configurations of 162 'adolescent' TBFs (5-12 years old) in the US (Bantel, 1998). The study found that six main broad categories or clusters:

- Cluster 1: Focus on narrow niche of specialised infrequently purchased large investment projects. These firms do direct sales and support;
- Cluster 2: 'Spin-offs' with relatively strong technology. Reliant on major projects, often with original employer;
- Cluster 3: Marketing and sales expertise targeted at narrow market;
- Cluster 4: Technology leaders with a high degree of specialisation, quality and service;
- Cluster 5: Lacking in any clear strategic focus;
- Cluster 6: Broard product/market reach with a relatively high quality and service.

Bantel found that firms in clusters 1, 2, 4 and 6 had moderate to strong technology positions with good growth performance. In contrast, firms in clusters 3 and 5 were weak on the technology side and performed poorly. However, one of the problems with this kind of snapshot of a firm's strategic configuration is that firm strategy evolves over time. Indeed, Bantel acknowledges that longitudinal examination of those firms that survived to examine their processes of strategic re-orientation might provide some valuable insight into how young firms continually revise and redirect their strategies to create a viable 'fit' with their environment.

A major international study for the World Economic Forum on the growth strategies of early stage companies identified a slightly different range of categories (WEF, 2010). Again, what is striking is the diversity in the strategies deployed by different types of firms:

- Wave Ventures – firms creating new waves which in turn create an entire new industry (e.g. Microsoft);
- New Product in New Category Ventures – innovative design, new business models, new distribution channels;
- New Product in Existing Category – innovative design, new business models (e.g. NET-A-PORTER);
- Re-design of Business Value Chain Ventures – faster, cheaper, redesign of value chain delivery (e.g. Easy-Jet);
- Discovery and Research Knowledge Ventures – fundamental research and discovery (new drugs) and exploration and discovery (new oilfield exploration techniques);
- Aggregation of Existing Player's Ventures – Using business acquisition to grow (e.g. WPP group);
- Government/Regulatory/Political Change Ventures – Changes to the regulatory environment provide huge opportunities for businesses to capitalise (e.g. First Group);
- Idea Transfer or Transplant Ventures – exporting existing ideas to new geographies or new sectors (e.g. Air Arabia adopted the low-cost business model to the Middle East).

While this classification system above is interesting and reveals the diversity of different types of new early stage companies, it has a number of flaws. First, some firms may incorporate different elements of these strategies within their overall business offering and so do not fall neatly into one. Second, it is a static classification and so fails to capture firms which have shifted entirely from one category to another. Third, it does not distinguish between the strategic behaviour of TBFs relative to all firms as a whole. Evidence seems to suggest that there are quite substantial differences in management strategies between firms in high and low technology industries. For example, a study conducted in the US looking at these two groups of firms some interesting differences (Covin et al, 1990). Growth-seeking firms in high-tech industries, relative to those in low-technology industries, tend to place more emphasis on:

- product-related issues (such as new product development and superior product warranties);
- formal planning activities;
- customer service/support;
- external financing;
- premium pricing strategies and advertising;
- entrepreneurial strategic postures.

Product Offerings

Products are at risk of commodification which, in turn, forces firms to compete on the basis of price. Many firms have responded to this trend by re-positioning themselves as 'solution providers' to their customers rather than offering a single product or service offering. Indeed, for some high tech companies it is now essential to prove to customers that they are buying a quality product supported by the provision of the whole 'solution' (Gilman and Edwards, 2008, p. 540). The predominant view of a solution in the literature is "a customized and integrated combination of goods and services for meeting a customer's business needs" (Tuli et al., 2007: 1). Doster and Roegner (2000, p. 51) describe a solution provider as "one who packages and integrates components to deliver a complex, turnkey solution that meets a specific business need." However, as several authors have noted, such claims may merely be fashionable statements of intent, rather than actual practice (Cornet et al., 2000; Johansson et al., 2003; Nordin and Kowalkowski, 2010). Indeed, these 'self styled solutions providers' can cause great harm to themselves by sending out the wrong message about their capabilities. This, in turn, damages relationships with customers who do not receive the full solutions that they were expecting (Doster and Roegner, 2000).

However, those firms that do successfully deliver on their promise of delivering solutions are able to differentiate themselves from competitors and therefore charge premiums for their services. This, in turn, gives them a significant advantage over competitors in terms of growth potential. Indeed, previous research examining high growth businesses in Scotland noted that many were solution providers offering complex bespoke products and services to their customers. This type of business model often involved recurring or ongoing income streams from customers and seemed to be a common strategy both within traditional and high tech businesses (Mason and Brown, 2011).

End User Engagement

A critical implication of this 'solutions' approach to business is the need for close engagement with the customer. This is illustrated in quotes from three respondents to Bhidé's (2008) study of venture capital-backed technology companies:

> "We need to touch and feel every customer and get a detailed understanding of exactly how they are using the product and its other potential applications. We need to hear off-the-cuff remarks—they can reveal a great deal."
>
> "When you are getting your initial product out, you want to be right there on the customer site, helping the deployment and learning about missing features so you can feed that back into your product and sales pitch."
>
> "It's very important that the people who are developing our software are in regular communication with our customers… They need to be visiting the customers' physical locations, see how the software is being used by talking to end users, and use that knowledge to design new features and capabilities"

This approach has two significant implications. First, it requires significant technical sales and marketing resource. Second, it is based on having sophisticated customers based locally. As one of Bhidé's (2008) respondents notes: "ideally I want people [customers] who are a bicycle ride away." This has implications for both the emergence and growth of technology companies in peripheral regions such as Scotland where the size and composition of the local company base is likely to offer fewer opportunities for technology companies to develop such close, interactive end-user engagement.

Organisational Structures

One of the major sources of tension in growing firms is the need to formalise management processes as the firm grows (Nadin and Cassell, 2007). Many firms find the transition from a small informal organisational structure to a more formalised, process-oriented business a very difficult process.

Recent case study evidence examining organisational issues within high tech firms finds enormous diversity in the types of management structures and reporting arrangements (Gilman and Edwards, 2008). In the high tech organisations which had been examined, HR practices, workplace flexibility, organisational culture and workforce development were often very individual to the companies under examination. It was found that all the companies experienced tensions between individual styles and a desire for systems and order (Gilman and Edwards, 2008). The conclusion appears to be that the behaviour of these high-tech firms is highly embedded in context of where they are located.

A major recent international study examined the role of management systems in company growth (WEF, 2011). Using econometric analysis, the study found that companies with the highest adoption rates of management systems, such as a quality managements system (e.g. ISO9000) in their early years benefitted markedly (either by year 2 or between year 2 and year 5) and had the fastest increase in headcount in their first five years . This would suggest that in order to achieve and manage a period of rapid growth early stage companies need to undertake a formalisation process within their business very early on.

Exit Intentions

We noted earlier that a significant proportion of TBFs undergo ownership change involving the 'exit' of the founding entrepreneur or entrepreneurial team. Nevertheless, there is very little research on the 'entrepreneurial exit' (DeTienne and Cardon, 2010), defined as "the process by which the founders of privately held firms leave the firm they helped create: thereby removing themselves, in some degree, from the primary ownership and decision-making structure of the firm" (DeTienne and Cardon], 2010, p, 5). In many cases the exit is a 'harvest event' which enables shareholders in the company to realise the value that they have created. A harvest event is most common, and will occur most rapidly, in businesses which have raised finance from business angels and venture capital funds. In other cases the exit may be linked to under-performance. The most common form of exit is acquisition. Other types include management

buy-outs, management buy-ins and secondary purchase (another investor buys the shares from existing shareholders). In family-owned businesses the typical exit is family succession. Finally, the most successful firms might have an Initial Public Offering (IPO), where it is listed on a stock market, enabling its shares to be publicly traded. However, investors will be 'locked in' for some time after an IPO before they can sell their shares so it is not regarded as an exit event, at least in the short term, for the entrepreneur.

The empirical research evidence which has examined exits has highlighted a number of interesting issues. First, entrepreneurs often plan for an eventual exit and this is often influenced by previous experience (DeTienne and Cardon, 2010). Second, experienced entrepreneurs are more likely to seek higher-impact and higher return exits such as IPOs and acquisitions (DeTienne and Cardon, 2010).

It would appear that the time horizons for an exit are different for TBFs than for traditional firms. Although there is a lack of substantive empirical evidence, it appears that a sizeable number of early stage technology-based businesses pursue early 'exit' strategies rather than seeking to grow to become 'companies of scale' and achieve a stock market listing. Indeed, for most entrepreneurs of technology-based firms, it is not a case of 'if' but 'when' to sell their company (Oakey, 2003). In many cases acquisition provides companies with access to managerial and financial resources and distribution channels to enable the company to continue to grow, albeit as part of another company. However, it is unclear whether this process is beneficial to the local or regional economy over the longer term. On the one hand, cashed-out entrepreneurs and senior management are able to 'recycle' their financial gains and expertise as serial entrepreneurs or business angels (Mason and Harrison, 2006). It also brings the region to the attention of external investors as a place that generates successful businesses. The acquired company may also be able to grow as a result to access to the resources of its new owner. On the other hand, acquired companies may have fewer needs to obtain high level producer services from local suppliers, sourcing them instead from their new owners or their suppliers. It has been suggested that TBFs that are acquired may lose their innovative edge over the longer-term. Moreover, the level of autonomy that they are given by their new owners may constrain their strategic direction. In the longer term, as corporate strategies evolve, acquired businesses may find themselves marginalised and at risk of closure. Research on HGFs that have been acquired is an important topic for future research.

There is evidence that venture capitalists increasingly prefer to exit by means of a trade sale rather than an IPO. NASVF figures, cited in Bessler and Seim (2011), indicate that in the USA IPOs as an exit route for VCs has fallen from about 40% to about 20% of exits over the past 20 years. A similar trend is apparent in Europe (Bessler and Seim, 2011). This is despite VC-backed companies having outperformed several European stock markets over a long period (EVCA, 2011).

Although these advantages and disadvantages are generic, the relative attractiveness of the IPO route is influenced by stock market cycles. Bessler and Seim (2011) suggest that the decline in VC-backed IPOs in Europe can be attributed to a change in the receptivity of European markets

to them since the 'tech collapse' of the early 2000s. In the late 1990s VCs were encouraged by a booming stock market and general investor euphoria to take their younger, more risky investee businesses to market. While many of these businesses achieved very high returns in their first year, their subsequent performance was poor. But since 2003, VCs have only been able to take their larger (in terms of total assets) and successful (in terms of pre-IPO profits) portfolio firms to market.

However, VCs have only been able to exercise the choice between an IPO and a trade sale because of the existence of alternative buyers of their investee companies. This reflects large cash-rich companies, particularly those created in the past 20-30 years (e.g. IBM, Microsoft, Cisco, Google) which have increasingly been following a 'buy-to-build' strategy rather than relying on internal R&D for new products to remain competitive. Indeed, companies in some sectors are spending more on acquisition than on R&D. One explanation is that internal R&D mainly generates incremental innovations, hence firms also seek to obtain technology from smaller, entrepreneurial businesses which are much more effective at developing revolutionary breakthroughs, by means of licensing arrangements, strategic partnering or the outright purchase of such companies (Baumol, 2004). An alternative explanation, which also accounts for the increase in trade sales, is that the productivity of corporate R&D has been declining in recent years. This is certainly argued to have occurred in the case of major pharmaceutical firms, so young, entrepreneurial firms, especially in biologic therapeutics, have become attractive for acquisition by large drug companies to replenish their drug pipelines (Merrill, 2009). Acquisition is therefore an important means by which large companies are able to continue growing. It is also a way in which they can re-energise their entrepreneurial culture that got them started in the first place. Large companies have therefore become an important market for VCs looking to exit from their investments, and an attractive alternative to an IPO. Moreover, the acquisition rate has risen steadily since 2001, apart from a decline in 2008 and 2009.

3.5.4 Environmental Factors

Regulation is widely seen as imposing a big cost on business. Moreover, these costs bear disproportionately on small businesses. However, regulation is also a necessary condition for the proper functioning of an advanced economy. Regulations protect investors, employees, citizens, consumers and the environment, as well as small business owners themselves. Moreover, evidence on the adverse impact of regulation is contradictory. Djankokov et al, (2006) argue that regulation has an adverse impact on business entry and economic growth. However, van Stel et al (2007) find no evidence of this. Surveys consistently reveal small business owners to have a high level of dissatisfaction with the regulatory regime. Empirical evidence suggests that the only a minority actually report that they had been negatively affected by any aspects of the regulation (Carter et al, 2009). A more significant impact of regulation is that it creates opportunities for alert entrepreneurs (Mason and Brown, 2010). Many of these opportunities emerge from efforts by government to regulate to protect the environment, including climate change. For example, government regulation is a key driver for

the growth of renewable sectors, such as solar, wind and power, thereby creating opportunities for new technology based firms.

3.5.5. Location and Growth

Much of the literature on industrial clusters reveals that firms gain certain agglomeration economies and positive externalities from being co-located with other similar firms (Marshall, 1919). High-tech firms seem to particularly benefit from this spatial clustering and many exhibit an uneven geographical distribution (e.g. Keeble, 1997; Hendry et al, 2000; Cooke 2001a; 2001b). Since the founders of new firms typically start their businesses in the location in which they are already living and working, it implies that technology firms will generally emerge in areas that have specialist technological knowledge and skills. Mason (2007) argues that the genesis of most technology clusters can be traced to a few individuals in a region who left their existing organisations in order to start their own companies to commercialise technological advances that they had been exposed to in their employment.

Once seeded, the cluster becomes part of a self-reinforcing cycle. The examples of the pioneering entrepreneurs prompt imitation, generating further spin-offs from the original 'anchor' organisation(s) and from the first generation new companies, thereby fuelling the initial growth of the cluster. Meanwhile, the entrepreneurial environment is enhanced as successful entrepreneurs become mentors of new entrepreneurs, investors in new businesses and engage in institution building (Wolfe, 2002), and specialist support infrastructure is established, suppliers and service providers emerge (Saxenian, 1994; Kenney and von Burg, 1999). According to Kenney and Patton (2005), there are three types of these support organisations:

- Specialist business services: notably, law firms with deep expertise in handling IP, marketing firms, executive search firms, accountancy practices that are familiar with the unique needs of technology start-ups, technology marketing and PR firms, management consultants, and technology assessment consultants
- Technical services: precision machining, prototyping, precision moulding, testing, etc
- Finance providers: venture capital firms, investment banks specialising in IPOs

Local universities may also develop new teaching and research programmes to meet the needs of companies for skilled labour. These support services facilitate the process of business start-up and growth by enabling new firms to focus on their area of expertise while buying-in specialist service and support (Saxenian, 1994).

These agglomeration processes, in turn, attract companies from other regions and countries in order to tap into local sources of knowledge and expertise. The effect of these developments is to lower the barriers to entry compared with other locations (Porter, 2000). The process accelerates over time, so that within a couple of decades there is a sizeable cluster of high tech companies. The outcome of this process of entrepreneurial activity is illustrated by the 'genealogical trees' that have been constructed for several high-tech clusters to show

organisational origins of the founders of new businesses (e.g. SQW, 1985; Garnsey and Heffernan, 2005; Myint et al, 2005 for Cambridge; Innovation Associates Inc, 2000 for San Diego; and Neck et al 2004 for Boulder). These genealogical trees show that in the vast majority of clusters a small number of key organisations are the source of a disproportionate number of multiple entrepreneurs.

This highlights the importance of 'incubator organisations' or 'anchor firms' (Feldman, 2003) as the source of high tech entrepreneurs. The origins of a new firm are when an individual realises the potential for a technology. This "requires a sophisticated understanding of consumer needs, existing markets for product innovation and factor inputs, and prevailing production technology (Feldman et al, 2005: 131). Such individuals typically derive this knowledge from previous employment. The literature emphasises the importance of the incubator organisation – the organisation that an entrepreneur worked for *immediately prior* to starting his/her own business, although as Harrison et al (2004) emphasise, most entrepreneurs have had several jobs, either in different organisations or within the same organisation, before starting their own business. Indeed, it is often through this process of job mobility that scientist-managers and engineer-managers, who are particularly important in the spin-off process, gain their management experience (Harrison et al, 2004).

The incubator organisation is where entrepreneurs acquire technical skills and product and market knowledge and gain access to information about appropriate organisational structures, strategies and systems. It is also where in the course of their work experience they identify market opportunities and notice ways of exploiting them. Because the knowledge needed to start a new firm is tacit and therefore difficult to transfer, it will only be possessed by those with direct technical experience. Similarly, the technological possibilities (and applications) and market opportunities will be most visible to those whose work is intimately related to the technology (Kenney and von Burg, 1999; Stuart and Sorenson, 2003). However, according to Klepper (2001), founders appear not to exploit their knowledge about the specific technology of their incubator organisation. Rather, they draw more narrowly on their work experience in the incubator as embedded in its organisational 'routines'. It is this knowledge which gives the spin-off company a key source of competitive advantage. The incubator organisation is also where entrepreneurs establish reputations and professional contacts with future partners, suppliers, customers and other key stakeholders.

The incubators also typically provide the stimulus to start. Entrepreneurs make the decision to start a business for either positive or negative reasons. Negative reasons tend to dominate. The most common reasons for starting a business are because of frustrations when their ideas are not endorsed by senior management, conflicts with their boss and redundancy. Saxenian's (1994: 113) comment that "Silicon Valley entrepreneurs … were typically engineers who were frustrated by unsuccessful attempts to pursue new ideas within the region's established companies" has much wider generality. Successful entrepreneurs also play a crucial role by providing role models which encourage imitation.

However, organisations vary quite significantly in terms of their effectiveness as incubators. Highly innovative firms and firms with a rich and broad knowledge base spawn the most spin-offs (Klepper, 2001). These firms, on the cutting edge of technology, will create too many commercial possibilities for one company to take advantage, prompting teams of engineers with rejected projects to resign and start their own firms. Rapidly growing firms operating at the frontiers of knowledge, active in the early phases of the industry and encountering rapid shifts in market acceptance of competing designs and technologies are also likely to be effective incubators. These firms often have an entrepreneurial culture, led by strong entrepreneurial characters and with decentralised decision-making and creative management. As an example, accounts of the Cambridge technology cluster highlight the importance of Acorn Computer as a source of spin-outs (Garnsey and Heffernan, 2005: 1135). Mature firms undergoing change as a result of the need to adopt new technologies to stay competitive can also be effective incubators. Although the R&D efforts may be successful in producing technological breakthroughs, such companies may be slow or unable to adopt them, prompting frustrated scientists and engineers to leave in order to exploit them on their own account.

Effective incubators also need to provide their employees with exposure to best practice technology and intimate knowledge of markets in order to uncover business opportunities based on novel applications. However, access to such information is likely to be limited to people working at corporate level (Miller and Côté, 1987). Thus, organisations with a truncated range of management jobs – typically a characteristic of branch plants – are unlikely to be effective incubators. Branch plants are poor incubators on account of being production-dominated and with limited exposure to the market place, having little or no R&D capacity, operating on an assembly line basis, and with limited local purchases capability. These factors explain why branch plants of electronics companies that were attracted to the declining industrial regions of advanced economies throughout much of the post-war period under regional policy in an attempt to offset the decline of traditional sectors have failed to stimulate indigenous development in these regions, and may actually have depressed new firm formation rates. This is well illustrated in the case of Scotland's 'Silicon Glen' (Brown, 2002; Clarke and Beaney, 1993; McCalman, 1992; Turok, 1993a; 1993b). However, Glasmeier (1988) notes that technical branch plants (stand alone profit centres with product-related R&D and employing both technical and non-technical workers) may also be poor incubators, depending upon the nature of the products and production process and extent of local supply linkages.

Government research laboratories are also very ineffective incubators. They lack exposure to markets and their research often does not have any obvious immediate market (Miller and Côté, 1987; Lawton Smith, 1996). Although there are some prominent exceptions, most universities are also poor incubators for the same reason, namely that the research is not dictated by market needs (Malecki, 1997). Miller and Côté (1987) emphasise that technical and scientific knowledge is insufficient: research needs to be performed in market-driven settings so that scientific activities are related to market needs and would-be entrepreneurs are exposed to hands on experience of state of the art technology. They suggest that the most effective research-oriented incubators are those which are engaged in market driven research, such as the advanced laboratories of technology-based firms and contract research

laboratories. This is supported by a range of evidence: the importance of technology consultants as major sources of spin-offs in Cambridge (SQW, 1985; Garnsey and Heffernan, 2005); the dominance of development-oriented rather than research-oriented work experience amongst Route 128 technology entrepreneurs (Roberts and Wainer, 1968); and evidence from the genealogy studies that research institutes (i.e. 'boundary spanning' organisations to promote university-industry interaction and technology transfer) generate more spin-offs than university academic departments. However, universities and research institutes are more important as incubators in the biotechnology sector (Mitton, 1986; Haug, 1995; Leibovitz, 2004).

Clustering occurs because of the overwhelming tendency for spin-off companies to be located in close proximity to the incubator, reflecting the general tendency for entrepreneurship to be a local event (Cooper and Folte, 2000). There are four principal reasons for this. First, entrepreneurs need to utilise their social networks of business associates and fellow employees to access the industry-specific tacit knowledge, human capital and specific resources (e.g. finance) required to start and grow their business. People almost always have more, more diverse and stronger ties to contacts in the region in which they reside. This suggests that the social networks used for resource mobilisation are geographically localised (Stuart and Sorenson, 2003). The consequence is that "these networks … bind entrepreneurs to the locations in which they reside because only there do they have the access to the resources and social support required to sustain their entrepreneurial ventures" Sorenson (2003: 524). Second, new technology firms typically begin on a part-time basis while the founder is still employed (i.e. as a 'garage' start-up), delaying full-time commitment until the venture seems sufficiently promising. The links that are built up at this stage with customers, suppliers, advisors, employees, and so on combine to embed the business, thereby limiting its locational flexibility when the transfer to full-time operations occurs. Third, family ties encourage locational inertia. The spouse can remain in employment so income continues to flows to the family and the aspects of the entrepreneur's life remain the same so that their full energies can be devoted to the start-up (Cooper and Folte, 2000). Finally, locational preferences (which may have discouraged relocation in response to corporate downsizing or other forms of turbulence) often play a role. Indeed, it is probably no coincidence that many high tech clusters (e.g. Ottawa, Calgary, Cambridge) have emerged in locations with high residential amenity. For example, accounts of the Cambridge cluster in England similarly identify its residential attractiveness as a reason why entrepreneurs started their businesses locally (Keeble, 1989). However, it is important to recall that whereas the spin-off process is local, the origin of most entrepreneurs is not; rather most have moved into the area at some time in their career, either to attend university or to work in one of the region's existing organisations.

3.6 CONCLUSIONS

The literature on high growth technology firms is significantly smaller than that on high growth firms in general. However, it is clear that technology-based firms account for a minority of high growth firms and certainly no more than their overall share of economic activity. Indeed, the majority of high tech firms do not appear to seek rapid growth – although in this respect they

are no different to firms in other sectors. This undermines 'barriers to growth' arguments often advanced by policy makers when trying to promote these types of firms which suggest that many firms will grow when these barriers are overcome. Key barriers to growth appear to be threefold: (i) over-emphasis on R&D-led technology and lack of commercial orientation; (ii) the financial strains associated with product life cycles; and (iii) the challenges of 'crossing the chasm' from the specialist early adopter market to the mass market.

As in the case of high tech firms in general, there is also no consensus in the literature on the characteristics of high growth high-tech firms. However, factors which would appear to be at least loosely associated with high growth high tech firms are as follows: (i) high levels of human capital amongst the founding entrepreneurs, industry-relevant experience, strong opportunity-driven motivation, high levels of entrepreneurial orientation and ambition; (ii) a large varied senior management team, venture capital-backing and a strong export orientation; (iii) firms which have 'product-as-service' business models, offering solutions rather than single products, with a strong sales and marketing focus and strong customer end-user engagement.
Finally, high tech firms are spatially concentrated , typically in clusters. This reflects two factors: first, founders of high tech firms have specialist technical and commercial knowledge which they have developed as employees, hence will emerge from existing technology organisations; second, new firm founders will typically locate their businesses in locations where they already living and working. This, in turn, means that high growth high tech firms will be geographically concentrated to a much greater extent than is the case with high growth firms in general (Mason and Brown, 2010).

4. A QUANTITATIVE ASSESSMENT OF HIGH GROWTH, HIGH TECH FIRMS IN SCOTLAND

4.1 Introduction

In order to estimate the aggregate size of the population of high-tech HGFs in Scotland, two data sources were analysed[3]. First, data from the Business Structures Database (BSD) held by the ONS data[4]. The BSD should be a reliable source of information on business as it draws on the official register of all businesses operating in Scotland from the Inter-departmental Business Register (IDBR). The BSD consists of 'snapshots' of the IDBR[5]. This is the data source which has recently been used by NESTA to examine the numbers of HGFs in the UK (NESTA, 2009). The benefit of using this data source is that it enables Scotland to be compared with other UK regional economies. Second, analysis was undertaken of the population of high-tech, high growth companies listed on the FAME database. The FAME analysis was undertaken to overcome some of the disclosure problems associated with ONS data and is reported in section 5.

This section is in two parts. First, to provide a context it examines the overall population of HGFs in Scotland in detail. It then goes on to examine the population of high-tech firms in Scotland and how this differs with other parts of the UK.

4.2 Defining high growth

Firm growth is generally an uneven, discontinuous process with high growth representing a transitory phase in a firm's lifespan (Garnsey et al, 2006). Quite often a period of high growth is interspersed with a period of moderate or low growth (or sometimes even contraction). High growth is therefore typically a temporary phase and does not designate a particular cohort of firms.

The OECD (2008) defines HGFs as: '*enterprises with average annualised growth in employees or turnover greater than 20% per annum, over a three year period, and with more than 10 employees in the beginning of the observation period*'. Unless otherwise stated, the analysis in this paper uses growth in turnover as the main criteria for measuring high growth.

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[3] A revised version of this section has been published (see Brown et al, 2012).

[4] The statistical data used here is from the Office of National Statistics (ONS) and is
Crown copyright and reproduced with the permission of the controller of HMSO and
Queens Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. The analysis upon which this report is based uses research datasets which may not exactly reproduce National Statistics aggregates. In the ONS Business Structure Database the firm location is given as its headquarters for PAYE and/or VAT registration purposes.

[5] Extracts of the IDBR in the BSD are not identical to the extracts used by the IDBR team (the latter version is then 'cleaned' by the ONS and then posted on the BSD). The core issue here is the OECD metric for calculating the incidence of high growth firms (HGFs). To be included in the 'population at risk' (i.e. the denominator of the HGF calculation) firms need to satisfy 3 conditions. Specifically, for high growth firms in the period 2007/2010, firms must: be born before 2007; be alive in 2010; andhave 10 or more employees (10+) in 2007.

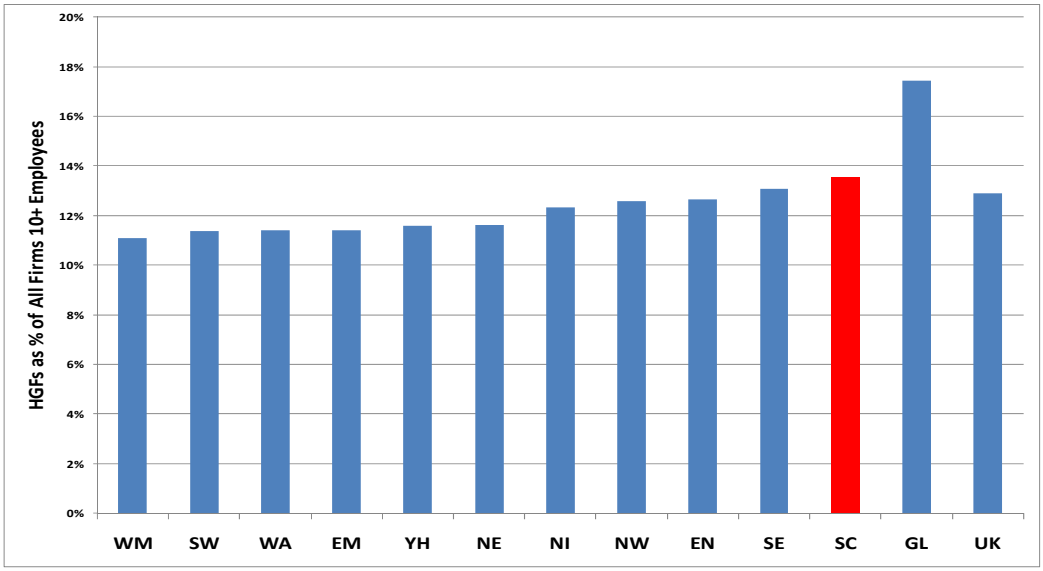
Although HGFs are very important generators of employment within economies, they constitute a very small proportion of the overall business population in Scotland. The OECD definition of three consecutive years of growth of 20% or above (for firms with 10+ employees) is a very exacting growth threshold. It is important to stress that the analysis in this paper refers only to enterprises with 10+ employees, which account for 5% of all private sector enterprises in Scotland (including self employed enterprises) and 69% of private sector employment (equivalent figures for the UK are 5% and 75% respectively).

4.3. High Growth Firms in Scotland: Aggregate Volume and Characteristics

The latest ONS data shows that between 2007-2010, Scotland had 1,544 HGFs (13.5% all firms with 10 + employees) – a rate above the UK average (12.9%). Because of the different data sources in this study this figure is significantly higher than in the previous work on Scottish HGFs (see Brown and Mason, 2010) (see Figure 4.1 below). Using an employment definition (to be consistent with the previous NESTA work), between 2007 and 2010, 7% of Scotland's businesses with 10+ employees were HGFs, which again is just slightly above the UK average (6.9%) (Nesta, 2011).

In recent years Scotland has outperformed much of the UK in terms of the percentage of businesses that are HGFs. In fact, data from the most recent time period available, 2007-2010, reveals that compared to all UK regions Scotland had the second highest proportion of businesses (behind Greater London) that were high growth (see Figure 4.1 below).

Figure 4.1: High-Growth Firms in the UK Regions 2007-10 (as a proportion of all firms with 10+ Employees)



Source: ONS Business Structure Database

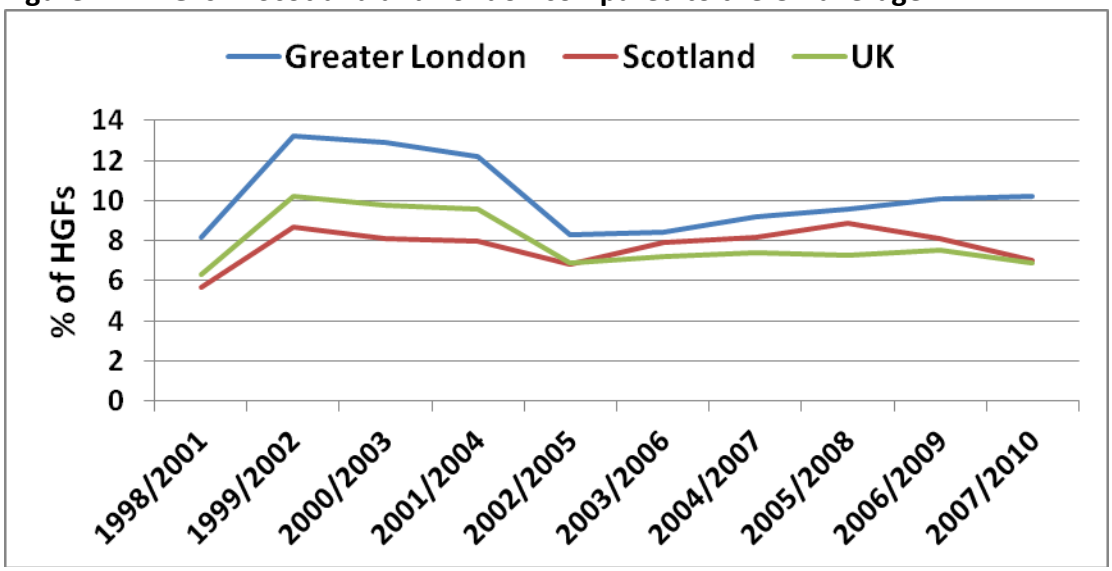
The 1,544 Scottish HGFs employed 285,146 people in Scotland in 2010 – an increase of 23% over the three years (+54,190 jobs). The equivalent percentage increase for the UK was 39.5% over the same time period. This suggests that Scottish HGFs are not as prodigious employment generators, in terms of domestically located employment, as UK HGFs. The precise reasons for this are unclear, but may partly be attributable to the small nature of the domestic market in Scotland coupled with the highly internationalised operations of many Scottish HGFs. During the previous high growth research for Scottish Enterprise, it was noted that Scottish HGFs often have significant overseas operations, hence a substantial amount of the employment that they generate is located outwith Scotland (Mason and Brown, 2010).

Key characteristics of the 1,544 HGFs in Scotland: are as follows:

- they employed 285,150 people over the three year time period between 2007 and 2010;
- they are relatively small – 45% have 10 to 19 employees and almost 80% employ 10 to 49 people;
- they are well established - just over half (53%) have been established for 10 years or more.

Figure 4.2 shows time series data on the incidence of HGFs in Scotland during the last decade and how this compares to the UK average. Throughout this period, the top performing UK region was Greater London. During the first half of the decade the performance of Scotland's HGFs was around the UK average, but since the mid 2000s it has been slightly above the UK average. The decline in the proportion of HGFs in both Scotland and the UK as a whole between 2007-2010 suggests that the recent economic downturn and recession has had a negative effect on the ability of companies to achieve high growth.

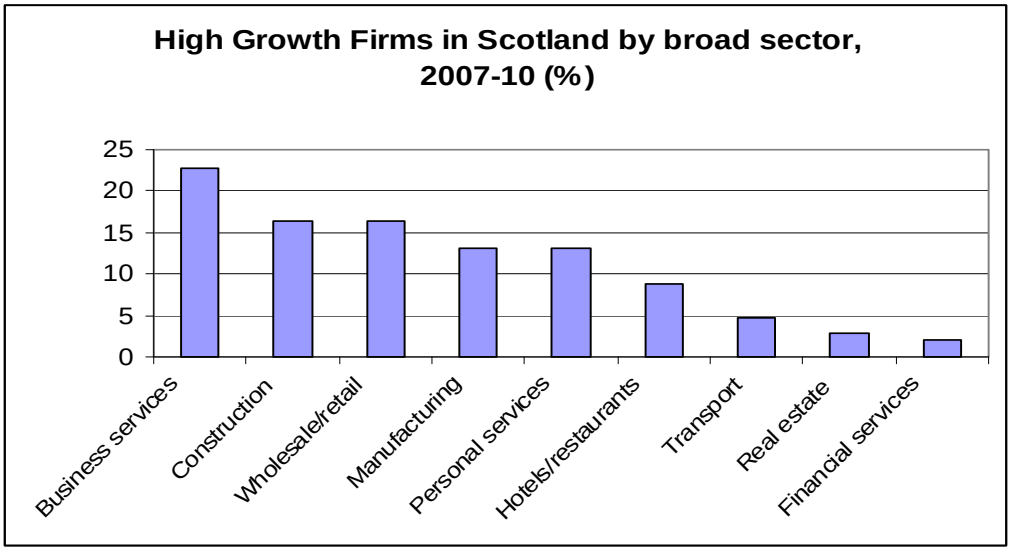
Figure 4.2: HGFs in Scotland and London compared to the UK average



Source: ONS Business Structure Database

One of the most important features of HGFs firms is their extremely diverse sectoral composition (Figure 4. 3). The largest single contributor of HGFs is the business service sector. Other sectors with high proportions of HGFs include construction, wholesale/retail, manufacturing and personal services. In common with other studies, there is not a particularly strong representation of technology-based firms among HGFs (Henrekson and Johansson, 2010).

Figure 4.3: High Growth Firms by broad sector, 2007-2010



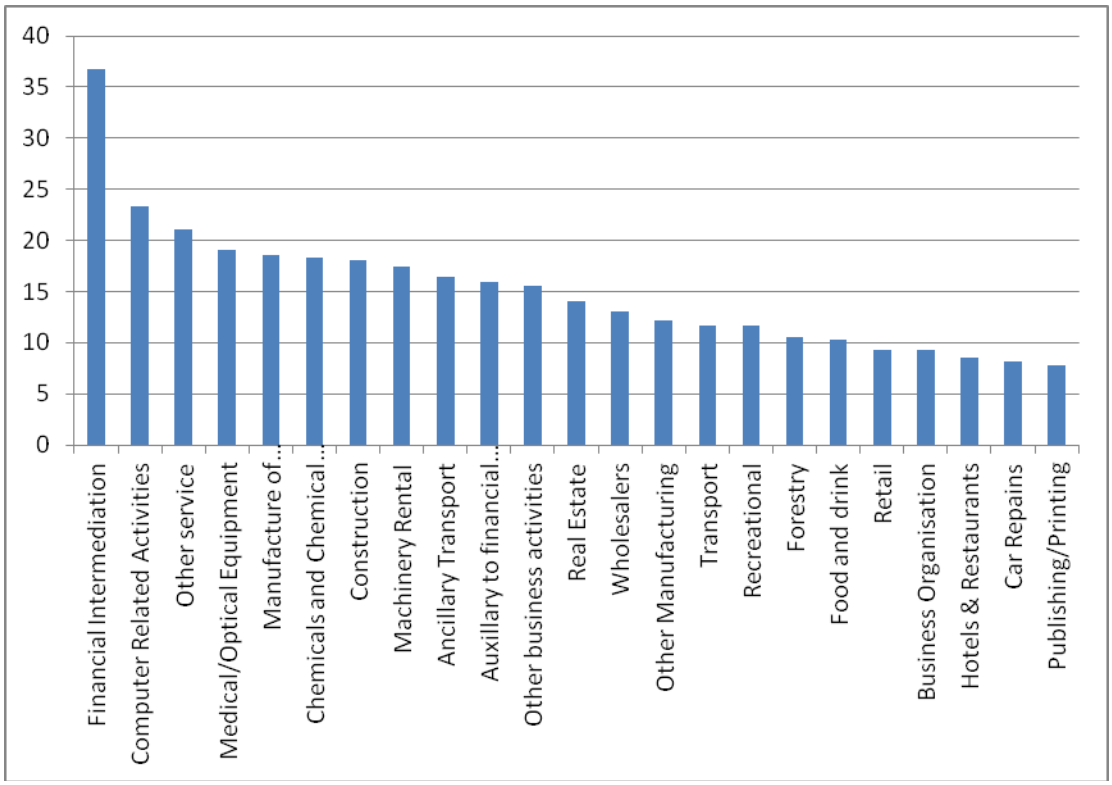
Source: ONS Business Structure Database

Closer inspection of the data reveals that some discrete sectors are more likely to produce HGFs. Analysis of their sectoral composition using two-digit SIC codes highlights that HGFs are more common within high-tech areas like financial intermediation, computer-related activities, 'other' services, chemicals, electrical equipment, medical and optical equipment (Figure 4.4). The single strongest performer is financial intermediation with nearly 40% of firms in this sector achieving high growth status between 2007-2010. Given the problems confronting the financial services industry during this time this performance seems remarkably robust. However, the very small number of overall companies in this sector (49) suggests that this should be viewed with a certain amount of caution.

There are other sectors with relatively low levels of HGFs (Figure 4.4). Sectors which have a relatively low proportion of HGFs (i.e. less than 10%) include: printing and publishing, hotels and restaurants, retail and car repairs. Other sectors which are below the Scottish average of 13.5% are food and drink, forestry and transport. So, while some sectors have considerable numbers of HGFs, for example hotels and restaurants (129), the large number firms in these sectors results in a 'conversion rate' (the proportion within the sector that achieve high growth)

that is below the Scottish average. What is also of note is that the high tech sectors which are traditionally the focus for public sector support (software, manufacturing, medical devices, chemicals etc) appear to display quite strong incidence levels of HGFs while sectors which are not traditionally assisted, such as retail and hospitality, show a low propensity for firms to become high growth.

Figure 4.4: Percentage of HGFs within Different Sectors, 2007-2010



Source ONS Business Structure Database

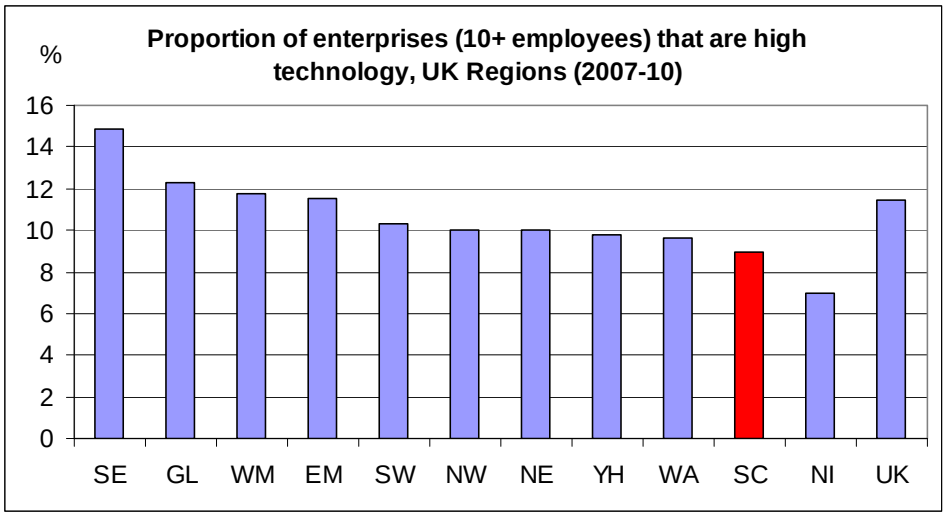
In terms of their spatial distribution Scottish HGFs can be found across the whole of Scotland. . However, their distribution is spatially concentrated in Scotland's major urban conurbations of Aberdeen (229), Edinburgh (168) and Glasgow (232). While Glasgow has the largest number of Scottish HGFs, Aberdeen is the top performer in per capita terms. This is attributable to the strong role played by the oil and gas sector in the local economy. Other areas with relatively high numbers of HGFs include Aberdeenshire, Fife and North/South Lanarkshire. Less economically prosperous (e.g. Inverclyde, West Dunbartonshire) and more remote or rural areas (e.g. Western Isles, Scottish Borders) contribute much less in terms of the overall HGF population.

4.4. High-Tech, High Growth Firms in Scotland

Research suggests that high-tech firms are not over-represented amongst HGFs (Henrekson and Johansson, 2010; Mason and Brown, 2010). To explore this in more detail for Scotland, ONS

data was analysed using a standard classification of technology-based firms (see section 2 above). One of the most significant findings from this analysis is the fact that Scotland, along with Northern Ireland, has one of the lowest proportions of businesses that are in high-technology sectors (Figure 4.6). Over the 2007-10 period, there were 7,462 high-tech firms in Scotland of which 1,021 had 10+ employees (accounting for 8.6% of all 10+ employee firms in Scotland). While it might be expected that Greater London and South East England would have high proportions of enterprises that were high tech, the differences between Scotland and parts of England such as the West Midlands and North East is a less expected finding. The reasons for this are hard to explain but may arise from Scotland's historic reliance on large scale employers in traditional industries (and low levels of corporate spin-offs) coupled with the strong role played by inward investment since the mid-1950s (Brown and Mason, 2012).

Figure 4.6: Proportion of enterprises that are in high technology sectors, by region



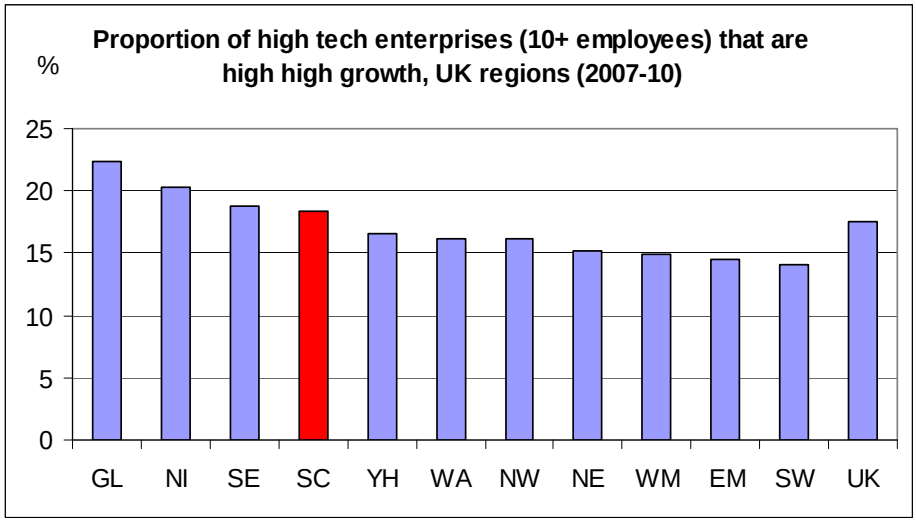
Source: ONS Business Structure Database

Despite this weak overall showing in terms of the proportion of firms that are high-tech, the proportion of high-tech enterprises achieving high growth status (18.4% – or 188 firms) is in line with the UK average (Figure 4.7). In fact, only three other regions (Greater London, Northern Ireland and South East England), are above the Scottish figure. This suggests that Scotland is better than many other regions at 'converting' its high tech businesses into high growth businesses. This also suggests that having a small population of high tech firms is not a direct impediment to the emergence of rapid growth high tech firms.

For each UK region, the proportion of high tech enterprises that are also high growth is significantly higher than the proportion of non-high tech enterprises that are high growth. This suggests that incidence levels of HGFs are higher in high tech sectors than non-high tech areas (Anyadike-Danes et al, 2012). This seems is particularly the case in Greater London, South East England, Northern Ireland, and Scotland (Figure 4.7). In other words, high tech firms have a

stronger 'conversion rate' to high growth than non-high tech firms and this holds for all parts of the UK.

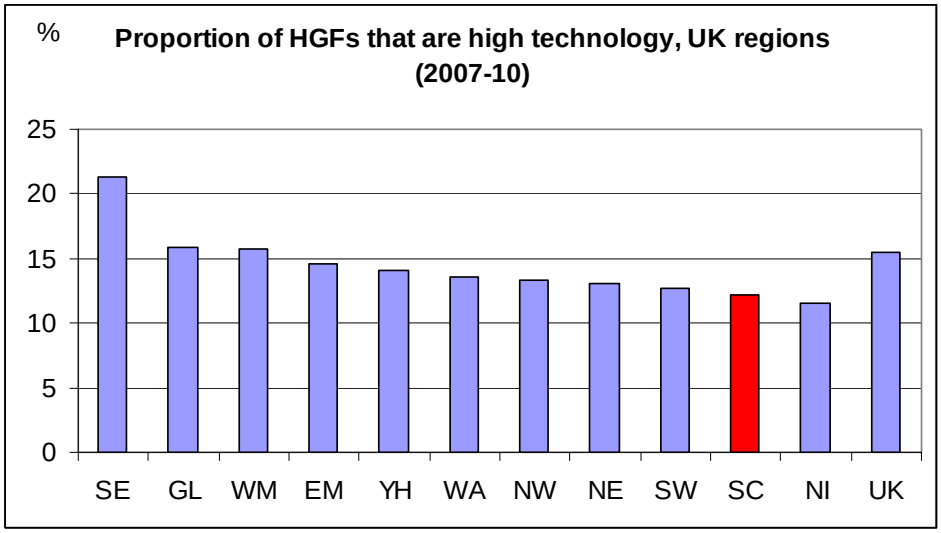
Figure 4.7: Proportion of high tech enterprises that are high growth, by region



Source: ONS Business Structure Database

Nevertheless, in most UK regions, high tech firms are a low proportion of the HGF population. For example, in Scotland only 12.2% of Scotland's HGFs are high tech**.** This is a lower proportion than most UK regions (Figure 4.8). This would appear to be attributable to Scotland's low stock base of high technology enterprises as highlighted earlier which imposes a constraint on the number of high tech HGFs which it generates, especially because high-tech HGFs often emanate from such existing businesses. However, more evidence is needed to provide a fuller explanation for this finding.

Figure 4.8: Proportion of high growth firms that are in high technology sectors, by region



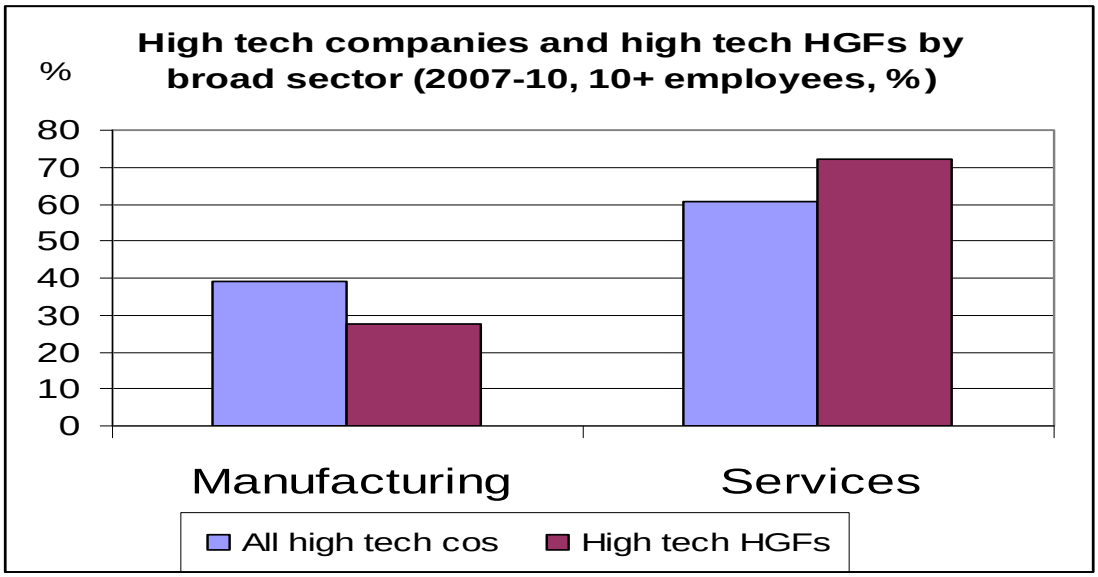
Source: ONS Business Structure Database

4.5 Characteristics of High-Tech High Growth Firms

Scottish high-tech HGFs tend to be younger and smaller than the overall population of Scottish HGFs. With regard to the size distribution, there is a greater number of smaller high-tech HGF employing between 10 and 19 employees (19.3%) than the overall population of Scottish HGFs (12.6%). Similarly, there are fewer large (100+ employees) high-tech high growth enterprises (9.8%) than in the overall high growth population (12.3%). Also of note is the fact that there is a greater proportion of high-tech HGFs (13.8%) which are more than 10 years old than the population of HGFs as a whole (10.3%). This suggests that technology-based firms may take a longer period of time before they embark upon a period of rapid growth than the business population as a whole. This certainly corresponds to the long time to market for some technology products such as life sciences where time consuming regulatory approval is often required before a firm can achieve significant turnover growth.

Because of the disclosure constraints stipulated by the ONS, the precise sectoral distribution of the Scottish high growth high-tech firms cannot be disclosed. However, we are able to make a distinction between service and manufacturing high-tech HGFs. Of the population of 1,012 high-tech firms with 10 or more employees, 39% are manufacturing firms and 61% are service-based firms. Manufacturing companies are therefore heavily over-represented in terms of their contribution to the population of high tech firms. Of all the 188 high-tech HGFs, 27.7% are manufacturing firms are 72.3% are service firms (Figure 4.9). Although service firms dominate the overall population of high-tech HGFs in volume terms, by contributing nearly one-third of the high-tech high growth cohort, manufacturing firms are strongly over-represented compared to services.

Figure 4.9: High technology companies and high technology high growth firms: in Scotland: manufacturing and services compared



Source: ONS Business Structure Database

The population of Scotland's 188 high-tech HGFs is highly spatially concentrated. Only five local authority areas in Scotland have more than 10 high-tech HGFs: Aberdeen, Edinburgh, Glasgow, South Lanarkshire and Fife. Again, this highlights the importance of urban economies as generators and hosts of HGFs (Mason and Brown, 2010).

4.5 Summary

Scotland performs well in relation the rest of the UK in terms of the presence of high growth businesses. However, Scotland performs less well in terms of high growth, high-tech firms. The primary reason for this most probably owes to the fact that Scotland's proportion of high tech firms in its business base is the second lowest amongst UK regions. As a consequence, the overall proportion of its high tech businesses that are high growth is low (12.2%).

However, the proportion of high tech firms in the UK which achieve high growth is greater than non-high tech firms. This is particularly the case for Scotland. Therefore, contrary to what seems to have been reported previously (Henrekson and Johansson, 2010), incidence rates of HGFs are 'detectably higher in a number of hi-tech and knowledge intensive services' (Anyadike-Danes et al, 2012). On the face of it, this would appear to justify the emphasis which policy-makers give to technology-based firms as a source of HGFs.

High tech-high growth firms in Scotland tend to be smaller than the overall population of HGFs, and there are relatively few large firms. They are also younger, although the proportion of high growth-high tech firms over 10 years old is higher than that for the proportion of HGFs as a whole. This suggests that high tech firms take time to mature before they can become 'growth-oriented' businesses. The research also revealed that the oil and gas industry plays a vital and disproportionate role in fuelling the growth of Scottish high tech HGFs.

5.0. ANALYSIS OF THE FAME DATASET

5.1. Introduction

One of the limitations of the IDBR and BSD datasets is that the individual companies are anonymous, hence it is not clear which specific companies are, and are not, included. Specifically, it includes companies that while registered and headquartered in Scotland are, in fact, subsidiaries of non-Scottish-owned companies. The FAME database overcomes this anonymity problem. Based on company accounts that are submitted to Companies House, it covers 7 million companies in the UK and Ireland. The downside is that only 2 million companies are covered in a detailed format, biasing the database to larger companies. However, this is not particularly disadvantageous as it provides a profile of technology companies that have, by definition, achieved growth at some point in their life. We will refer to these as *significant Scottish technology companies*.

5.2. Ownership

There were 278 Scottish-based technology companies in the FAME database employing more than 10 employees at June 2011 in the sectors that were defined as being 'high tech' within this study. This compares to the figure produced from the BSD analysis of 1021 TBFS with more than 10 employees (see section 4.4 above). This illustrates the much smaller coverage of FAME in comparison to the ONS dataset.

Our analysis found that in the majority of cases the ultimate ownership and headquarters of these companies was outside of Scotland, predominantly in the USA (Table 5.1). Investigation of their ownership shows that only 29% were Scottish, with a further 12% being subsidiaries of companies with their head office in Scotland. Nearly half were subsidiaries of foreign companies (mostly US) and 13% were subsidiaries of English headquartered companies. In many cases this reflects the acquisition of companies that had been founded by Scottish entrepreneurs. So, quite clearly, the Scottish economy exhibits a high level of non-Scottish ownership. Nevertheless, as the recent example of the contact lens company Award shows, Scottish companies that are sold to foreign buyers become vulnerable to closure if their new owners need to rationalize their capacity, especially if, as in the case of Award, the company's commercial activities are stripped out and it becomes a production-only operation.[6]

There are 11 companies that are listed on Stock Markets – nine on London's Main List, one on AIM and one on NASDAQ.

[6] Award was set up in Livingston in 1993 by Ron Hamilton. It was the first company to manufacture one-day disposable contact lenses. It was bought by US multinational Bausch and Lomb in 1996 for £30m. In 2009 Bausch and Lomb announced that it would close the plant, with a loss of over 500 jobs because of manufacturing over-capacity and shift production to Ireland. At its peak the plan employed 1200 people. Hamilton went on to found Daysoft, a daily disposable contact lens manufacturer and internet retailer.

Table 5.1: Ownership status of significant Scottish high tech companies

Ownership	Number	Percentage
Scottish	76	28.8
Subsidiary of Scottish company	32	12.1
Subsidiary of a company in the rest of the UK	35	13.3
Subsidiary of a company in the rest of the world	121	45.8
Sub-total	264	100
Insufficient evidence	7	-
Not relevant (e.g. commercial arm of non-commercial organization; social enterprise)	7	-

Source: FAME plus additional research

5.3. Age and Founding Circumstances

As might be expected, the 76 Scottish companies are extremely diverse. In terms of age, none are less than 10 years old, underlining the absence of genuine gazelles (i.e. TBFs less than five years of age) in technology sectors. However, 15 (19.7%)[7] companies are less than 20 years old. At the other extreme, the oldest is Johnson Press plc which was founded in 1767. Overall, eight companies (10.5%) are over 100 years old. Many of Scotland's significant technology businesses have therefore had interesting evolutions. Some began in traditional sectors and at some point switched into technology. The best example of this transition is the John Wood Group started as a family-owned ship repair and engineering company servicing the fishing fleet before switching in the late 1970s, under a new generation of family members, to providing services for the oil & gas and power generation markets. Other companies, such as the Weir Group, have a history of continual development of innovative products.

The importance of management buy-outs as a source of high growth companies, highlighted in in previous research (Mason and Brown, 2010), is again conformed. Nine significant Scottish technology companies (11.8%) have been the subject of management buyouts.

Serial entrepreneurship, which was found to be fairly significant in previous research of Scottish HGFs, (Mason and Brown, 2010), appears to be largely absent. The only serial entrepreneur

[7] This may be an underestimate as it was not possible to establish the date of formation in every case.

identified founded his business in 1998. He started his first business selling telephony systems in 1984. Since selling that business he has established, grown and sold five more profitable concerns in the telecoms and internet sector. He is also a significant investor in another AIM-listed TBF (but not on this list of significant technology companies) which was started by his brother-in-law and with whom he had started some of his earlier businesses.

5.4 Size

The size distribution ranges from under £1m to over £1bn. The distribution was skewed in favour of firms with less than £25 million turnover (68%). However, it also included 13 firms (17%) with turnover in excess of £1bn. The largest firms were Scottish and Southern Energy plc, The Wood Group plc and the Weir Group. With just six firms with turnover below £1m it confirms that point noted at the outset, that FAME's coverage is strongly biased towards larger firms.

Table 5.2. 2009 Turnover of Technology Firms

turnover	No.	%
Less than £1m	6	7.9
£1m - £4.99m	12	15.8
£5m - £9.9m	12	15.8
£10m - £24.9m	22	28.9
£25m - £49.9m	6	7.9
£50m – £99.9m	5	6.6
£100m -£249m	7	9.2
£250m-£499m	3	3.9
£500m-£999m	0	0
£1000m and over	3	3.9

Source: FAME

5.5. Industry Sector

Technology companies are engaged in a diverse range of activities. However, a number of clusters can be recognised: oil and gas exploration (13%), construction (11%), metal products, machinery and equipment (17%), information technology (14%), business services (12%) and publishing (8%) (Table 5.3). The absence of life science firms in this list of significant Scottish technology companies is noteworthy.

An industry classification underplays the significance of the oil and gas sector as a source of significant Scottish technology businesses. The energy market is significant for several of the firms in the construction, metal products, machinery and business services sectors. Indeed, from a review of the web sites of these companies we were able to identify a further five

companies (7%) that exclusively serve oil and gas markets and a further nine companies (12%) which derive a significant proportion of their sales from the oil and gas sector. In other words, more than ***1 in 5 of Scotland's technology based firms derive all of their revenues from the oil and gas sector***. Adding in those firms that derive some of their revenue from the oil and gas sector raises this proportion to 32%. This includes things like the manufacture and refurbishment of engineering products such as valves and gauges, drilling services, equipment services, pipework, recruitment and consultancy. And, as we will see in the next section, since oil and gas firms typically operate not just in the North Sea but also in other energy regions around the world, this provides their Scottish suppliers with access to these international markets. In short, the growth of a substantial proportion of significant Scottish technology companies is attributable to the oil and gas sector.

Table 5.3 Industrial distribution of Scottish owned technology companies

SIC (2003)		number	%
11	Extraction of crude petroleum and oil and gas	10	13.2
22	Publishing, printing and reproduction of recorded media	6	7.9
28	Manufacture of fabricated metal products (excl. machinery and equipment	7	9.2
29	Manufacture of machinery and equipment (n.e.s.)	6	7.9
32	Manufacture of radio, television and computer equipment and apparatus	5	6.6
33	Manufacture of medical, precision and optical instruments	4	5.3
45	Construction	8	10.5
72	Computer and related activities	6	7.9
74	Other business activities	9	11.8
-	Other activities (covering 10 sectors)	14	18.4
	Total	76	

Source: FAME plus additional research

5.6. Location

The companies are widely distributed across Scotland. Just over half (53%) are in the Central Belt with similar numbers in Edinburgh and Glasgow. Given the dominance of oil and gas related firms, it is not surprising that the Grampian region hosts 14 companies (19%), of which 13 are in Aberdeen. Fife is the location of seven companies (9%). The only other minor concentration is in Dundee which has four companies. The remainder are based in various small towns across the length and breadth of Scotland, including Troon, Kilmarnock, Perth (2), Inverness, Fraserburgh and Thurso.

5.7. Summary

This analysis gives a further perspective on the larger technology companies in Scotland. There are three important points to note from the analysis of FAME. First, the majority of companies are subsidiaries of non-Scottish companies, in some cases reflecting acquisition. Just 30% are Scottish owned and headquartered. Second, these Scottish companies exhibit considerable diversity in terms of age, size and sector. Only 20% are less than 20 years old. Many are long-established engineering companies with a tradition of innovation. Companies vary in size from under £1m turnover to over £1,000m turnover, but concentrated in the under £50m range. Finally, and perhaps the most significant finding, is the importance of the energy sector, particularly oil and gas, both as a direct source of technology businesses and also as a major market for technology firms in other sectors.

6. INTERVIEW FINDINGS

6.1. Introduction

Quantitative data are essential to estimate and analyse the number and significance of high-tech HGFs in Scotland and provide some basic information on some of their characteristics. However, official data does not allow analysis of the nature and dynamics of these businesses. Nor does it give a sense for how the nature of their competitive advantage and how they operate. To investigate these issues, in-depth interviews with 19 high tech firms were carried out. These firms were identified using the business database FAME and the majority were either experiencing or had recently experienced a period of high growth.

These interviews were conducted between August and December 2011 through a mixture of face-to-face interviews and telephone interviews, supported by a search of secondary material (e.g. newspapers, web sites, company reports, company presentations). Appendix 2 lists the firms that were interviewed.

6.2. Age and Ownership

The 19 companies that were interviewed exhibit considerable diversity. In terms of age, eight are less than 10 years old, with a further seven founded in the 1990s. A further two originated in the 19th century while the others were founded in the 1960s and 1980s. Some have undergone significant ownership changes including that have undergone management buyouts (MBO). One of these firms - Wollard and Henry – was actually an employee-led MBO. Another firm – the Amor Group – was created through a management buyout of two formerly Scottish owned businesses that had been acquired by the French company The Sword Group. The effect of this MBO was therefore to return two former Scottish companies to Scottish ownership and control.

Many of the TBFs interviewed had quite turbulent origins and initial growth trajectories. Scottish Biomedical had originally been established as a partnership between the then privately owned HCI hospital group in Clydebank and six Scottish universities. However, this arrangement collapsed after five years and the company restructured itself as an independent contract research organisation (CRO). CST Global has a similar history, being founded originally as a commercialisation vehicle to commercialise the optoelectronics research of Glasgow and Strathclyde universities. This model proved to be unsuccessful and the company was restructured following new investment. Axeon Power changed ownership and management after going into administration in 2008. Finally, the founder of Touch Bionics stepped aside and a new CEO was brought in, while one of the two-person founding team of Critical Blue left the company.

6.3 Origins and Founding Circumstances

The companies interviewed had diverse founding circumstances. Many of the entrepreneurs involved in the businesses interviewed had experience of working in the industry their venture had entered. Indeed, it was their knowledge of the industry which enabled them to see the opportunity that they went on to exploit through their own business. This was found during some of the earliest studies investigating the growth of technology-related firms (Cooper and Bruno, 1977; Cooper at al, 2003). Indeed, the biggest category of founding entrepreneurs that we interviewed (eight) had previously worked in the same industry in which they set up their business. From the sample of firms interviewed examples included: Calnex Solutions, Tissue Solutions, Amor Group, Clansman Dynamics, Edge Testing Solutions and Critical Blue. Plus, two firms were founded by serial entrepreneurs looking for opportunities in the same industry as their previous venture.

Often the decision to start their own business was precipitated by changes in the companies in which they previously worked which they regarded as being detrimental to the quality of their employment. Here again, the need for some kind to displacement to precipitate entrepreneurial action is well established in the literature (Shapero and Sokol, 1982). Clearly, by establishing a venture in an area that they had previously worked the entrepreneur(s) clearly had pre-existing knowledge of the business they were entering. Quite often this industry knowledge meant that the entrepreneur knew of an existing gap in the market for a product or service which, on the face of it, would enhance the capabilities of a new business. They also benefited from having contacts and networks which helped develop potential customers at an early stage of the firm's life-span.

In one instance, an entrepreneur established his business (Clanex Solutions) in the specific area of business (electronic instrumentation) where he had previously been employed by the US firm Agilient. Indeed, one of the most importance sources for producing these new TBFs was people from large existing corporate organisations in Scotland (especially for the oil and gas industry) and inward investors (especially for electronics/software firms). It seemed to be the case that these entrepreneurs had the experience of internally running large scale operations for their past employers which gave them the confidence and skills to grow an independent business. Coming from a respected business in the industry in question also gave the entrepreneurs the credibility when approaching new customers. These types of organisations therefore seem to act as a fertile 'breeding ground' for providing high tech entrepreneurial new ventures.

6.4. Activities

The companies comprise a mixture of activities, covering both manufacturing and services. Manufacturing firms account for seven of the sample, in health/medical products, engineering equipment, telecoms hardware, semi-conductor chips and battery systems sectors. Typically these firms also undertake other activities, notably research and development, software and

distribution. Two other companies undertake manufacturing related activities – refurbishing machinery and customising, repairing and refurbishing values and gas turbines. The remainder are in services. The biggest category comprises four software related companies. Two firms are life sciences services providers. Three other firms also provide services: internet dating, IT services, and architectural and design services. Scottish Biomedical was the only example in the sample of a 'soft' company which was entirely reliant upon contract R&D for their existence.

The interviewed firms deliver their products and services in a variety of ways, including customised solutions, one-off and small batch production, subcontract work and through subscription services. Three firms emphasised the importance of their business models. Following regulatory changes relating to the sale of contact lenses which required opticians to give patients a prescription which they can get dispensed anywhere Daysoft made the decision to add B2C to its existing B2B activity. As well as selling to opticians and resellers it now sells direct to customers all over the world via the Internet. The cost savings have been critical in a business where the scope for further technological advances in the product or the ability to reduce the cost of production is limited. With B2B sales remaining static, Daysoft's rapid growth is entirely due to its move into B2C. Craneware, which sells billing, revenue and audit software to US hospitals, has an annual recognition model based around multiple year contracts (five years on average). Finally, Tissue Solutions have a unique product model based around a brokerage mechanism to find or source tissue samples for its customers, which include big pharma, biotech companies and CROs.

6.5. Size and Scottish 'footprint'

The majority of the interviewed firms are small. Six have sales of less than £5m (including two with less than £1m in sales) and a further six have revenues in the £5m-£9.9m range. Two other have revenue between £10m and £49m, while the largest firms that were interviewed have revenues of £50+m and £120m.[8]

There is also considerable diversity in employment. Nine firms have under 50 employees with the smallest having 6 employees. A further two have between 50 and 99 employees, three have between 100 and 249 employees and one is in the 250-499 employee range. Four firms have more than 500 employees, with the largest company employing 1400 people.

The aggregate data discussed earlier masks the geographical location of this employment. As a result there is a danger of assuming that it is all in Scotland. However, a significant proportion of the jobs in many HGFs are located outside of Scotland, reflecting their international operations. This feature is also found in this group of high tech firms, although it is less pronounced. There are at least two reasons for this. First, as noted above, the sample comprises a relatively high proportion of manufacturing and manufacturing-related firms which tend to have a larger Scottish footprint. Service firms, on the other hand, often need a physical

[8] One firm did not give its revenue

presence in overseas markets to generate or support overseas sales. Second, the sample is also biased towards smaller firms which also tend to have all, or the majority, of their activities in Scotland. So for example, seven firms - Clansman, CST Global, Edge Test Services, Semi-Scenic, Scottish Biomedical, Tissue Solutions and Wollard & Henry – five had sales of £5m or less and have all of their employment in Scotland. A further two have just a handful of overseas sales staff.

At the other extreme five companies have half or more of their employment outside of Scotland. In the case of Cupid plc, an owner of internet dating sites, only 18 of its 400 employees in Scotland, with the rest mainly in Ukraine. This reflects its start-up circumstances as a company co-funded by a Scot and a Ukrainian. Axeon Power has its head office, and the research and design and prototype manufacturing of its innovative electric vehicle batteries in Scotland, accounting for 70 jobs (including 30 engineers). However, the majority of its 715 employees are based in its volume battery business in Poland which it acquired to provide volume revenue. It also has small operations in the West Midlands, continental Europe, USA and Asia. Around two-thirds of Craneware's 240 employees are based in the USA, reflecting the company's focus of its entire sales of medical billing software on the US hospital system. The Dacoll Group has about 500 employees of which just 150 are based in Scotland. This largely reflects the group's main means of expansion through the acquisition of companies in England. It also includes a recent US acquisition. Finally, Touch Bionics, manufacturer of a prosthetic hand, has half of its employment in Scotland in head office, research and manufacturing operations, and half in two locations in the USA, one which undertakes manufacturing which was acquired, and the other mainly performing customer support and sales functions. The companies with the biggest employment in Scotland are quite diverse: oil and gas industry support (Score Group), software (Amor), manufacturing (Daysoft) and Dacoll (IT support).

The manufacturing firms which were interviewed generate a demand for suppliers of related supplies and materials. Indeed, there was evidence that manufacturing firms have created local links with suppliers (where they can be found). For example, Calnex Solutions outsourced the production of their hardware equipment to a single Scottish supplier becoming their largest client and who had benefited greatly from this supply relationship. However, evidence of widespread local sourcing of materials was not found during our interviews. Many of the service type operations procure virtually nothing from Scottish suppliers. Even manufacturers had fairly limited supplier linkages. In some cases this was because manufacturers of certain materials could not be found within Scotland. This was the case with Clansman Dynamics who had to source electrical motors from Germany because no local suppliers existed. In other cases, non-local suppliers could not provide these firms with the small volumes they desired.

The clear message for policy makers is that successful Scottish technology companies – just like high growth firms in general – are likely to focus more and more of their employment creation outside of Scotland, through a combination of organic growth and acquisition. Growth through acquisition seems especially important for this cohort of firms and the majority of these acquisitions are likely to be made overseas. The overwhelming demand and customer base for these types of sophisticated technology companies is based outwith Scotland, especially in

North America, Europe and Asia. Services in particular require a physical presence in distant markets (including England). However, the jobs created in Scotland tend to be high quality, with a bias to head office functions, research and design. In addition, the non Scottish operations are likely to create a demand for back office functions in head office. So retaining these HQ functions in Scotland is very important.

6.6. Growth Patterns and Trigger Points

The growth process within these TBFs was even more non-linear and uneven than for the population of HGFs as a whole. The majority (11 or 60%) of the interviewed companies had exhibited steady, and in some cases rapid growth in recent years. Most of the remainder (7) reported growth until the onset of the economic downturn in 2008. Three of these companies reported that growth had subsequently resumed but another three reported that sales had not recovered. Growth was largely organic. Five firms had made acquisitions but even in these cases most of their growth was from organic sources.

As with HGFs, many of the TBFs encountered key growth trigger points which have a major influence on the firm's future growth potential. It appears that trigger points within TBFs (e.g. new product development, injections of venture capital, new market entry) may occur even more rapidly and repeatedly than in firms in more traditional industries (Brown and Mawson, forthcoming). Factors such as regulatory change are also more keenly felt in areas of emerging technology than more established areas of technology which again can potentially foster growth triggers.

The case of the precision engineering company Clansman Dynamics illustrates the role of how trigger points can set a firm on a new growth trajectory (Brown and Mawson, forthcoming). Established in 1994, the company endured a very difficult formative period and struggled to win new business due to established incumbent competitors. However, in 1997 Clansman was awarded a major contract with a leading German automotive company. Following the award of this contract the firm was able to attract other customers and grow rapidly owing to the 'reputational effect' gained from being a supplier to a leading automotive company. This acted as a valuable 'intangible asset' for winning further new sales, illustrating the cumulative and powerful nature of the initial growth trigger.

6.7. Financing

The interviewed companies have been financed in a variety of ways. An important source is internally generated finance. Five firms have been entirely self-funded. In most cases this has either been because bank finance was not available, or the terms and conditions of debt finance was unacceptable, or an unwillingness to dilute ownership to raise venture capital.

Two firms – Craneware and Cupid – are currently listed on AIM. Axeon was listed on AIM in 2005 but went into administration in 2009 where it was bought out by its biggest shareholder

and lender. Two firms had raised finance to go through a management buyout. In one case – Amor – this was funded by private equity. In the other case – Woollard and Henry – the change in ownership was to an employee-owned company, so in this case it was jointly funded by the Baxi Partnership (which funds employee owned companies) and a bank. Six firms raised venture capital – four from VC firms and two from angel groups. Finally, four firms have been financed by bank debt.

The majority of firms (74%) reported obtaining various forms of public sector funding including R&D/technology and capital investment grants. Public sector support is discussed in greater detail in section 6.13.

6.8. Technology

There is a stereotype of a technology firm as being what Bhide (2010) termed 'a science project', with highly qualified staff in white coats, strong links with universities, proprietary technology, patent protection and leading edge products. Perhaps not surprisingly in view of how technology businesses are defined (see section 2) the reality is rather different. For sure, some firm match much of this stereotype. However, they are only a minority and the vast majority do not fit the conventional characteristics of a technology business (i.e. strong R&D focus, graduate workforce, protected IPR etc).

All of the firms that were interviewed are trading on the basis of their technological knowledge. In many cases this knowledge is internally developed from in-house research and development. In other cases it simply derives from the deep domain knowledge of the management team. Many firms attribute their expertise to their close working with customers. Not every firm has an R&D department. Because of the way such activities are configured, for example, being embedded in project teams, not every firm has an R&D department or formalised R&D activities.

This is reflected in the employment of graduates. Just over one-third of the interviewed firms have over 75% of graduates amongst their workforce. At the other end of the spectrum, around one-quarter had fewer than 25% of graduates in their workforce. In all cases these were manufacturing and manufacturing-related businesses.

Only two firms have significant research links with Scottish universities and another firm has a project with a local university. One company – which is claimed as a university spin-out – said that it now has very few links with that university. Three other firms had university links but these had ceased. Many of the firms were slightly dismissive of Scottish universities as a source of knowledge. One of these firms was critical of universities for "operating on a different time scale and slow to react." None of the respondents mentioned universities as an important source of manpower.

Most – 16 out of 19 – say that their technology is proprietary. In some cases this technology is embodied in products and software. In other cases it contributes to process innovation. In yet

other cases it is used to develop customised solutions for customers. However, just five firms have patent protection. Some firms take the view that patent protection is ineffective ("it can be blown away"), is at risk to 'patent trawls' and too expensive for small firms to defend against infringement. Other firms simply say that patents are too expensive, particularly if there is a need to register them in multiple jurisdictions.

6.9. Customers and Markets

Most of the interviewed firms are selling to other businesses. Just two firms have significant consumer sales. However, there is considerable diversity in terms of the markets served. The biggest concentration is in medical-health with five firms selling into this market. For three of these firms, US hospitals are their major customer. Underlining a point made in the previous section about the importance of the North Sea oil and gas sector as a source of 'market pull', four companies sell into the North Sea oil and gas sector. This, in turn, can open up opportunities to work with the same customers in other energy markets. For example, the Score Group Ltd has leveraged the oil majors that it has served in the North Sea to work with them in other energy regions around the world. The Score Group Ltd now has 15 subsidiary companies, and operates in 234 locations across every continent. The Amor Group, an IT company, has also 'travelled' with its North Sea oil and gas customers into export markets and is doing the same in airport operation systems where most airport operators are now international. This type of 'piggybacking' is an important route for the internationalisation of oil and gas suppliers (Raines et al, 2002).

The sample of technology firms is highly international in terms of their markets. Two-thirds derived half or more of their sales from exports while one-third derived in excess of 90%. Some firms were nearly 100% reliant on non-local supply relationships. This includes both small Scottish based companies as well as the larger companies with significant physical presence in international markets.

6.10. Competitive Advantages

The interviewed firms identified what they felt were their 'competitive advantages'. Several themes emerged:

- factors associated with their unique product or service offering (42%);
- knowledge and expertise of the product and market (37%);
- customer focus (26%)
- people and skills(21%).

Other comments related to strategic positioning, lack of direct competitors, and the large size of competitors. Also noticeable was the lack of comments relating to technology as a source of competitive advantage. As one entrepreneur noted, being 'better than the competition' is critical. However, this is not necessarily on account of having superior products or technology – no one buys a product or service for its 'technology'.

Partnerships also emerged as playing a significant role for several companies. In the case of Semi-Scenic, their relationship with LAM Research, an OEM, is fundamental to their business. Started by ex-LAM employees the company supports LAM customers servicing and refurbishing their equipment. LAM tried to develop similar relationships with other companies but they all failed. Semi-Scenic is therefore LAM's sole refurbishment provider. Interestingly, what was a strategic advantage may become a disadvantage in the future. Semi Scenic's success in growing the refurbishment business from a very small market has resulted in it coming to the attention of LAM's senior management who regard this dependence on a small Scottish company as a risk and may therefore encourage Semi Scenic to be acquired by a larger company. Davenport (2010) has similarly reported in a study of New Zealand firms that become acquired by a larger company is often a result of their strategic importance to their customers.

Craneware, which develops and sells billing and audit software products to US hospitals, derives a significant part of its revenue from sales through channel partners. Cupid plc runs both its own internet dating sites and also 'white label' sites for companies (e.g. newspapers) that do not have the expertise or capability of running their own sites. Other companies, notably in software, also rely to some extent on partnering. Edge Testing Services which provides software testing services sometimes partners with companies which do the installations.

6.11. Barriers and Constraints

There were a variety of company-specific barriers to growth. The main constraint related to the wider environment was recruitment difficulties, cited by one-third of companies. Just under one-third highlighted access to further finance, especially debt, as a key constraint. These companies were predominantly small manufacturers. More generally, there appears to be a particular problem for the electronics hardware companies interviewed which arises from their distance from the US and Far East where most of their customers are based. The absence of a major company such as Siemens or Phillips with the market power to commercialise new technologies and act as a 'technology champion' and the lack of government support for the electronics sector as occurs in the Far East. These companies suffer from 'liabilities of smallness' (the problems of being able to compete with larger enterprise) which hampers their ability to win contracts and imposes a ceiling on their growth. This was also the case for one life sciences firm which claimed that the lack of a single major customer such as the NHS acted as a critical growth constraint. Two companies also reported that they were disadvantaged by their small size in bidding for government contracts. Software companies are perhaps easier to scale, grow faster and can be branded.

6.12. Location in Scotland: benefits and disadvantages

The overwhelming reason for the interviewed companies being based in Scotland is that the company founders were located in Scotland. Although some of the founders had been geographically mobile in their careers they were living and working in Scotland at the time that they took the decision to start their business. Several companies stated that there was no real

advantages of a Scottish location. Nevertheless, at least half could be said to be embedded in Scotland either because of their market orientation (especially oil and gas) or their premises which often included specialist facilities.

The interviewed companies gave a wide variety of advantages from being based in Scotland. These were often very firm specific. The only common theme related to employees, but this also covered a variety of factors, such as the availability of engineering and software skills, availability of graduates, quality of people, and characteristics of Scottish people (e.g. friendliness). Two electronics firms mentioned the benefits of being able to draw on a pool of engineers that were created by the companies that were part of 'Silicon Glen'. Some firms mentioned the stability of their staff. This might be linked to another comment relating to the lower risk of having staff poached because of distance from potential competitors. Finally, the benefits of English speaking staff was noted. Three companies also noted that the perception of Scotland as a strong technology location was beneficial. There were also some positive comments about support from Scottish Enterprise.

However, there was much greater consensus on the disadvantages of a Scottish location which related almost exclusively to distance from markets, compounded by poor airline route networks and the lack of domestic customers. For most of the companies, reflecting their high export propensity, major customers were either in England or overseas. The electronics hardware companies (e.g. semi-conductors, photonics) were particularly affected by the location of their customer base in the USA and Far East. Indeed, from a market proximity perspective the only companies which derived benefits from a Scottish location were firms selling into the North Sea oil and gas sector. These companies were predominantly located in Aberdeen or elsewhere in the Grampian region.

6.13 Public Sector Support

The vast majority of firms have received government support of one kind or another. As well as financial support in the form of technology and investment grants and direct equity investments, other types of support, support for trade missions, attendance at international exhibitions and other forms of overseas market entry support and training grants. Most firms were very positive about the support that they had received and in particular support to enable firms to visit international exhibitions, conferences, trade shows and clients was highlighted. One firm said that this had "a massive effect on the awareness of the company" while another said that "pound for pound this was the most important form of support" that it has received. This form of support would seem to be essential in view of the limited or non-existent market in Scotland for most technology firms and their strong export-orientation which is a essential for their survival.

In our previous study of high growth firms we noted that firms can also benefit from other forms of government activity, notably procurement and regulation. However, for this sample of technology companies just two had significant public sector customers. Significantly, more firms

complained that they felt they were shut out of public sector markets. Also, in the sample no firms stated they had benefited from regulation, and in fact two firms were highly critical of the effect of government regulation on their businesses.

6.14. Future Prospects

Two major themes emerged from the concluding discussion with the firms about their future prospects.

First, 16 of the 19 firms anticipated they would grow, through developing new products and entering new markets, including international markets, and in some cases by changing their business model. Two-thirds of these firms predicted substantial growth, with the remainder expecting growth to be slower. Growth would largely be organic. Moreover, it would not necessarily occur in Scotland. Three firms thought that they had, or would soon, reach growth ceilings.

Second, many of the firms also predicted possible ownership change. This had two dimensions. The first relates to the age of the current owner. Four firms had owners who were approaching or beyond the retirement age and some kind of transition of management and ownership was inevitable in the near future. None though appeared to have any obvious succession plan. However, some transition to employee ownership seemed to be a possibility in some cases. The second dimension relates to the possibility of company sale. Indeed, several companies had already received unsolicited expressions of interest from other companies seeking to buy them. Management of six companies – all smaller ones – seemed likely to seek an exit in the foreseeable future. In many cases selling would be a response to a lack of finance. A further two companies, both larger ones, had external shareholders who might seek a 'liquidity event' (i.e. a chance to realise their initial equity stake) in the future.

Whether the acquisition of Scottish owned technology companies is good for the economy or not remains a debatable point. One respondent suggested that it depended on the motivation of the acquirer: were they buying the people (or other asset), in which cases the business did not matter, or were they buying the business? Several of the companies that discussed the possibility of being sold argued that they were sufficiently embedded in Scotland, either because of the skills of their employees or specialist facilities, that a new owner would not relocate the business.

Of course, acquisition enables a process of 'entrepreneurial recycling' (Mason and Harrison, 2006), with the entrepreneurs and other members of the top management team starting new businesses, becoming business angels, mentors or non-executive directors. However, the extent of this recycling depends on the size of company when it is sold. When small businesses are sold it limits the scope for reinvestment in another business whether as a serial entrepreneur or business angel. This also restricts the learning that can be applied to another business as a founder, investor, mentor or NX director. The critical issue is therefore not whether Scottish owned companies get sold, but how big they become before (and after) they

get sold. The Scottish experience is that many technology companies get acquired – often because of a lack of further finance – while they are still quite small (Oakey, 1993). Meanwhile, growing indigenous 'companies of scale' is likely to generate multiple externalities, including a source of demand through supply chains, potential to create new subsidiary companies and joint ventures, and new business creation by former employees, either as spin-outs or management buyouts (Royal Society of Edinburgh, 2010).

The evidence from the two acquisitions for which we have information is inconclusive, not least because they have only occurred within the past two years. The impacts of acquisition – both positive and negative – on both the acquired business and the entrepreneurs (and other investors) –is likely to take time to emerge. This is something which needs much more detailed research to properly investigate and assess.

Mpathy was founded in 2003 to provide solutions to a particular health problem of women for which there was a huge market. The company was originally established by Dr James Browning in 2003. It was funded by Archangels, the Scottish Coinvestment Fund and grants. Its original business model which ran until 2007 was to sell the IP. This failed so the company made the strategic decision to build a business based on direct sales. Sales demonstrated market acceptance so the owners decided to sell the company. The reason was that if the company was to remain independent it would require $10m-$20m to build a direct sales team in the USA. Moreover, if did go down this route this would provoke competitive reaction from its competitors, so this investment had significant risk attached to it. The alternative was to sell to an established company which already had the distribution in place. From 2008 to 2010 the business was prepared for sale. This was done by demonstrating credible market presence, IP, proof of clinical efficiency, customer relations sales team and product and material branding. Further rounds of funding were raised. The company attracted interest from several companies. Some were direct competitors and so were motivated by the desire to remove Mpathy from the market. The company was sold to Coloplast of Denmark for which it offered complementary products. Early investors got a 6-7 times return on their investment while later investors got a 3-4 times return. In terms of the impact on Scotland, manufacturing is undertaken by a third party organisation and remains in Scotland, investors have recycled their returns and the three members of the top management team have gone on to other jobs in Scottish technology companies.

Lab901 was founded by two Motorola engineers after the company closed. Although they worked in specialist automation they made a conscious decision to focus on the life sciences industry where they saw a need for greater automation. Their vision was "to automate something" in science labs. Having engaged various people in the life sciences industry they partnered with two academics from Edinburgh University Medical School who helped them identify the problem that they could solve. This was an instrumentation system which they manufactured themselves. The company was initially funded by a SMART Award which, in turn, led to a patent. Having a patent necessitated forming a company. This occurred in 2001. They then raised start-up funding from Archangels, ultimately raising £9.5m from Archangels and other investors over several rounds. Their first sales were in 2007. By 2010 the company had

developed a world class team and innovative product. The product had been shipped and they had a state of the art facility to manufacture the product. Having demonstrated proof of manufacturing process stability and scalability and with product sold to customers around the world the investors thought the company was 'exit ready' and so sought a buyer. They approached several companies seeking a 'good home' for the company – not a buyer that would close it down. In early 2011 the company was sold to Agilent Technology (formerly Hewlett Packard) of the USA, the world's premier measurement company. This provided Lab901 with security, additional resources and R&D investment. Agilent got a world beating technology and team, the manufacturing process and complementary products. Its customers got the Agilent brand, new applications and global sales and support. Subsequently it got approval for its patent from the US Patent Office which seems likely to be connected to Agilent's acquisition. The team remains in place and the two founders are working to develop the business within Agilent. Since acquisition new R&D products have come on-stream, manufacturing capacity has expanded, and the customer base has expanded considerably.[9] Investor returns were not disclosed.

6.15. SUMMARY

The interviews have added further insight into Scotland's indigenous technology sector.

The companies interviewed exhibit considerable diversity in terms of their age, size and the nature of their business, with many far removed from the 'white coats' stereotype of a technology business. They are predominantly small and medium sized businesses, with less than £10m in sales and less than 50 employees. Most are engaged in B2B activities. A variety of business models are in evidence. Most have overseas sales and a significant proportion derive most or all of their sales from overseas exports. Several of the larger companies have international operations which reduces their Scottish footprint.

Companies are competing largely on the basis of their technical and domain knowledge, capabilities and offering. Both IP and formalised R&D activity were less common than might have been expected. Universities are of minor importance as a source of innovation. Only two companies could be classified as a university spin-outs and neither has any remaining links with their former institution. Two other companies emerged from failed university ventures and only one company has strong research links with a local university.

Most of the interviewed companies have been growing, many quite fast, but some were hit hard by the economic downturn and are only now resuming growth. The majority are anticipating further growth, albeit at varying rates. However, some are at, or anticipate hitting, growth ceilings which, in some cases arise from financial constraints. Hardware companies are more likely to encounter growth constraints than software companies.

[9] In subsequent personal discussion after the presentation Joel Fernley said that he would be "hugely disappointed" if Agilent subsequently closes the company – but should this occur then at least two new companies would be started by Lab901 employees.

The main growth constraints that were reported are recruitment, both debt and equity finance, especially for smaller firms, and distance from major markets, especially for hardware companies.

The companies were based in Scotland because that was where their founder was living. However, there were few significant advantages of a Scottish location, except for companies selling into the North Sea oil and gas sector. The distance from customers, restricted airline routes and lack of indigenous markets were seen as the biggest disadvantages.

Many of the companies had been approached by potential buyers and several owner-managers seemed likely to sell in the foreseeable future. This raises questions about the pros and cons of the acquisition of Scottish technology companies, the size of the companies that get acquired, and the benefits of growing more companies of scale.

7. CONCLUSIONS AND IMPLICATIONS

7.1. Summary of the Findings

This report follows an earlier study of high growth firms in Scotland (Mason and Brown, 2010). One of the surprising findings from that study was the relatively small number of TBFs in the population of high growth firms. This study was commissioned to specifically examine Scottish TBFs. We defined TBFs using SIC codes. The analysis of ONS data provided confirmation that TBFs are not over-represented in Scotland, both in the population as a whole and amongst high growth firms. TBFs represent around 12% of the overall population of HGFs in Scotland and indeed, Scotland's proportion of high growth firms that are TBFs is the second lowest of all UK regions. However, the growth performance of these firms is on a par with the UK as a whole and that the incidence levels of HGFs within the population of TBFs is above the stock of firms a whole. High growth TBFs are also smaller and younger than high growth firms as a whole.

A further characteristic of Scotland's technology sector is its high level of external ownership. Based on an analysis of FAME data, which has the advantage over ONS of listing firms by name although the disadvantage of limited coverage of the smallest firms, just 28% of technology firms are Scottish owned, rising to 40% if subsidiaries of Scottish owned firms are included. Some of the non-local ownership can be attributed to acquisition of Scottish owned businesses, but we cannot determine as yet the true extent of this as a cause.

Drilling down further, Scottish-owned technology firms exhibit considerable diversity in terms of their age, size and activities. Indeed, the profile that emerges suggests that the typical stereotype of a TBF is unrepresentative of the sector as a whole – for example, in terms of the technological sophistication of their products and services, importance of patented knowledge and IP and proportion of graduate employment.

The North Sea energy sector is shown to be highly significant as a source of technology-based firms. First, some 13% of technology firms are engaged in oil and gas exploration activities. Second, the customer base of a significant proportion of firms in other sectors is the energy sector. Indeed, the North Sea oil and gas sector accounts either directly or indirectly for one-third of technology firms in Scotland. Third, firms selling into the North Sea market have been able to access other global energy markets through their North Sea customers (see Raines et al, 2002).

Scottish owned TBFs are predominantly engaged in B2B markets. As is the case for high growth firms in general, most of the larger technology firms have a significant international presence and employment overseas, which reduces their Scottish footprint. Most are international in orientation: two-thirds derive more than 50% of their sales in overseas markets and one-third derive more than 90% (and some 100%) from international sales.

Firms are competing on the basis of their technological and industry knowledge, strong connections to customers and expertise rather than on the basis of their technology *per se*.

Specifically, universities emerge as being relatively insignificant to Scottish TBFs, either in terms of being spin-offs or a source of knowledge. In this respect, TBFs are no different from firms in other sectors in the sense that their commercial success depends on the quality of the offering and execution rather being focused on protected IP or universities for their sources of innovation.

The majority of the firms interviewed expect to continue to grow, some fast, others more steadily. However, some smaller firms, particularly in manufacturing, are facing ceilings on their growth as a consequence of lack of finance, liabilities of smallness and distance from markets. Several seem likely to sell out as a means of overcoming these constraints. With the important exception of firms involved in North Sea oil and gas, TBFs derived limited benefits from a Scottish location. They were based in Scotland because that was where their founders lived. Most have limited embeddedness in Scotland. Finally, the majority of the firms that were interviewed have had significant public sector support. This support was generally regarded as being helpful – and in some cases extremely beneficial.

7.2 How Do Scottish TBFs Compare with those Examined Elsewhere?

It is worth assessing how the above findings, especially the findings from the sample of firms interviewed, correspond with the wider research and analysis of TBFs. A key conclusion to make is that too much attention has been paid to new or young TBFs within the academic literature on technology firms. The analysis of Scottish TBFs shows that the majority are well established firms and that their growth is very non-linear and discontinuous. Indeed, as previous research of HGFs has shown, the nature of Scottish TBFs is likely to be highly context dependent.

Four broad areas that influence growth can be identified in wider research of NTBFs and TBFs: founder characteristics, business characteristics, business strategy and environmental characteristics. The Scottish experience is compared to the wider research below.

First, the literature on founder characteristics showed that those with high levels of human capital who had worked in the same industry and who demonstrate strong levels of entrepreneurial orientation and ambition were the most likely people to achieve growth within their new ventures. The findings from the Scottish study in the main endorse these findings but with certain important caveats. Most of the businesses interviewed had been established by people with high levels of human capital: the majority being graduates, postgraduates and some with doctorates. Scottish founders who had worked previously within industry (sometimes the same industry) strongly benefited from this experience, benefiting from 'insider' knowledge to make contacts and knowing what was required to grow a business within their area of expertise. The entrepreneurs who had worked in larger firms previously also seemed more ambitious than those from smaller business backgrounds. Therefore, there may be 'untapped' sources of entrepreneurial talent locked up within existing larger firms in Scotland. The one area where the Scottish experience seemed to be somewhat contradictory

to wider research findings surrounds the area of entrepreneurial orientation and growth ambition. Many of the successful Scottish TBFs were driven by ambitious entrepreneurs but some seemed to place 'ceilings' on their overall growth ambitions. Despite the fact that they were growing rapidly, some viewed that they had peaked in terms of their growth capacity while others felt that they'd need to 'exit' the business for the business to achieve its full potential. Clearly, levels of growth ambition differ between individuals and not all people want to grow a significant company of scale with a turnover and large scale employment.

Second, from our review of the literature we found that businesses which were team-based, venture capital-backed and those with a very strong international orientation were the most likely TBFs to achieve strong growth. Again, the Scottish experience broadly endorses this but again important differences remain evident. The vast majority of the successful Scottish TBFs were team-based management teams and many had Boards of Directors to help guide the strategy of these firms. Venture capital backing was important for only around a third of the businesses interviewed. What seemed slightly at odds with the literature was the fact that a similar proportion of Scottish TBFs were entirely dependent on internal sources of finance to fund their growth and expansion (sometimes due to the lack of available credit from banks). This finding may have been affected due to the current time period which finds many businesses facing problems attracting various sources of finance.

A stronger indicator of the success of these TBFs seemed to be the level of business internationalisation. Due to the lack of local demand for many of these product groupings, Scottish TBFs have no alternative but to embark on extensive internationalisation and many resemble the archetypal 'born global'. However, there appeared to be some sizeable oil and gas and software businesses who had been able to grow largely on the back of domestic demand and who had then become internationalised much more incrementally. An interesting research question is whether the former or the latter is a more effective or sustainable recipe for successful business internationalisation.

Third, in the area of business strategy the literature showed that successful TBFs tend to adopt a variety of different business models (both hard and soft), offering customers a wide range of bespoke solutions and product offerings and many have formalised management structures. The Scottish experience strongly endorses these previous findings on a number of levels. First, successful TBFs are highly adaptive and offer 'hybrid' business models to enable growth. Second, many of the firms are highly adaptive to the needs of their customers and offer bespoke offerings to give their customers unique 'solutions' (Parker et al, 2010). As was found from the earlier study of Scottish HGFs, many had business models which are able to capture recurring forms of income from customers (such as Optos, Craneware etc). Third, formalised management structures seemed to be a factor behind the success of some. Often when owners acquired these firms or managers undertook an MBO a key initial objective of the new owners/managers was the need to implement more formalised and sophisticated management systems (IT, quality, regulatory approval and training). This may partly explain the reason why entrepreneurs from large companies were often drivers of these growing firms given their exposure to large company management systems and practises.

Finally, the literature stressed the importance of overall business environment for the success of firms. Factors such as regulation, levels of local entrepreneurship and spatial clustering are all important factors behind the growth of TBFs. The research found that regulation was an important driver of growth within these firms, a finding which again endorses previous work on Scottish HGFs (Mason and Brown, 2010). The Scottish research also found that entrepreneurship is very much a 'local event' and the majority of the businesses were founded by people who were previously located in Scotland. A strong finding from both the quantitative and the qualitative research was the importance of geographical clustering amongst this cohort of firms. From our analysis of the high-tech HGFs we found that only five local authority areas had more than 10 of these firms. Interestingly two of these areas were in the north-east of Scotland which clearly demonstrates the importance of the oil and gas industry as a driver of high growth TBFs. Indeed, the oil and gas cluster plays a critical role in shaping the population of TBFs in Scotland.

7.3 Future Areas for Research

This research exercise has raised a number of interesting issues which may merit further investigation. First, in view of the importance of the oil and gas industry as a key engine of growth within the technology based sector in Scotland, perhaps there is merit in more detailed investigation why this sector so disproportionately benefits TBFs in Scotland. Second, given the nature of the successful TBFs in Scotland (low R&D, applied focus, end-user engagement) perhaps there is merit in ascertaining the types of problems less successful TBFs face in terms of their 'absorptive capacity' (Harris et al, 2012). Finally, and perhaps most importantly, the issue of acquisition surfaced as a very important issue within the population of TBFs. Not only do many successful TBFs become acquired but many successful Scottish TBFs are highly acquisitive. Given this much more needs to be known about how the process of inward and outward acquisition affects these firms and the economy as a whole in Scotland.

7.4 Policy Implications

The research raises a number of interesting and challenging policy issues which need to be further unpacked and explored. Issues such as whether the nature of current support to TBFs needs to be adapted, the role of public procurement in developing TBFs and the role of inorganic growth within the growth strategies of TBFs are all aspects which merit further investigation. It was also found that companies of scale play a significant and strategic role in developing TBFs in Scotland, notably as a source of significant customers through the supply chain. Policy makers therefore need to give consideration to how the major firms in the Scottish economy might be encouraged and supported to play a more strategic role in the economy both as incubators and investors in TBFs is a further policy issue to be explored.

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APPENDIX 1. Definition of High Technology Industries Used in a Study of Oxfordshire

High-tech manufacturing
Electronic publishing (part of 1992 SIC category 22.1) (all other publishing activity is excluded)
Pharmaceuticals & medical diagnostics (1992 SIC category 24.4)
Biotechnology (no SIC category)
Composites & other advanced materials (no specific 1992 SIC category, although included in 25.24, 26.15 & 26.82)
Precision engineering & precision components (no specific 1992 SIC category, although included in 28.52)
Automated machinery & robotics (no specific 1992 SIC category, although included in 29.56 and other 29 codes)
Computer equipment & office machinery (1992 SIC categories 30.01 & 30.02)
Electrical equipment—selected (1992 SIC categories 31.1, 31.2 & 31.62)
Electronic equipment & components, communications equipment, and household TV, radio & audio equipment (1992 SIC categories 32.1, 32.2 & 32.3)
Medical & surgical equipment, precision instruments, process control equipment, optical instruments & photographic equipment (1992 SIC categories 33.1, 33.2, 33.3 & 33.4)
Motorsport & automotive engineering/design activities (no SIC category)
Aerospace & related activities (e.g. aircraft maintenance) (1992 SIC category 35.3)

High-tech services
Telecommunications (1992 SIC category 64.2)
Software development, consultancy & supply (1992 SIC category 72.2)
Web/internet services (no specific 1992 SIC category, but included in 72.6)
Other computer services (1992 SIC categories 72.1, 72.3, 72.4, 72.5 & 72.6)
R&D—natural sciences & engineering (1992 SIC category 73.1)
Architectural & engineering activities & related technical consultancy (1992 SIC category 74.2)
Technical testing & analysis (1992 SIC category 74.3)

Source: Glasson et al (2006)

APPENDIX 2: COMPANIES PARTICIPATING IN THE INTERVIEW SURVEY

Absoft
Amor Group
AG Holdings Ltd (Axeon Power)
Calnex Solutions
Clansman Dynamics
Critical Blue
Craneware
CST Global
Cupid
Dacoll Group
Daysoft
Edge Testing Services
Keppie
Score Group
Scottish Biomedical
Semi Scenic
Tissue Solutions
Touch Bionics
Wollard & Henry
MPathy Medical
Lab 901