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Technology-Based Entrepreneurship

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1st edition

ISBN 978-87-403-0564-7

Contents

Preface

Technology-based firms (TBFs) have an innovative role in the emerging knowledge economy (RAE, 2012), especially at an international level (EC, 2005; BERR, 2008). Indeed, the effective use of technological innovation is considered to be a prerequisite for business survival (Packham, 2002; Packham et al, 2005). It has long been recognised that technology-based entrepreneurship is important for economic growth and it has been noted that there is a need for an international focus on businesses having access to international markets (OECD, 2005). Within this context it has been acknowledged that business development programmes and assistance should enable firms to take advantage of innovative global technologies (OECD, 2005). Although significant opportunities are presented to businesses through the adoption of new technologies there needs to be awareness to the barriers of implementation and this has led researchers to focus on adoption factors (Parasuraman, 2000). In fact, there has been little success linking the determinants of adoption in businesses with expected outcomes such as innovation, apart from specialised research and development (R&D) intense sectors (Thomas and Simmons, 2010).

TBFs with an above average absorptive capacity tend to exhibit experience, knowledge, a skills base, knowledge creation and sharing processes (Cohen and Levinthal, 1990; Zahra and George, 2002; Gray, 2006). Their effective use of networking and an optimal use of technological innovation are the focus of this book. Here an approach appropriate to TBFs is taken by considering technology transfer policy, the diffusion of innovation into TBFs, technology clusters, university technology small firms, university business collaborations and partnerships, and the growth of a technology concept. Given this exciting new approach to technology-based entrepreneurship it is a pleasure to commend this text not only to students, researchers and scholars of entrepreneurship but also to policy makers, small business practitioners and owner managers. In this way it is hoped that this textbook will provide a greater understanding of technology-based entrepreneurship (Hsu, 2008) in the emerging knowledge economy.

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Acknowledgements

The publication of this book would not have been possible without the assistance of a number of people and institutions to whom I am grateful. I am indebted to the Business School at the University of South Wales for their support in the course of writing this book. Special thanks go to Book Boon at Ventus Publishing, and its publishing team, for helping this publishing project keep to schedule. Finally, I would like to make a special thank you to my family for support and encouragement.

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September 2013

1 Introduction

"The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency."

BILL GATES (1955–)

This chapter at a glance

- Overview, Definitions and Background
- Technology-Based Entrepreneurship Education
- Technology-Based Entrepreneurship and Regional Development
- Organisation of the Book

1.1 Overview, Definitions and Background

In the entrepreneurship academic literature technology-based entrepreneurship (TBE) is referred to in a number of ways including technology entrepreneurship and technical entrepreneurship (MacKenzie, and Jones-Evans, 2012). According to Bailetti (2012) technology entrepreneurship is centred around the growth of firms, and regional economic development and involves the selection of stakeholders to take ideas to market and to educate managers, engineers and scientists. Moreover, Bailetti (2012) outlines technology entrepreneurship as "an investment in a project that assembles and deploys specialised individuals and heterogeneous assets to create value for the firm" (Bailetti, 2012, p. 2) and reports that the first symposium where researchers assembled to report findings on the topic was at Purdue University in October 1970 (p. 3). In a literature search 93 journal articles published in 62 journals on technology entrepreneurship were identified between 1970–2011 with eight themes which were technology entrepreneurs, technology opportunities, university and business incubators, spinoffs and technology transfer mechanisms, government programmes, funding new technology-based firms entrepreneurship education and commercialisation capability (Bailetti, 2012, p. 5). Although most of the technology entrepreneurship articles were published in non innovation or entrepreneurship journals, of the 62 journals publishing the 93 articles there were only eighteen found to be journals that contributed to entrepreneurship or technology innovation management according to Franke and Schreier (2008) and seven journals met the criteria for "good" journals in the area which were ET&P, IEEE, IJTM, JBV, JPIM, R&DM and RP (p. 8).

With regard to definitions in the literature Bailetti (2012) suggests that technology entrepreneurship concerns (a) the operation of enterprises by scientists and engineers, (b) identifying applications or problems with a technology, (c) exploiting opportunities, starting new applications or setting-up new ventures involving technical and scientific knowledge and (d) collaboration for technical change (p. 9). Furthermore, Bailetti (2012) notes that the technology entrepreneurship field, when compared to other fields such as management, economics and entrepreneurship, is in its infancy and provides the following definition "Technology entrepreneurship is an investment in a project that assembles and deploys specialised individuals and heterogeneous assets that are intricately related to advances in scientific and technological knowledge for the purpose of creating and capturing value for a firm" (p. 10). In conclusion Bailetti (2012) notes that technology entrepreneurship over the past four decades has become an international phenomenon and is considered to be important for competitive advantage, differentiation and growth of the firm at national, regional and firm level (p. 14).

In a study of technology-based entrepreneurship and the role of the University Tekic et al (2009) analyse TBE and provide research evidence about characteristics of new technology-based firms (NTBFs), define a technology-based firm as a firm that is depending on technology for its development and survival and note that TBE is a highly regional phenomenon. According to Hsu (2008) TBE is a field formed from the two areas of technological innovation and entrepreneurship (p. 367). In fact, TBE seems to have developed in the early 1960s (Roberts, 2004) from the emergence of NTBFs and research-based new ventures (RBNVs) in areas such as Cambridge in the UK, Munich in Germany, Silicon Valley and Route 128 in the United States of America (Tekiz, 2009). Hsu (2008) further notes that following the entry decision being made for the origin of a new venture there are two types of important knowledge for the entrepreneurial process which include technical and commercial knowledge (p. 369). Here there are three forms of technological knowledge for technology-based entrepreneurship which are intellectual property, knowledge spillovers and technological search (Hsu, 2008, p. 371). In order to overcome local search behaviour technology entrepreneurs will acquire knowledge in varying rates from other technological domains (Hsu and Lim, 2007). The preliminary founding effect will be important although it will not totally affect the organisational practices in innovation (Cockburn, Henderson and Stern, 2000). With technological knowledge absorptive capacity (Cohen and Levinthal, 1990) is important and is an alternative pathway to the exploitation of technological knowledge. Other important factors will be knowledge spillovers (Zucker, Darby and Brewer, 1998), the locality of the patent citations effect (Thompson and Fox-Kean, 2005), and geographic location since in regions where there is an aversion to entrepreneurial failure start-up capital will have higher costs (Landier, 2006). For intellectual property licensing there is the possibility for value enhancement for start-up licences (Shane, 2001a, 2001b), as well as the technology owner such as universities and corporations (Gans, Hsu and Stern, 2002; Arora, Fosfuri and Gambadella, 2001). Further to this whereas Agrawal and Henderson (2002) found that knowledge diffusion through patenting was only a small amount of knowledge flow (especially graduate student training and the publication of papers), Shane (2001a; 2001b) found evidence of new venture formation related to patent radicalness. Although inventors may have to be incentivised to partake in these activities (Jensen and Thursby, 2001). In these areas technology-based entrepreneurship research has tended to investigate medical science areas and there would be benefit from the study of other fields and areas.

In terms of commercial knowledge for the entrepreneurial origins of technology-based firms spin-offs from established companies which form new ventures are important (Hsu, 2008). Here there are two different conceptions of the spin-off process (Gompers, Lerner and Scherfstein, 2005). First, there are entrepreneurs who develop links and networks when they are working for a large company. Second, organisations that are bureaucratic tend not to commercialise innovations and as a result employees will leave and try to develop their own company. According to Gompers, Lerner and Scherfstein (2005) employee learning better explains spin-offs with capital backing than organisational failure. Furthermore, Agarwal et al (2004) found, with regard to the hard disk drive industry, that people with technical knowledge and who were pioneers in the market generated less spin-offs. It has been found by Burton, Sorenson and Beckman (2002) that status effects are transferred to the offspring from the parent organisation. Klepper (2002) notes that "while diversifying firms on average outperformed de nova entrants, de nova entrants founded by individuals that worked for leading automobile firms outperformed all firms and dominated the industry" (p. 645). Klepper and Simons (2000) further noted that "no non-producer ever captured a significant share of the television market" (p. 998). Shane (2000) illustrates that information on how to exploit entrepreneurial opportunity will not be standard for different people but will be heterogeneous for potential entrepreneurs. Technology-based entrepreneurship will be based upon serendipity, previous knowledge, the ability to solve problems and will be dependent on active search. Shane and Venkataraman (2000) further elaborate that it appears that venture creation involves entrepreneurial opportunity creation and recognition dependent on entrepreneurial conjectures. With regard to the television industry Klepper and Simons (2000) noted that experienced radio firms tended to enter and succeed in television manufacturing and Helfat and Lieberman (2002) concluded that entry was more likely to be successful if the founders felt that their capabilities and resources suited entry.

Once the business idea has been developed and evaluated the next stage in the technology-based entrepreneurship process is the acquisition of financial and human resources (Hsu, 2008). For instance in the labour market for PhD biologists, encompassing industry and academia, Stern (2004) found that there was a trade-off of financial gain for employment benefits such as being able to follow a line of scientific enquiry. High rating scientists can be attracted by business environments involving open science policies (Hsu, 2008). Further to this Baron, Hannan and Burton (2001) found that changes in organisations could be disruptive causing a high rate of turnover for employees. Through modelling Lewis and Yao (2003) have shown that open R&D policies are a variable business environment function in terms of intellectual property, product development and labour market conditions.

With regard to start-ups and the formation of strategic alliances the role of venture capital has been highlighted (Hellmann and Puri, 2000, 2002; Hsu, 2006). For technology-based entrepreneurial funding two mechanisms have been conceived which are the contractual approach where funding is offered involving tight requirements by financiers to provide screening (Kaplan and Strömberg, 2003) and external actors who make decisions based on the start-up affiliate's quality to indicate the quality of the start-up. Although start-ups, who affiliate with a venture capitalist with a high reputation, will pay a price (Hsu, 2004).

An important dynamic for the success of a start-up is its strategy. One start-up strategy is to enter into a niche market staying out of the sight of established businesses (Yoffie and Kwak, 2001). Another strategy is to differentiate the product or service offerings involving the protection of intellectual property (Hsu, 2008).

By adopting a novel business revenue model a new enterprise can differentiate its product which will have operational implications for enterprising businesses (Zott and Amit, 2007). There are different types of product development involving co-operation between well established companies and innovators and these vary from acquisitions, strategic alliances and the licensing of technology (Gans, Hsu and Stern, 2002; Mathews, 2006). Further to this Gans, Hsu and Stern (2002) have examined the factors that can influence the commercialisation strategies of technology-based start-ups and these are intellectual property and patents and their role in the negotiations with larger companies, information brokering and the role of venture capitalists which reduces transaction costs involved with the costs of entry (Hsu, 2008). When testing these factors Gans, Hsu and Stern (2002) found that they had a significant effect on co-operation at start-up. Following this the evidence of the role of patents in creating technology transfer was provided (Gans, Hsu and Stern, 2008), and a dataset was constructed with information on the timing of co-operative licensing and patent allowances by technology based entrepreneurs, using the timing of patent allowances to determine the patent grant's role on technology licence timing (Gans, Hsu and Stern, 2008). It was further found that there was an impact on the market for ideas transfer due to delays in the patent grant system (Gans, Hsu and Stern, 2008).

An important theme for technology-based enterprises is the development of corporate governance and leadership (Hsu, 2008). It is apparent that venture capital supported businesses tend to have “professional” directors (Baker and Gompers, 2003) through directors who are independently linked to corporate value (Gompers, Ishi and Metrick, 2003) in bigger businesses.

It has been found that the tendency towards the founder leaving a company is greater with business size, becomes less with ownership by the founder, and exhibits a relationship with the growth of the firm that is U shaped (Boecker and Karichalil, 2002). Two occurrences that are linked to chief executive officer / founder departure are the completion of product development and venture capital funding. The regional consequences of new venture founding rates for prior biotechnology IPOs have been examined by Sorenson and Stuart (2003) and the entrepreneurial motivations for merging ventures were investigated by Graebner and Eisenhardt (2004).

The above discussion illustrates that there is a broad spectrum of business issues concerning technology-based entrepreneurship. These involve issues at the various stages of enterprise development including the origins of the venture, resources, strategy, growth and business success. As a consequence there is growing awareness of the importance of technology-based entrepreneurship by small business academics.

According to Preston (2001, p. 2) the success factors for technology-based entrepreneurship include attitudes, management talent, patents, passionate behaviour, quality investors, speed of innovation, high quality products to market quickly, flexibility, location and clusters of excellence. With regard to attitudes radical innovations will not originate from a market leader (Utterback, 1994). The sitatuion where there is a top management team with an average technology tends to be better than a leading technology and a lesser management team since top managers have a higher success rate (Preston, 2001, p. 5). Patents provide the basis of sustainable advantage for technology-based entrepreneurship and in the past there have been incremental patents from Japan and from the Unites States laboratories radical breakthrough patents (Preston, 2001, p. 6). Here industries with creativity appear to have higher achievements in the United States (such as software) whereas in Japan those industries where there is improvement appear to perform better (such as consumer electronics where manufacturing techniques are improved) (Preston, 2001, p. 12). In terms of shortening the time to market product development cycles repeated rapidly have led to successful companies in America in the semiconductor, computer, software and electronics industries, and speed to market has been a significant determinant of success and profitability of products (this is also the case for those industries not dominated by intellectual property with less importance given to patents) (Preston, 2001, pp 12–130). Finally, with location clusters create competitive advantage and regional advantage can be gained by clustering enterprises with competitive and complementary skills resulting in regional excellence (Porter, 2008).

Strategies for success to accelerate technology-based entrepreneurship for regional economic development and growth include partnerships, technology alliances and collaboration with business, academia and government (IC^2, 2007, p. 1). This can be achieved through emerging industry clusters with growth potential involving research and development (R&D) based growth, intellectual property, incubators, innovation based growth and business know-how (also of importance are high tech companies, knowledge-intensive new businesses, new technology-based organic growth ventures, networks, company spinout activity, partnerships for research excellence, collaboration and technology-based education) (IC^2, 2007, p. 5).

In order to achieve these strategies for success a constructivist approach for technology-based entrepreneurship can be followed (Giones et al, 2012, p. 1). Although the support of technology-based entrepreneurship has been prioritised by governments with initiatives for success to help technology-based ventures the results have not necessarily delivered the returns expected (Lerner, 2010). According to Alvarez and Barney (2007) there is a need for objective opportunities to promote technology-based entrepreneurship with dynamic environments (Clarysse et al, 2011). In fact, technology-based entrepreneurship has been seen as a process of plan, design and action as activities that are separate and sequential (Baker et al, 2003). There are also uncertainties in the exploitation of technology (Gruber et al, 2008) and in the initial stages of conceptualisation of technology opportunity, and through moving to an objective opportunity from a subjective idea (Sheperd et al, 2007). This iterative interaction has also seen other theoretical perspectives involving bricolage, creation theory and effectuation (Alvarez and Barney, 2007; Baker and Nelson, 2005; Sarasvathy, 2001). For such uncertain contexts there is limited knowledge about the processes and activities that develop the conceptualisation for technology-based enterprises (Fisher, 2011) and the mechanisms used for the conceptualisation of opportunity to develop opportunity from human ideas (Giones et al, 2012). Technology-based entrepreneurship is therefore a process involving technology entrepreneurs who face high uncertainty (McMullan and Sheperd, 2006) with business ideas concerning disruptive market solutions and undetected technologies.

1.2 Technology-Based Entrepreneurship Education

Technology-based Entrepreneurship Education (TEE) (Byers, 2005) has evolved as a particular strand of Entrepreneurship Education (EE) (Frank and Boocock, 2008). Enterprise Education started in the UK in 1976 (Breen, 2001) with the Labour Government strategy to combat anti industry culture in schools and this was developed further by subsequent governments. In the United States it is called entrepreneurship education and includes a business creation focus. A definition of enterprise education is that it 'is directed toward achieving a learning culture which will result in greater numbers of students equipped and enthused to identify, create, initiate and successfully manage personal, business, work and community opportunities' (Ed-ventures Magazine, 1997).

A paper by Clouse (2001) concerning a controlled experiment relating entrepreneurial education to students' start-up decisions notes that over the last two decades institutions of higher education have experienced an increased demand for courses dealing with entrepreneurship education. According to Clouse (2001) this has been based on the substantial effect entrepreneurship education has on entrepreneurial success and the positive relationship between entrepreneurship education and economic development. In response to the growing demand for entrepreneurship education a variety of course offerings have been created by universities.

Dana (1992) researched entrepreneurial education in Europe and found that it was developing rapidly. By comparing trends in Europe with the United States it was found that the principal strength of European programmes was their practical approach. Another difference was that entrepreneurship education had spread more rapidly into European rural areas than American non-urban areas. The strengths of American programmes were a greater diversification of courses. Dana notes that Shigeru Fijii pioneered applied education teaching in entrepreneurial studies in 1938 at Kobe University in Japan. This was slow to gain recognition and it has taken half a century for entrepreneurship education to become universal.

In a study of entrepreneurship education and research outside North America Brockhaus (1991) reports that courses on topics related to entrepreneurship and small business are appearing in the curriculum of many colleges and universities throughout the World. Carter and Collinson (1999) consider the retrospective perceptions of alumni towards the general provision of entrepreneurship education in higher education institutions (HEIs). Although many HEIs provide enterprise training for their students, few have considered extending this provision to their alumni. They attempted to determine the demand for post-qualification entrepreneurship training among HEI alumni. It was found that respondents thought that HEIs should provide a more practical grounding for graduates. Financial management and business communications skills are considered to be the key elements missing from undergraduate courses.

In the UK enterprise education curriculum materials were developed by Gibb (Breen, 2001) at Durham University. Galloway and Brown (2002) have noted that there is increasing attention being paid to the potential of university entrepreneurship education to facilitate high quality growth firms in the UK.

Garavan and Cinneide (1994a) reviewed the literature on the design of entrepreneurial education and training programmes. A number of problems were highlighted including inappropriate learning methodologies, little methodology on development of entrepreneurial competences and a lack of consideration of the outcomes of programmes. Garavan and Cinneide (1994b) followed this with a consideration of six entrepreneurial education and training programmes. This indicated a variety of entrepreneurship education and training programmes in Europe.

Hynes (1996) remarks that one of the core components of an enterprise culture is education and how various educational programmes can incorporate entrepreneurship as a subject to foster interest in enterprise. It is suggested that a process model for enterprise education can be used to target student groups in an interdisciplinary way. The need to teach entrepreneurship to non-business students is emphasised. These students are often originators of ideas but do not have business knowledge to develop these further.

Binks (1996) argues that, although the Enterprise in Higher Education (EHE) initiative is a product of the perceived needs of larger business it needs to be judged in the wider context. Bisk (2002) addresses the effectiveness of the matching process of third party managed entrepreneurial mentoring programmes. The results of his study suggest that the entrepreneur's age and education are key factors that impact upon whether there is benefit from the engagement.

Chadwick (1999) has considered the facilitation of the progression of modern apprentices into undergraduate business education. The main focus is a case study of the progression links into a new undergraduate business programme (Business Enterprise) that have been established for modern apprenticeships. The work explores the implications for the design of higher education programmes aimed at apprentices.

Ibrahim and Soufani (2002) have undertaken a critical assessment of the entrepreneurship education and training efforts in Canada and have identified common challenges facing this process. Shacklock et al (2000) have explored the emergence of enterprise education in Australian schools in the late 1990s. Claims about the restorative potential of enterprise education as new vocational learning for the "re-invigoration" of education in schools is scrutinised. In relation to policy initiatives for vocational education the link between key competencies and enterprise education is explored. Discursive consequences of new metaphors for teaching and learning linked to enterprise education and their impact on teacher's work are explored.

McMullan and Gillin (1998) provide an industrial viewpoint of entrepreneurship education regarding developing technological start-up entrepreneurs and provide a case study of a graduate entrepreneurship programme at Swinburne University of Technology in Melbourne Australia. This was set against the fact that although universities had been offering courses in entrepreneurship education for over thirty five years graduate level programmes only go back to the early nineties. In their study since 87% of those surveyed started ventures it was apparent that the programme not only launched meaningful entrepreneurial careers but was also of micro-economic significance.

According to Lewis and Massey (2003) the aim of enterprise education is to develop a set of skills and attitudes in individuals that will allow them to be job creators and seekers and to contribute to the "knowledge economy". It is noted that in New Zealand there is interest in the contribution of enterprise education to these objectives and legitimising self-employment as a work option. Sexton et al (1997) report that the existing education literature related to teaching and/or learning skills to grow business do not address the problems created by growth. They remark that studies have examined students in an academic environment. This has been away from real world problems, in a structured setting of specific duration and involving similar levels of knowledge and competency. Bosire and Etyang (2003) have considered the effect of education on business skills cognition and the case of indigenous micro-scale enterprise owners. They argue that one of the expected utilitarian values of education is the development of competencies for effective business practice after school. Kolvereid and Moen (1997) noted that only a small number of studies have investigated the effect of entrepreneurship education. The results of their study indicate that graduates with an entrepreneurship major are more likely to start new businesses and have stronger entrepreneurial intentions than graduates in other areas. Jack and Anderson (1999) have studied enterprise education within the enterprise culture in terms of producing reflective practitioners. They observe that there are very different expectations of those stakeholders promoting entrepreneurship education. Laukkanen (2000) explores alternative strategies in university-based entrepreneurial education in response to the nebulous conceptual and efficacy notions of entrepreneurship and its education, breeding unreasonable and unpredictable expectations.

The background to TEE in the United Kingdom (UK) developed from the UK Government's "Third Mission" for Higher Education (DTI, 2000). This influenced universities to take their mission further than research and teaching to develop linkages with local communities and businesses and empower science and technology transfer to businesses (Franck and Boocock, 2008). Although the broad agenda has evolved the philosophical underpinning has been kept and has influenced universities in the UK to (i) deliver entrepreneurship and enterprise education to Science, Technology, Engineering and Mathematics (STEM) students, and (ii) engender the development of new firms through start-up businesses especially spin-off firms with inventions and innovations by faculty staff and students (Boocock and Warren, 2005; Boocock and Frank, 2006; Boocock et al, 2008; Frank and Boocock, 2008). To further this Torres et al (1996) perceives Technology-Based Entrepreneurship courses to be based on the methodology of the "Business Assembly Engine" to promote creative and innovative thinking involving creative problem-solving techniques to emulate technology-based industries and the technology-driven business environment. Hamilton et al (2005, p. 239) have described their experiences on a technology-based entrepreneurship course with a course model to "spin-in" high technology product concepts into the environment of the university involving issues of intellectual property (IP), and the influence of the course on alumni in terms of entrepreneurship and business.

1.3 Technology-Based Entrepreneurship and Regional Development

With regard to regional development the concept of technology-based entrepreneurship is considered to be an important phenomena in terms of regional growth which involves new technology-based firms (NTBFs), spin-off processes, research and development (R&D) and technology development (Dahlstrand, 2007). In fact, technology-based entrepreneurship has become ever more important over recent decades and has an important role for economic growth and industrial renewal, especially with new technologies and fast growth knowledge based sectors. This is further supported by the OECD (2001) which has observed that not only is technology advancement important for growth and economic development but that industries which are technology intensive are increasingly significant for trade at an international level. The focus on technology-based entrepreneurship has consequently arisen from the importance of technology and entrepreneurship within this context (Dahlstrand, 2007). Interest and research into technology-based entrepreneurship originated in the United States of America (USA) and following this it has become important in Europe in the last twenty five years (Dahlstrand, 2007). This has been evidenced with the ever increasing number of NTBFs across the World (Keeble et al, 1998; Autio, 1997). Although these developments have taken place technology-based entrepreneurship has only been explored to a limited extent and consequently there is incomplete knowledge on its effect on economic development and growth (Dahlstrand, 2007). Therefore technology-based entrepreneurship can be considered to be a phenomenon that is regional (Venkataraman, 2004). Characteristics that are prevalent with NTBFs include that they tend to be established by entrepreneurs linked with higher education, there are teams of founders, they contribute to technology transfer, benefit from science parks and incubators, usually cluster in certain regions, have a need for internationalisation, and involve product development and growth potential (Dahlstrand, 2007).

With the regional perspective the requirement by businesses to source technology and innovations (Chesbrough, 2003) causes firms to join innovation networks and in these networks NTBFs who provide science based inputs are important. Very often “high tech” clusters will be created and these are important for NTBFs and can be influenced by personal contact networks and also dependence on externalities (Dahlstrand, 2007). Here the role of technology-based entrepreneurship is important in the transformation of the region (Venkataraman, 2004). According to Dahlstrand (2007) for a regional cluster to operate as a network there should be learning processes which are collective and there needs to be local interaction. Part of this local interaction involves staff mobility and recruitment, know-how and technological expertise and the diffusion of technological competences for collective learning between businesses and universities which have a crucial role for the renewal of regional technology (Dhalstrand and Jacobsson, 2003). The way in which universities contribute to technological change will vary according to the field of knowledge (Salter and Martin, 2001). Furthermore, the technological profile of a good university will affect regional technology-based entrepreneurship (Dhalstrand and Jacobsson, 2003). University spin-off companies will enhance learning processes and knowledge development through managerial and technological expertise being transferred within a region. Here technology-based entrepreneurship will require ‘talent’ and the production of talent (Cooke, 2005). Both human and technological resources will be required if technology-based enterprises are to become successful (Mustar, 2001; Clarysse et al, 2005).

1.4 Organisation of the Book

This book contains chapters concerning the academic field of technology-based entrepreneurship and considers technology transfer policy, diffusion of innovation into technology-based firms, technology clusters, university technology small firms, university business partnerships, university models of technology transfer offices and the growth of a technology concept (Figure 1.1).

Figure 1.1 Organisation of the Book

Chapter 2: Technology Transfer Policy

The aims of the opening chapter are to examine technology transfer policy and the technology-based firm (TBF) sector, especially the importance of external sources of inputs in the development of successful technological innovation within TBFs.

Chapter 3: Diffusion of Innovations into Technology-Based Firms

The objectives of the chapter are threefold: first, to investigate technology diffusion in the form of new or improved technology through formal and informal networks enabling learning by interacting; second, to develop a model of technology diffusion including external sources, channels of technology transfer, and mechanisms involved in the transfer of technology into the innovative TBF; and third, to relate the model to "best practice" and to note situations where "low activity" can be improved. Finally, the implications for policy relevant to technology and entrepreneurship arising from the model of technology diffusion are investigated and conclusions drawn.

Chapter 4: Technology Clusters

This chapter investigates the movement of labour in technology-based clusters. Labour mobility and knowledge spillovers in clusters are interrelated phenomena with knowledge embodied in entrepreneurs and specialised workers spilling over from one enterprise to another through labour mobility and direct revelation (Guarino and Tedeschi, 2006). The mobility rate of labour in clusters is considered with reference to the growth of the clusters. Through the study of the mobility of labour the value of intellectual capital (IC) in the cluster can be considered (Oliver and Porta, 2006).

Chapter 5: University Technology Small Firms

The chapter relates the formation and outcomes from university-based technology small firms (UTSFs) through examination of the genesis of Further and Higher Education spinout companies which add value to their existence by their owner-managers who network, share experiences and update knowledge in areas such as management, finance, marketing and selling. In this context universities are seen as crucial components by regional and national governments in developing and transferring knowledge to the commercial market place.

Chapter 6: University Business Collaboration

In this chapter the organisational aspects of university/business collaboration are considered followed by the investigation of the motivations for university/business relationships, the formation process, university/business inter-organisational relationships and conclusions concerning the management of university business collaboration.

Chapter 7: University Business Partnerships and Models of Technology Transfer Offices

This chapter compares business partnerships in different universities by considering a sample of six UK universities. Three models of university technology transfer offices (TTOs) are investigated which have different approaches to university business partnerships with industry. University TTOs/business development units are central to the exploitation of university business partnerships and they undertake many activities to bridge the academic industry divide including the creation of networks of industrial links.

Chapter 8: The Growth of a Technology Concept: A Case Study

The chapter considers the case study of the exponential growth of the Technium 'concept' on the Internet in relation to business incubation and support for new and existing enterprises in Wales. The Technium 'concept' was a new form of incubation developed in Wales which resulted in new participants entering the incubation industry (Thomas et al, 2004). This new wave of incubation can be related to regional dynamism (Gonzalez and Lucea, 2000, 2001) and the creation of new incubators. A simple calculation of the rate of increase in the posting of items on the Internet on the Technium concept has been made. This involved the net rate of multiplication (geometric rate of increase) over the period 2001 to 2005.

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2 Technology Transfer Policy

"A policy is a temporary creed liable to be changed, but while it holds good it has got to be pursued with apostolic zeal."

MAHATMA GANDHI (1869–1948)

This chapter at a glance

- Introduction
- Views of Policy Makers
- Technology Transfer Processes
- Discussion
- Conclusions: Policy Implications

2.1 Introduction

Recent studies into technology-based firms (TBFs) have considered innovation and the business ecosystem (RAE, 2012), the nature of growth (Brown and Richmond, 2012; Mason and Brown, 2012), and the role of technology in economic development (Coad and Reid, 2012). A further dimension for TBFs is technology transfer through external sources of technology. Due to the different levels of regional industrial development in Europe there are variations in the importance of external sources of technology to TBFs (Saxenian, 1991). This inequality is considered to be most prevalent within the peripheral or industrially declining regions of Europe, where low technological development can make access to knowledge, technology and human resources difficult. This will affect not only the development of firms in these regions, but also the efficiency and effectiveness of the regional innovation systems. Innovation policy, especially with regard to technology transfer into TBFs, must respond to these variations, and develop programmes and initiatives sensitive to the needs of TBFs within different European regions. In the past, European policies have promoted inter-firm collaboration and technological exchanges with regard to "far-from-market" collaboration (up to and including the pre-competitive stage). Nevertheless, this is better directed to the needs of large firms with dedicated research and development (R&D) functions rather than holistically managed TBFs. Moreover, small firms are often involved in strong "near-to-market" interactions, working on product or process development along the vertical supplier-manufacturer-customer chain. Many existing policies need to be adjusted to reflect the importance of vertical linkages and near-to-market interactions to respond to the formal, and informal, sources of technology accessed by small firms. For example, a review of Research and Technological Development (RTD) programmes (EC, 1995) reported that participants in transnational collaborative arrangements had problems working with small firms since they were too market-oriented. As a result there is a need to propagate and understand "best practice" for technology transfer amongst the different regions of Europe. This approach, according to the Action Plan for Innovation (EC, 1996), is important to small firms, since emulation amongst these firms enables them to compare themselves with the international leaders in their field and is an effective way of encouraging good practice.

According to EU policy, successful European countries in the twenty-first century will be those that embrace creativity and innovation linked to an integrated enterprise support infrastructure. By doing this it will be possible to respond to the barriers to growth on a regional basis (NAFW, 2003). In fact, the UK has 11 regions for the purposes of the EU benchmarking index (European Trend Chart on Innovation, 2003). Within the 34 countries, which make up the Index, the UK is amongst the top 4 alongside Germany and Sweden, with innovative regions above the country mean. This means that 25% or more of the UK's regions are performing at or above the EU competitiveness mean. Areas such as the Eastern region and the South East region (of the UK) are identified here and the criteria include new science and engineering (S&E) graduates, employment in high-tech services, business R&D, innovation expenditure and high-tech venture capital, for example.

2.2 Views of Policy Makers

The aims of the chapter are to examine innovation and entrepreneurship within the TBF sector, especially the importance of external sources of inputs in the development of successful technological innovation within TBFs. The research strategy aimed to use the most appropriate methodology to address the specific research questions. To test the proposition outlined in this chapter a semi-structured interview approach was adopted since it enabled policy makers' viewpoints to be "teased out" concerning the five main discussion areas of the research (Table 2.1). Eight interviews took place with key policy makers involving the use of an interview guide (King, 1994, Bryman, 1992). For this study a policy maker is defined as "someone who sets the plan pursued by a government or business" (WW, 2005) and as "individuals, especially those in official bodies, who have the authority to make decisions about what problems will be addressed within a particular sector and how these problems will be handled" (EEA, 2005). The justification of the approach was that the interviewees were identified as having knowledge of innovation processes and were in significant positions dealing with innovation policy in their organisations. The respondents were selected on the basis of the researcher's experience of liaising with organisational contacts regarding technological innovation and from contacting the relevant bodies to confirm the participation of the appropriate policy makers. The interviews lasted for approximately an hour and a five page report was transcribed following each interview. Building on earlier findings (Thomas, 2000) as a means of justification four primary areas and one secondary area were discussed during the interviews (summarised in Table 2.1).

Sequence	Discussion areas	Primary(1)/ Secondary(2) Questions	TBF (T), Regional Industry (R), National (N) Focus
A	External sources of inputs into the innovation process	1	T
B	Importance of external sources in the development of technological innovation within TBFs	1	T
C	Nature of relationships with external sources of innovation inputs	1	T
D	Different mechanisms of transferring inputs into the innovation process	1	T
E	Policy issues involved in the transfer of technology into TBFs	2	R, N

Table 2.1 Areas discussed during the interviews with key policy makers concerning technology transfer policy

The first column in Table 2.1 shows the sequence/order in which the five main topics of the interview were discussed according to the design of the research. The third column in the table shows whether the questions were of a primary nature of direct relevance to the study (relating to the external sources in the development of technological innovation within TBFs). Or whether they were of a secondary indirect nature (relating to policy issues involved in the transfer of technology into TBFs). The fourth column shows the focus of the interview sections whether concerning the TBF (external sources, relationships and mechanisms) or regional industry and national (policy issues).

The methodology described in this chapter involves two distinct stages for the policy study. Firstly, pertinent findings from detailed interviews that took place with key policy makers (although only eight interviews were undertaken these were with policy makers from a wide spectrum of organisations involved with technological innovation and TBFs including regional government, development agency, higher education funding council, TUC and universities) were analysed and secondly recommendations for the provision of future support for technological innovation for TBFs are made. Three of Storey's (2002) six steps for a policy study were utilised. With regard to step I concerning the take-up of schemes the criteria evidenced by the study shows that some TBFs had taken up schemes but others had not. For step II, opinions were obtained through interviews with policy makers. Regarding step III, views of the difference made by the assistance provided, these were reported at interviews. Since the study was concerned with monitoring aspects step IV (comparison of the performance of 'assisted' with 'typical' TBFs), step V (comparison with 'matched' TBFs) and step VI (taking account of selection bias), which would have formed an evaluation, were not undertaken since these were not appropriate to the study. Because the research involved a "supply side" policy study it can be seen to fall short of the more ambitious objectives of larger research projects which consider the particular contributions to economic development of government programmes in some detail.

2.3 Technology Transfer Processes

A. External Sources of Inputs into the Innovation Process

The external sources of inputs into TBFs include customers, suppliers, equipment, manufacturers, other firms (competitors), universities and foreign sources. These are in contradistinction to internal sources, which include technology development, adaptation, improvement and the use of internal R&D. Internal sources can be directly managed from within the TBF whereas external sources can only be indirectly managed since they involve influences, which may be beyond the control of the firm.

Results from the interviews showed that innovation networks provide TBFs with opportunities for networking and universities appear to be proactive in these networks through their Industrial Liaison Officers (ILOs). TBF innovative activity involves a wider embrace of relevant issues including knowledge transfer from the research side. This is central to the UK Government's policies involved with Technology Foresight (OST, 1997). Key inputs include financial resources and the problem of a lack of finance has been highlighted by venture capitalists (Evans, 1997).

It was reported that external sources can "motivate and excite" internal sources although they may not quickly affect innovative activity. These sources shape the development of innovation within TBFs and point to possible futures and provide companies with ideas. For example, a company can win a prize for a particular innovation, which influences how other companies perceive technology and innovation activity. This provides "reality" and is recognised by other companies of the same size and sector.

B. Importance of External Sources in the Development of Technological Innovation within TBFs

The different external sources in the development of technological innovation within TBFs appear to have varying degrees of importance. Studies (see Carter and Williams, 1957; Myers and Marquis, 1969; Achilladis, et al, 1971; Jayanthi, 1998) have for some time reported the importance of external sources in the development of the innovation process. These have focused on the source and types of knowledge and technology employed in the development process, neglecting the origins and nature of the relationships that link the sources and recipient of technological innovation. There has been little investigation of the more informal sources of technology, especially the process of transfer from the source to the TBF.

Results of this study indicate that it is important for there to be both an internal and external stimulus. An internal stimulus is stronger and more useful and through a culture of innovation a company can be more receptive to taking advantage of external sources. A question that needs to be answered is how to develop the culture of innovation. The results also show that external and internal sources of innovative activity are intrinsically linked. The policy makers considered that if a firm has an "innovative culture" it seeks external sources of opportunities for innovation. How the external and internal sources are developed in relation to each other depends on the TBF.

C. Nature of Relationships with External Sources of Innovation Inputs

TBFs can be involved in a number of relationships with external sources of innovation inputs. These depend on the source, the type of relationship, and the reason for the relationship. TBFs have different informal and formal relationships with suppliers, competitors and customers, which result in advantages (benefits) and disadvantages (costs). Different relationships include co-operative agreements, affiliations, alliances and partnerships, for example.

It was reported that the main sources of technology are informal networks, and as well as formal networking relationships they played a key role as a means for sourcing ideas and information during the development process. TBFs in these networks are less reticent to share their experiences since respect, trust, personal contact are more important in these networks than the media and technology transfer agencies. Informal as well as formal relationships play a key role as a means for sourcing ideas and information during the development process.

D. Different Mechanisms of Transferring Inputs into the Innovation Process

There are various mechanisms for transferring knowledge and technology into TBFs. These include patents/licences, publications, consultancy, meetings and conferences, joint ventures, the transfer of people, training and industrial/research services. Studies have argued that different mechanisms are important – some have argued that the re-deployment of people between the source and the recipient organisation is important (Langrish, et al, 1972; Von Hippel, 1988) whereas other studies have indicated the importance of personal contacts or formal literature (Utterback, 1971).

Whether the re-deployment of personnel between the source and the recipient is the most effective mechanism for technology transfer depends on the size of the TBF. For medium and larger TBFs the interchange of personnel who carry "know-how" and knowledge is likely to be recognised. The larger TBFs are more likely to be in the market for personnel with specific expertise. The smaller TBFs (with ten or less employees) are less likely to do this but will benefit more than the larger TBFs if they did and it is therefore dependent on the size of the company. The re-deployment of people between the source and the recipient involves personnel moving from one firm to another, the workings of the labour market, and the owner/manager of the TBF. In this case the TBF has to be receptive and the recruitment process sometimes has to be planned/sometimes unplanned. Trade journals are another important mechanism although there has to be a specific need for smaller firms and they generally do not feel that journals are an important source of information. This applies to smaller TBFs since they are fortuitous and they do not see these as a prime source. Mechanisms such as patents and franchising are less significant since few firms will be involved in licensing. Generally mechanisms include product champions, visiting a major trade show, customers who are a major source of technological innovation, trade publications and TBF owner/managers.

E. Policy Issues involved with TBFs

The European Commission has reported that the SME sector, including TBFs, may be vital to the future development and regeneration of Europe and it has been argued that they are making an important contribution to technological innovation within industries at regional, national and European level. European programmes are seen as a vehicle for technology transfer across industrial sectors to small companies and assistance has been provided in Framework Programmes. Support is also being provided at regional and national levels.

Interviews showed that policy is influencing the selection of existing innovation activities by identifying and addressing problems. European initiatives are also significant in terms of the innovation agenda and they raise the importance of technology as a key dimension of regional policy. With the enlargement of Europe and the accession countries there will probably be less funding available. Although EU initiatives are significant it was remarked that TBFs do not perceive them as being relevant since the genuine small business does not know how to access them.

2.4 Discussion

The policy makers reported that there should be a balance between external and internal sources in the development of innovation within TBFs. This involved the desire by TBFs to grow the business and to be prepared to take greater technological risks. There should also be the devolution of financial decision making to the regional level regarding the financing of technology including pump-priming investment in technology for TBFs. A positive climate was needed which could be created by policy makers involving support and advisory mechanisms including indigenous support. It was felt that there is a need for TBFs to develop a culture of innovation to be receptive to technological change and to work more closely with higher education institutions in order to benefit from research and development.

Regarding the nature of relationships with external sources of innovation inputs the policy makers answered that TBFs needed to be made aware of innovation services, develop better mechanisms and to forge relationships. This could be achieved by creating a culture in which this happens in a systematic way. TBFs also needed to be more open in relation to enhancing their learning powers.

With regard to the different mechanisms of transferring inputs into the innovation process policy makers considered that efforts should be made to set up methods for cascading technologies and undertaking new ventures. There needed to be stimulation in the implementation of innovative activities by TBFs being more receptive and thinking about innovation. Also creating a more positive environment for innovation and to define this should raise the innovative base of the economy. There should be policy action not only to identify industries but also to invest people, resources and money.

The policy makers interviewed considered that there were a number of policies that needed to be put in place. Firstly, there was the need to make TBFs aware of the technology gaps in the market by delivering awareness training. Secondly, to provide a modest subsidy to firms to enable them to have science and technology graduates. Thirdly, to enable firms to take on networking abroad more conscientiously in relevant industrial and technological areas to create a culture and environment for spontaneous activity. And finally, to rationalise the plethora of soft support provided.

2.5 Conclusions: Policy Implications

The chapter has considered the presumption that policy makers have a clear agenda as to what technological innovation and entrepreneurship mean. From the policy interviews it is clear that this may adversely affect the effectiveness of economic regeneration if the wrong agenda is followed. For these strategies to be more effective they need to be developed by improving access to innovation and technology support by making services demand led rather than supply led. There needs to be the devolution of financial decision making for the financing of technology. Policy makers should create a positive climate for support including indigenous support. Awareness training should be delivered for TBFs so that they are made aware of technology transfer services. The creation of an innovation culture can influence economic regeneration in a systematic way and methods can be set up to cascade technologies and undertake new ventures.

There are many services, both specific and general, available to the TBF community. The various sources of support need to be co-ordinated to perpetuate improvement in innovation within the TBF sector. Services need to be easily accessible, appropriate and delivery based. The providers should work together to develop provision in order to sustain improvement of technological innovation within the TBF sector. For services to benefit TBFs there is a need to build network relationships and to overcome the reluctance to access these services through innovation delivery mechanisms. The significance of the study, in terms of the policy, practical and managerial implications for universities and government, is that there is an opportunity to improve access to innovation and technology support provided by universities and government by making services demand led rather than supply led.

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3 Diffusion Of Innovations Into Technology-Based Firms

"Innovation is the specific instrument of entrepreneurship."

PETER DRUCKER (1909–2005)

This chapter at a glance

- Introduction
- Technology Diffusion
- Technology Transfer Networks
- A Model of Technology Diffusion
- "Best practice"
- Implications for Policy
- Conclusions

3.1 Introduction

Governments today regard technology diffusion as an important route to increased competitiveness, especially diffusion into Technology-Based Firms (TBFs) (La Rovere, 1998; Tran and Kocaoglu, 2009) with advantages of flexibility, dynamism and responsiveness. However, TBFs have disadvantages related to finite technological and financial resources which can lead not only to problems in their ability to source technology but also in their capability to absorb it into their organisation and diffuse it into their industrial sector (Jones-Evans, 1998).

The objectives of the chapter are threefold: first, to investigate technology diffusion (Brooksbank et al, 2001) in the form of new or improved technology through formal and informal networks enabling learning by interacting; second, to develop a model of technology diffusion including external sources, channels of technology transfer, and mechanisms involved in the transfer of technology into the innovative TBF; and third, to relate the model to "best practice" and to note situations where "low activity" can be improved. Finally, the implications for policy relevant to technology and entrepreneurship arising from the model of technology diffusion are investigated and conclusions drawn.

Since there is a time dimension involved in the study of the diffusion of technology into TBFs, similar to other investigations of innovation, theories based on these studies will tend to lag behind the "best" current practices. All models of technology diffusion, including refined models such as the Bass Norton model, are a simplification of reality (Islam and Meade, 1997) and, therefore, have a measured influence upon policy. One theoretical model that has informed policies is the Centre Periphery Model (Schon, 1971) which rests on three basic assumptions –

1) the technology to be diffused exists prior to its diffusion,
2) technology diffusion takes place from the source outwards to TBFs, and
3) the support of technology diffusion involves incentives, provision of resources and training.

This model is shown in Figure 3.1.

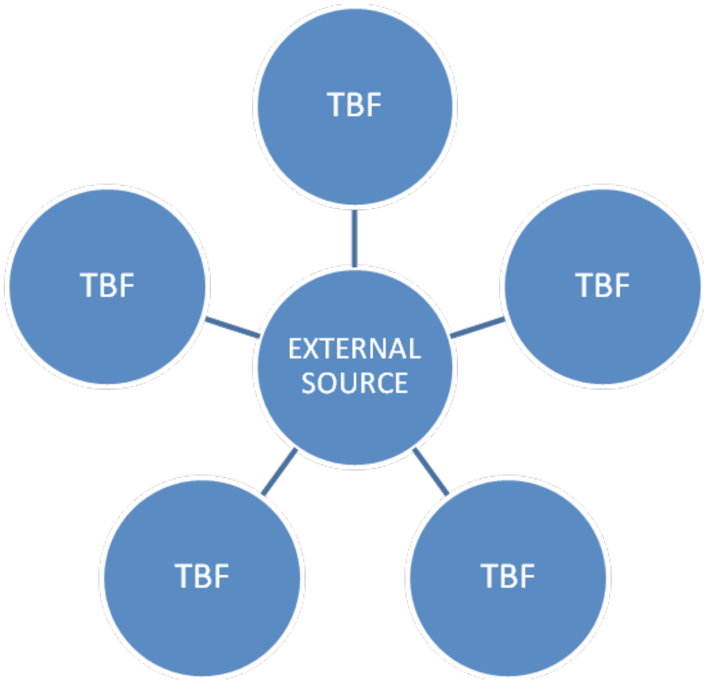

Figure 3.1 Centre-Periphery Model

By applying the Centre-Periphery Model to Technology Transfer Network Theory it is possible to construct what can be described as the "Hub and spoke" or "Star" network. This is a simple construct that can be used as a building block for more intricate networks. Diffusion will take place from the source of the technology through channels by a "diffuser", using a transfer mechanism, to the TBF. The effectiveness of the system will depend upon the resources available to the external source to enable the transfer, the efficiency of the diffuser and the mechanism involved, and the ability of the TBF to acquire technology. The scope of the system will vary directly with the level of technology and the flow of information.

3.2 Technology Diffusion

When a new technique has been adopted the speed at which other TBFs adopt may differ widely. This leads to what can be called the rate of diffusion (imitation). The rate of diffusion will be faster, the greater the improvement over existing technology and, the lower the cost of the technology in general (Roy and Cross, 1975). Using the definition of Bradley, et al, (Bradley, McErlean and Kirke, 1995) technology diffusion can be defined as the spread of a new technique from one TBF to another (`inter-firm diffusion') (Stoneman and Karshenas, 1993). The two principal types of technology diffusion are "disembodied" diffusion (the transmission of knowledge and technical expertise) and "embodied" diffusion (the introduction into production processes of machinery, equipment and components incorporating new technology) (Papaconstantinou, Sakurai and Wyckoff, 1995). Research spillovers are the means by which new knowledge or technology developed by one firm become potentially available to others and the absorptive capacity of the receiving firms will determine the extent to which the technology is incorporated.

The time pattern of adoption and the speed at which it takes place are distinct happenings. The exploration time period when implementing an innovation can provide imitators with a "window of opportunity" to proliferate (Jayanthi, 1998). Empirical studies suggest that the adoption of a new technology follows a bell-shaped, or normal, distribution curve (Norris and Vaizey, 1973). By plotting cumulatively this shows the number of TBFs who have adopted a new technology in any given year, and the distribution will give an `S'- shaped curve. (It was Gabriel Tarde who in the Laws of Imitations, 1903, proposed that adoptions plotted against time assume a normal distribution, or if plotted cumulatively assume the `S'-shaped curve.) (Baker, 1976; Pijpers et al, 2002; UoT, 2004) An `S'-shaped distribution, not necessarily derived from a normal distribution, shows the spread of most new technology. There are two general reasons for the occurrence of this distribution.

(i) The diffusion process for TBFs is a learning process.

TBFs who are potential users have to become aware of the technology and then attempt to evaluate it. Consequently they may use the technology on a trial basis. The learning process takes place at this stage. Information about the technology has to be disseminated, and as it is adopted by other TBFs, or by the TBF on an experimental basis the information becomes more reliable. The importance of accumulated knowledge and expertise is an important factor determining whether firms are likely to adopt new technology or to act as sources of innovation (Gurisatti, Soli and Tattara, 1997). `Bugs' will be overcome, which will in turn reduce the risk of adopting the technology. The concept of the individual TBF learning curve can be extended to a network group of TBFs where experience with a new technology increases as each successive TBF adopts the new technology. As a result, the distribution of TBFs adopting a technology might be expected to yield a normal curve.

(ii) An interaction effect occurs for TBFs.

When only a small number of TBFs have adopted a technology, there are a small number of diffusers who can generate information on the technology and from whom the technological idea can spread. Diffusion rates at this point are low. When the number of TBFs using the technology increases the "information base" broadens and because there is still a considerable number of TBFs who have not adopted the new technology the rate of diffusion increases. When there is a large proportion of TBFs using the technology the number of potential TBFs still remaining becomes small. The remaining TBFs will be resistant to change and there will be a slow down in the cumulative number of TBFs using the new technology. This will yield an `S'-shaped curve. The first formal study of diffusion was the spread of hybrid corn (Grilliches, 1960). The adoption rate in different states in the USA was studied and it was found that there were significant differences between states in the rate of hybrid corn adoption. Logistic growth curves were fitted by Grilliches to his data and the parameters found from the curves for the different states showed wide variations.

Another formal study of the rate of diffusion was carried out by Mansfield who studied the rate of diffusion of twelve innovations in four industries – coal, iron and steel, brewing and rail (Mansfield, 1961, 1968). Although small firms were not included in the analysis, for medium-sized and large firms in most cases, the spread of innovations over time approximated the `S'-shaped curve. According to Mansfield the spread of innovations is best described by a logistic curve.

Despite the shape of the curve for technology diffusion appearing `S'-shaped, there will be differences in the speed at which technology is diffused and the length of the diffusion process. Both within and between industries there will be considerable variations in the rate of the diffusion of technology between TBFs.

Important factors which appear to affect the rate of diffusion (speed at which a new technology is accepted) are the characteristics of the TBF and the characteristics of the technology itself. Early work on the categories of adopters found that further to adoption following a normal distribution curve the distribution could be used to show the categories of adopters (Rogers, 1962). Table 3.1 shows the categories of adopters with the majority of adopters lying between the mean and the mean minus/plus the standard deviation on the normal distribution curve.

Table 3.1
The Categories of Adopters

Categories	Innovators	Early Adopters	Early Majority	Late Majority	Laggards
Number of Adopters	2.5%	13.5%	34%	34%	16%
	x – 2σ	x – σ	x	x + σ	

Years

The categories of adopters can be described as follows:

Innovative TBFs are those who want to explore new technologies. They will have relationships with other TBFs in their network, and with suppliers and customers.

Early adopters will be TBFs who will adopt new technology if it is to their advantage. Since they will act as 'opinion leaders' their influence will be greater than innovative TBFs.

The *early majority* will be intentional while the *late majority* will be sceptical and will adopt when the technology has diffused.

Last, the *laggards* will be so late adopting a new technology that it will have been superseded.

The categories of adopters show that TBFs which adopt an innovation independently are innovators (Tassopoulos and Papachroni, 1998). Early research studies aimed at defining the characteristics of adopters found that early adopters relied to a greater extent on impersonal sources of information from wider and more sources (Rogers, 1962). They used sources in close contact with the origin of new ideas including technical journals. TBFs that are early adopters will tend to be “technically progressive” and will be close to the best that can be achieved in the practice of applying technology (Carter and Williams, 1957). On this assumption a progressive TBF will take a wide range of authoritative technical journals, will have a variety of contacts with sources of technology including similar TBFs, and will assess ideas from these sources. It is expected that communication within the TBF will be well organised and co-ordinated and there will be a willingness to share knowledge with other TBFs in its network. A progressive TBF will set its standards by reference to best practice in other TBFs.

The speed of diffusion will also be faster the greater the awareness of TBFs to the advantages of adopting a new technology. The process of communication will be important here as well as the ability of TBFs to assess the merits of the technological advance. A TBF is more likely to adopt a new technology as it diffuses due to being under increasing competitive pressure to do so, through the technology becoming more attractive, and as a result of information about the technology being broadcast from an increasing base (Green and Morphet, 1975).

3.3 Technology Transfer Networks

Technology transfer networks are of particular importance to TBFs with finite in-house resources to explore the potential of new technologies. Two basic mechanisms available to TBFs are technology exchange (technology passed from one TBF to another) and technology exploitation (technology transferred to a TBF from an external source).

Technology transfer networks enable TBFs to reach a common understanding regarding new technologies quickly. Important aspects of TBF technology transfer networks are the type and size of the network. Whereas, small networks appear more efficient, since communications are easy and network dynamics controllable, large networks benefit from a greater pool of resources. There are four principal types of networks. The "star" network has already been reported. A "nodal linkage" network involves TBFs on an equal footing and is not suitable for those businesses with different levels of experience. "Ad hoc" or "informal" networks are those without a formal structure where TBFs intimately know each other concentrating communication where required. These tend to be mature networks, but are not well suited for heterogeneous groupings, or those with little commonality between TBFs. "Regional" networks are the most complex type consisting of multi-tiered structures linking local networks. These are suitable for heterogeneous TBFs. The descriptions of these four types of network are exemplars in their purist form. Networks adapt to changing internal and external factors and evolve from one (centre-periphery) to another (multi-tiered). Although co-operation with other technology transfer networks provides the possibility of accessing a wider contact base it carries with it some competitive risk.

3.4 A Model of Technology Diffusion

A model of the diffusion of technology into TBFs can be described as innovation (supply) from the source of technology (origins) and diffusion (demand) to the TBF (destination). The model can be expressed concisely in algebraic form:

Origins	$i = 1, 2, \ldots m$
Destinations	$j = 1, 2, \ldots n$
Supply at each origin	a_i
Demand at each destination	b_j
Constraint; supply = demand	$\sum a_i = \sum b_j$

In order to find a solution we must specify the variable x_{ij} as the unit(s) of technology transferred from origin i to destination j over time t.

All supply $\sum_j x_{ij} = a_i \qquad j = 1, 2 \ldots n$

All demand $\sum_{i} x_{ij} = b_j$ i = 1, 2 … m

The diffusion of technology D can be expressed:

$$D = \left[\sum_{i=1}^{m} \sum_{j=1}^{n}\right] x_{ij}$$

where i = 1, 2, … m and j = 1, 2, … n

The rate of diffusion of a new technology to TBFs can be likened to waves of adoption involving distinct time packages.

The rate of diffusion (R) can be calculated according to time (t) (number of years) as follows:

$$R = \frac{\left[\sum_{i=1}^{m} \sum_{j=1}^{n}\right] x_{ij}}{t}$$

where i = 1, 2, … m and j = 1, 2, … n

This equation is a temporal model (Thomas et al, 2001) of technology diffusion which measures the speeds of diffusion (or rates of technology transfer) (Bradley, McErlean, Kirke, 1995).

Technology transfer is an active process whereby technology is carried across the border of two or more social entities (the external source and the TBF), and technology transfer channels are the link between the entities (in which various technology transfer mechanisms are activated) (Autio and Laamanen, 1995). A technology transfer mechanism is defined as any specific form of interaction between entities during which technology is transferred (Autio and Laamanen, 1995). The ability to establish external linkages is of critical importance to TBFs and a critical mass of TBF users will spread the usage and acceptance of the technology (Jain, 1997). The success or uptake of technology depends on how successful the performed community of (implied or ideal) users match the characteristics of actual users (Woolgar, Vaux, Gomes, Ezingeard and Grieve, 1998). Success can be achieved by "configuring the user". Further to this Malecki has stated that "as new technology and products are learned, acquired, evaluated, and improved upon, a firm or region comes to know about best-practice technology…" (Malecki, 1991, p. 122). Laranja calls these "cumulative processes of learning" (Laranja, 1994, p. 173).

3.5 "Best practice"

Technology transfer networks are one of the best forums for TBFs to learn from each other, to exchange experiences, and to diffuse technology. The typical areas where the benefits of "best practice" can be found are technology transfer skills (determining a TBFs' needs by auditing and drawing-up agreements and contracts), technological expertise and know-how (including standards and regulatory issues), service provision (assembling the provision of services), and management and organisation (public relations) (Commission of the European Communities, 1998).

Networks are usually segmented by geographical region, industry sector or by technology and they can work with a mixed sector-technology focus. The danger with specialisation is that it carries the disadvantage that eventually the potential market will be exhausted. It is possible to overcome this by anticipating and looking for opportunities in complementary technology areas.

"Best practice" procedures for the diffusion of technology within networks usually include minimum standards for the TBFs, external funding apportionment, expected performance, and confidentiality. Procedures will usually become less formal over time due to ideal size attainment and growth realisation. Good practice for the successful operation of a network is the realisation by TBFs that it is not only an alliance of enterprises but also a partnership of entrepreneurs. (Entrepreneurs will act as technological gatekeepers and will have an important role to play in the operation of networks.) (Thomas, 1999) This needs to be reflected in network communications and good relationships between the TBFs will form the basis of good practice for the operation of the network.

Success in the diffusion of technology within networks is often the result of TBFs following "best practice" and this usually involves performance management. This is not easy to attain since the process of technology transfer can be long and without success, the results of the network are difficult to define and there may be discrepancies between the TBFs. "Low" activity may arise due to conflicts in a network. When these are efficiently managed and resolved they provide opportunities for the TBFs to broaden their experience and widen their understanding of other TBFs' views. When they are not conflict may lead to "low" activity. Conflict management and identification will form part of the "best practice" of successful technology diffusion. Typical examples of "low" activity are misunderstanding between TBFs, different objectives and motives and under-performance of a TBF.

3.6 Implications for Policy

The implications for policy of a model of the diffusion of technology into TBFs, and the technology processes involved, necessitates the need to formulate technology transfer related action. This includes raising TBFs' awareness of the potential of technology transfer to help solve problems and the existence of networks to provide practical support. Once TBFs comprehend the possible benefits of technology transfer they will need more help to realise the benefits. Two further types of action to achieve this are specific support provided to individual TBFs (assistance during the establishment of network relationships) and technology transfer support to TBFs in general (to foster technological knowledge and establish network links from external sources such as universities and research providers for the dissemination of know-how into TBFs).

Coupled to the three forms of policy action described above the three main types of external sources involved in the diffusion of technology to TBFs are public and non-profit organisations (regional and national development organisations (RDOs/NDOs), regional technology advice centres (RTACS) and chambers of commerce), private consultants (technology brokers, management consultants, patent attorneys), and Research and Technology Organisations (RTOs) (contract research firms, science parks and technology centres). Technology transfer networks may comprise all three types although homogeneous networks are usually easier to form and develop. Amongst the three types public bodies are best placed to undertake policy programmes, private companies concentrate on providing focused assistance and RTOs provide technology knowledge and know-how. For TBFs involved in technology transfer networks key mechanisms include information transfer (newsletters and databases), technology transfer (R&D audits), skills transfer (training) and specialist support (financial guidance). Value for money of the mechanisms will be a key policy measure. There will need to be care that changes in policy will not make a TBF withdraw from technology transfer activities and that policy reacts to difficult situations by providing TBFs with incentives.

3.7 Conclusions

Although the variables involved in the model appear to be the most important influences on technology diffusion into TBFs there will also be a multiplicity of influences that accelerate or alleviate the rate of diffusion. This spectrum of influences on diffusion rates broadens when considering technology transfer among the various different TBFs in multi-tiered networks. An extension of the hypothetical example of diffusion is the diffusion of technology into TBFs through multi-tiered networks. In these TBFs' sociological forces will have an important role to play. The rate of adoption of a new technology will be faster if it is compatible with the previous experience and present normative values of TBFs. Other influences on the speed of diffusion include the complexity of the new technology and random influences.

The model illustrates that the successful diffusion of a new technology involves considerably more than technical competence. Many complementary factors will be prominent and a TBF may be retarded in its acquisition of technology by other firms who are slow to adopt. `Laggards' can have a deleterious effect on the diffusion of technology by other TBFs. The rapid diffusion of a technology will be facilitated by a willingness of TBFs to make adjustments.

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4 Technology Clusters

"The new industries are brainy industries and so-called knowledge workers tend to like to be near other people who are the same."

EVAN DAVIS (1962–)

Chapter contents:

- Introduction
- Clusters and Knowledge Flows
- Mobility within clusters
- Conclusions

4.1 Introduction

Sticky knowledge (Lagendijk, 2000, p. 165) or knowledge accumulations (Florida, 2002; Storper and Venables, 2002), according to Oliver and Porta (2006), constitute the available intellectual capital (IC) sources of a cluster. Sticky knowledge is described as the knowledge embedded in the local industrial milieu which is difficult to copy or transfer to other areas (Oliver and Porta, 2006). Furthermore, sharing knowledge involves firms with a community of workers in a cluster (Harrison, 1991). IC arises from knowledge creation through linkages between firms (knowledge spillovers), firms and institutions, and informal relationships arising from an interaction process in a local skilled labour pool. Knowledge in the cluster is tacit, embedded and transferred within the cluster (Oliver and Porta, 2006).

For the transfer of knowledge within a cluster three mechanisms identified by Keeble and Wilkinson (1999) include new firms, spin-offs from firms, universities and public sector research laboratories, interactions between the makers and users of capital equipment, interactions between customers and suppliers, and inter-firm mobility of the labour in the cluster. The relationships and mechanisms create flows within the cluster and the knowledge transfer processes result in cumulative know-how that is external to firms remaining internal to the cluster (Oliver and Porta, 2006). Empirical evidence has shown how knowledge sustainability (expenditure on education), regional economic outputs (earnings and labour productivity), knowledge capital (patents and R&D) and human capital (high tech employment) components have influenced regional competitiveness (Porter, 1990). Economic productive activities are enabled by tacit knowledge, the contribution of local businesses and infrastructures such as research institutes and universities, by employee exchange and the mobilisation of human capital resources (Oliver and Porta, 2006). According to the resource-based view of the firm (Penrose, 1959; Peteraf, 1993) the competitive advantage of companies arises from the core competences or knowledge of firms.

The community of people is an important element of a cluster (Harrison, 1991). Indeed, Porter's (1990) model included the skilled labour pool involving territorial human resources specialisation in clusters. Representing a cluster resource, the skilled labour pool is available to cluster firms (people educated on specific cluster university courses and trained through educational programmes in cluster requirements) (Oliver and Porta, 2006). In addition to training and education there are the social capital aspects associated with tacit knowledge and information flows attributable to directors, managers and workers in cluster companies (Uzzi, 1996). It has been reported by Dahl and Pedersen (2004) that in clusters knowledge flows take place through informal contacts. The local labour pool will contain the available pool of entrepreneurship, competences, education and traditional crafts (Oliver and Porta, 2006). But absorptive capacity is needed to capture, use and disseminate knowledge within the cluster (Zahra and George, 2002).

The movement of labour in technology-based clusters is investigated in this chapter. Labour mobility and knowledge spillovers in clusters are interrelated phenomena with knowledge embodied in entrepreneurs and specialised workers spilling over from one enterprise to another through labour mobility and direct revelation (Guarino and Tedeschi, 2006). The mobility rate of labour in clusters is considered with reference to the growth of clusters. Through the study of the mobility of labour the value of intellectual capital (IC) in the cluster can be considered (Oliver and Porta, 2006).

4.2 Clusters and Knowledge Flows

How embedded knowledge flows through labour mobility in regional clusters in Denmark was investigated by Dahl (2002, p. 3) who defined a cluster as "a geographically concentrated group of firms active in similar or closely connected technologies and industries with a degree of both horizontal and vertical linkages". He goes on to note that firms are inter-connected through the formation of a local labour market and that this is for a particular kind of labour. Furthermore, with regard to knowledge clusters and the specialisation of technological and economic activities resulting from agglomeration economies, the local labour force is specialised (Marshall, 1890; Piore and Sable, 1984; Krugman 1991(a); (b); Arthur, 1994; Saxenian, 1994; Porter 1998). In the area of the market suited to the companies in the cluster the growth of the cluster creates an increased demand for labour (Dahl, 2002). Feldman (2000) notes that job moves by workers between companies in an industry is influenced by ideas that are embedded in individuals' minds. Such moves allow the accumulated knowledge of the workers during their careers with companies to be taken advantage of by employers. As a result knowledge flows through the movement of workers between companies, and when start ups offer jobs (Dahl, 2002).

Accumulated experiences from parent companies allows start ups to have knowledge diffusion which has been shown to be important in a number of industries (Franco and Filson, 2000; Klepper, 2002). Reasons why workers move within a cluster include existing social ties and risk aversion (Breschi and Lissoni, 2001). Similar companies in a cluster offer workers wider employment prospects and companies will pay higher salaries for needed knowledge from a previous employee of a similar company. The social and institutional context is important (Breshi and Lissoni, 2001). Employee mobility needs to be supported by the innovation culture involving not only the company but the community (Angel, 1991). Knowledge flows between companies will be greater where the culture and institutional setting of the cluster promote mobility (Dahl, 2002).

In order to climb the occupational ladder through job mobility requires a change of employer. Hall and Kasten (1976) show that for most job changes there is a move to a higher occupational category involving higher pay. The work of Saxenian (1990; 1994) includes many examples of mobility and inter-firm knowledge flows. But there is only indirect evidence on the link between employee mobility and knowledge flows from the literature (Rosenkopf and Almeida, 2001). One of the first empirical studies to delve further into knowledge spillovers was Zucker and Darby (1996) who found that workers had the skills and knowledge for technological development through the embodiment of ideas. In biotechnology case studies the star scientists (who had made major breakthroughs) drew on their intellectual capital in the innovation process. The knowledge on breakthrough techniques was held by these scientists.

It was found by Zucker, Darby and Brewer (1998) that there were clear linkages between the start-up of biotech firms and star scientists. Further investigation of these aspects was undertaken by Alemeida and Kogut (1997) who used patent data to track the inter-firm moves of the star engineering scientists to trace knowledge and idea diffusion in the semiconductor industry and showed that inter firm mobility enabled the transfer of ideas between companies with subsequent new patents through the star scientists. Franco and Filson (2000) focused on the mobility of employees creating spin offs which diffused knowledge. Patent citation analysis of the semiconductor industry was used by Rosenkopf and Almeida (2001) to study the way in which the search for new knowledge in companies through mobility and alliances was undertaken. They found clear evidence that companies used mobility to fill holes in knowledge (Rosenkopf and Almeida, 2001) which clearly supports inter firm mobility of workers facilitating inter company knowledge flow.

In the latter period of cluster development it was reported by Dahl (2002) that there was entry by multinational firms. Lorenzen and Mahnke (2002) found acquisition of small firms by multinationals resulting in the local business environment changing. It was also found that social networking was discouraged by multinationals which focused on inter company networks (Lorenzen and Mahnke, 2002). This resulted in knowledge diffusion through networks and co-operation decreasing and knowledge diffusion through worker movement subsiding (Dahl, 2002).

Dahl (2002) noted that there can be mobile and non mobile engineers. It was found that mobile engineers were paid more for their acquisition of knowledge and in job learning than non mobile employees. New companies paid them more than they earned at previous companies because of the knowledge they brought. It has also been found that there is a positive impact of education since a longer education increases the ability to learn and absorb knowledge (Dahl, 2002). Furthermore, mobility appears to have a positive effect on earnings growth. Whether an employee has a degree, masters or PhD affects annual earnings (Dahl, 2002).

4.3 Mobility within clusters

The mobility of highly qualified labour in a cluster is an important vehicle for knowledge flow and indicators of the movement that takes place can help the investigation of important linkages. Mobility indicators can be used to determine the effects of the movement of labour on the development of the cluster. A parameter that can be used as an indicator of the potential in a knowledge based cluster is the stock of knowledge and the rate of mobility of labour can be used to indicate innovation potential. Information investigated includes gender, age, education and employment at a particular time and can be used to compare the stock of labour with different types of education across a cluster and describe the flow of labour between companies within the cluster. Higher education institutions (HEIs) and research institutes play an important role in the education and development of the workforce within a cluster. The mobility of highly educated labour is probably the most apparent mechanism of knowledge transfer. Mobility may take place without knowledge transfer and similarly knowledge transfer can take place without the mobility of labour. For example, information and communication technology (ICT) enables knowledge transfer without the physical movement of labour. In addition to the mobility of labour other knowledge transfer mechanisms include buyer-supplier relationships, co-operations, networks, R&D collaborations, staff placements and temporary staff exchange. Further indicators are the number of co-operations and external contacts, joint patents and citations and co-authorships. There is particular interest in the importance of senior labour as a vehicle for knowledge transfer. It has been found that PhD mobility appears to be a weak knowledge transfer mechanism (Stenberg et al, 1996).

The mobility of senior labour between companies indicates the basic assumption of knowledge transfer. This depends on the ability and opportunity of the labour to learn from the company in which they are employed and on their education and time in employment which are variables that are available for analysis. Also, the occupation and position of senior labour within an organisation influences their learning. Mobility can be considered to be a change of workplace, organisation or company. Knowledge exists in a number of forms including codified knowledge, competencies, formal knowledge, skills and tacit knowledge. The indicator that has been taken to denote the level of knowledge has been formal education. Formal education has advantages over indicators of other forms of knowledge which have data that are difficult to collect and collate. Although the highest level of formal education achieved has limitations as a knowledge indicator it is the most appropriate available. Senior staff will tend to be highly educated (including those with research degrees) with a high degree of specialisation. Here indicators of formal knowledge should be an acceptable knowledge indicator.

Mobility of senior staff will involve both permanent employment and the temporary exchange of labour. There will also be higher and lower mobility exhibited by companies involving both 'movers' and 'stayers' (Graversen et al, 2002). Mobility will arise due to takeovers and acquisitions and it will also result from the entry and exit of companies into a cluster and where firms go out of business or are restructured they will change their identity. This impacts on the definition of mobility in terms of what is 'real' mobility and what is 'artificial' or 'false' mobility caused by change of company ownership in the cluster. As well as change in employment as a focus for knowledge transfer, involving labour transferring knowledge from their previous to their current workplace, there is also the turnover of labour in firms arising from employees leaving and retiring resulting in the employment of new staff from other companies, the unemployed or recent graduates. These employees will contribute to the renewal and flow of knowledge through new knowledge being brought into the company.

The senior labour's field with formal education will be of interest due to potential innovation power – this assumes that labour with high education have a higher level of innovative knowledge than those with intermediate or low education levels. The exchange of labour not only brings new knowledge into companies but also results in the loss of knowledge and the right balance is a major challenge for human resource departments in companies.

It is apparent for companies that 'job to job' mobility involves 'in flows' and 'out flows'. Those workers who have accumulated experience for one company may be viewed as valuable labour for another and will be considered to be experienced workers. If they change employers frequently they can be considered to be 'experienced nomads' (Graversen et al, 2002). On the other hand, inexperienced workers who have a tendency to move are 'inexperienced nomads' and will be recently educated seeking appropriate employment (Graversen et al, 2002). The loss of experienced workers will be considered to be more serious than the loss of those recently employed. Furthermore, senior labour that stays with the same employer will be considered to be stable workers. It has been found that the share of stable workers increases with age and the share of mobile workers decreases with age (Graversen et al, 2002).

4.4 Conclusions

With a local technology cluster a local production network exists around companies. An extensive knowledge network will be built around the firms facilitated by senior staff movement between them. Competition within the group is intense and formal collaboration rare, and international concerns and relationships are of importance resulting in well developed global production facilities, suppliers, customers, partners and competitors, and contradictions exist between perceptions of members and the reality of linkages within the cluster. A cluster may be local to a region but part of a wider international industry cluster with simultaneous importance of local cluster effects and extensive international links. In the early days of a local technology cluster, most firms may be associated with a particular technology, but as the industry matures all of the major players can employ a range of technologies in their products. As a consequence of maturity the focus shifts from technical development to marketing and distribution of the product.

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5 University Technology Small Firms

> *"What we become depends on what we read after all the professors have finished with us."*
>
> THOMAS CARLYLE (1795–1881)

Chapter contents:

- Introduction
- Factors Influencing University Technology Small Firms
- Conceptualising University Technology Small Firms
- Conclusions

5.1 Introduction

This chapter relates the formation and outcomes from university-based technology small firms (UTSFs) through examination of the genesis of Further and Higher Education spinout companies which add value to their existence by their owner-managers who network, share experiences and update knowledge in areas such as management, finance, marketing and selling. Universities are seen as crucial components by regional and national governments in developing and transferring knowledge to the commercial market place. As a result, there is increasing evidence that the university sector can undertake a variety of roles in developing the technological and industrial potential of a region. These can range from the transfer of technology to smaller firms to the development of a technologically skilled workforce that can attract inward investing multinationals. However, the European Commission has recognised that one of the more direct ways of developing a technological base from academia is through the creation of new firms from the university sector. This is not surprising, as higher educational institutions contain a high proportion of scientifically sophisticated individuals within regions who have the ability to generate innovative ideas and technological knowledge which can be channelled and diffused by new ventures established by academics or students from a university department. As Downes and Eadie (1998) have demonstrated, UTSFs have been recognised as one of the primary routes to the commercial exploitation of university research. Supporting the creation and development of UTSFs through networks can yield medium to long term returns for the dynamism and competitiveness of the local economy (although this process is not an automatic or natural consequence of the existence within a region of a strong university base).

For many regions, the current industrial base consists of manufacturing plants established by inward investors, and small and medium-sized indigenous companies. The multinationals tend not to undertake research or development activity, and their R&D decision-makers are located elsewhere. In addition, many small firms do not undertake research activities, which can lead to a low incidence of industrial R&D. As a consequence UTSFs can make an important contribution to the indigenous company base, increasing the levels of R&D activity in a region, as well as the number of technologically skilled workers. Various regions of Europe have successful networks of UTSFs, usually based on technologies developed within universities. There is an important role for universities to play to support economic growth and development within their local economies, particularly through encouraging networking activities.

Many university-industry linkages in the UK, Europe and globally are focusing on UTSFs to help generate industrial growth. This calls for academic entrepreneurship applicable to the range of institutional and regional settings to overcome the barriers to success. In many cases, universities, usually supported by regional and national government, are adopting a direct entrepreneurial role in supporting these new ventures (Kinsella and McBrierty, 1997). There is therefore a strong potential for developing UTSFs if the right policies are instigated. In particular, given the current circumstances, there is a need for a radical approach involving strong drivers to support UTSFs in a region to keep pace with higher education activities in other regions of the UK and Europe, for example.

5.2 Factors influencing University Technology Small Firms

A number of factors will influence the ability to establish and develop UTSFs. Some of these arise from the priorities and views of university researchers and the characteristics of academic culture. Others are from the wider business environment and the ability of the academic-industry infrastructure to promote and support the development of UTSFs. Important factors will include the business background, skills, relevant experience and access to finance, of the founders/co-founders of the UTSF and the research intensities of universities.

The main purpose of this chapter is to focus on the specific needs of UTSFs making a case for their particular contribution to an economy, and why their needs may not be provided for at the present time. Related to this the chapter considers the economic development potential of UTSFs which has been given insufficient attention and notes the contribution of UTSFs, the lack of support and lack of policy towards them.

The methodology described in the chapter involved interviews with owner/managers of UTSFs. Pertinent findings from detailed interviews that took place with a wide spectrum of university-based technology small firms are reported. These ranged in age from over forty to under one year of existence and were based off and on-campus. They were mainly formed by academics wishing to commercialise their own research, although for most of the larger firms the current 'manager' tended to be a non-academic. The experiences and in many cases grievances of the owner-managers towards their own academic institution and in more general terms towards the 'business support' sector are also considered.

5.3 Conceptualising University Technology Small Firms

The last two decades have witnessed a growing enthusiasm for entrepreneurs as catalysts for economic development and change, with increasing attention paid to the role of small technology-based companies as contributors to wealth creation, technological innovation and employment in high technology industries (Autio, 1997; Jones-Evans and Klofsten, 1997; Jones-Evans and Westhead, 1996). As a result, there has been considerable academic and policy interest in examining the process of entrepreneurship within such organisations. Early studies identified the research-based academic environment – universities, non-profit research institutes and government research centres (Schrage, 1965; Roberts and Wainer, 1966; Wainer and Rubin, 1969; Cooper, 1971).

UTSFs have played a major role in the development of specific industries. The growth of the biotechnology industry is linked directly to the development of small firms set up by academic researchers who transferred basic research activities into innovations (Dodgson, 1993). During the 1970s, the biotechnology industry influenced universities to give more attention to control over intellectual property by their researchers and professors (Kennedy, 1986). Financing institutions, especially venture capital companies, became interested in academic research, and this led to a shift in the boundaries between non-commercial basic research and commercial research (Mansfield, 1991, 1995). As suggested by Rosenberg and Nelson (1994), commercialisation was possible, since funding in the biomedical field had created a reservoir of knowledge from which the biotechnology industry developed new products. In the 1970s, participation by universities in commercialising biotechnology research not only led to new knowledge but also academics starting their own enterprises by maintaining or leaving their academic tenure. As a consequence UTSFs play a central role in the growth of new industrial sectors and the innovation process. It must also be remembered that there are new sectors where universities play no role – the 'new coffee shops' are an example.

UTSFs have their roots in university research through at least one of the founders working in an academic research establishment before inception of a firm (Jones-Evans et al, 1998). These enterprises are established to commercialise a product or service developed in a university. They usually occur when a new enterprise is formed by university scientists seeking to develop further the commercial possibilities of their research (Garvin, 1983). In one of the first studies of small technology-based businesses, Schrage (1965) considered the establishment of new ventures by scientists emerging from their organisations. Since then most studies have related the development of UTSFs to two main criteria. First of all, the business must be related to technology developed at the university and secondly, the founder must be a former employee or student of the university who has worked on developing that technology. For example, Cooper (1971) defined high technology small firms as those that have their roots in a research organisation i.e. at least one of the founders worked in a research establishment before starting the firm and was established to commercialise a product developed in a research organisation.

Olofsson and Wahlbin (1984) defined a university technology small firm as having at least one founder employed at the university when the company was formed and a business idea which is aimed at commercialising knowledge and technology developed at the university. A wider definitional approach by Giannisis et al (1991) considers three types of UTSF models, which are, based on the origins of the business itself. The first – the entrepreneurial model – is a new firm which has been established as a result of a combination of the expertise and independent motivation that the entrepreneurial faculty member has brought to the commercialisation process. The second type – the traditional model – is where the commercialisation of a university-based technology is pursued by an outside business entity. Finally – the institutional model – is where the university through an organisation such as the Industrial Liaison Office (ILO), or a wholly owned not-for-profit subsidiary of the university, manages the commercialisation process.

Other Swedish researchers (McQueen, 1990; McQueen and Wallmark, 1988) have referred to a UTSF as based on a product or service resulting from university research, and founded (or co-founded) by a person (or persons) from a university research group where the founder moved directly from the university to the firm (McQueen and Wallmark, 1985; 1991). This definition has been adopted for this chapter.

As has been demonstrated, various studies have recognised that a significant number of new technology-based businesses have been established by scientists emerging from different types of academic-based organisations, such as non-profit research institutes, government research centres and universities. However, despite the increasing interest in the development of businesses from academic research, there are only a few studies, which have attempted to consider the economic impact of such organisations.

In the USA, a variety of studies have demonstrated how various regions have developed university small firms (Saxenian, 1994; Roberts, 1991) although these have tended to concentrate on Route 128 in Boston and Silicon Valley in California as the main examples for small firm developments from universities such as MIT and Stanford. However, as Malecki (1991) points out, the presence of an outstanding university within a region in the USA does not necessarily lead to the development of an entrepreneurial climate in which UTSFs are created.

In Europe, there are only a few studies, which have examined this phenomenon, and only in limited regional settings. Linköping – one of the fastest growing regions of Sweden – contains a strong high technology industrial environment, which includes the presence of Saab's Aircraft Division, Ericsson Radio and the Swedish Defence Research Establishment, and is at the forefront in the creation and development of new technology-based firms in Sweden. Academics and students from Linköping University have played a leading role in this. Over 450 small technology-based firms emerged directly from academic research activities at the institution (Klofsten and Jones-Evans, 1996), with a high number of the others using or developing university research findings as the basis for their products or services.

In the UK, the most famous study of UTSF activity is that of the 'Cambridge Phenomenon', which found that nearly all of the 350 high technology businesses in the area had ultimately been generated from Cambridge University, especially the departments of physics, engineering and computing (Segal, 1986). Similar clusters have been identified at other universities, for example Imperial College, Heriot Watt and Aston, although these have not been developed to the same extent, and the research on successful UTSFs is limited.

Whether these approaches are the right way to develop entrepreneurial businesses is still open to debate. The role of universities in creating these milieux of innovative firms within different regions has led to a proactive approach by universities, usually supported by regional or national government, in adopting direct entrepreneurial roles. However, these can range from the establishment of university-owned holding companies to the promotion of fledgling academic entrepreneurs (Gibson and Smilor, 1991) to the development of specific centres of research and training which promote and assist the process of academic research into a network of industrial firms and business ventures (Klofsten and Jones-Evans, 1996). Although there is no recommended model for the creation of UTSFs on UK university campuses, there are individual university models and this has resulted in the establishment of a variety of commercial infrastructures on campuses, often alongside the development of incubators and science parks.

5.4 Conclusions

The causes of financial market failure can arise for many reasons and these may take the form of tax problems, late payment, administration burdens, lack of finance and information provisions (Storey, 2002). These are not only related to SMEs but also university spinout ventures in particular. With spinout companies market failures may be associated with R&D and learning through experience. This will especially be the case when R&D from universities may be too expensive to recreate under market conditions or is not appropriate to the market situation. Also, there may be little experience of learning by doing from the academic environment as evidenced by the spinout founders leading to naïve market approaches with consequent market failure. There is therefore the need for identification of market failure by policy makers with appropriate government intervention to make things 'better'. This is especially evidenced in programmes derived from public policies to support small businesses.

In these terms the approach described by Storey (2002) to evaluate the impact of public policies to support small businesses in developed economies is appropriate.

This chapter has assessed the existing knowledge, detailed information and recommendations for future action for supporting UTSFs. These businesses are companies whose activities are based on technologies developed as a result of academic research programmes. Such companies are significant in a local economic development context, since they are likely to lead to the commercialisation of research in fairly close proximity to the HEI involved. This has benefit for both the local economy and the HEI itself. Risks and problems in forming and growing UTSFs must not be underestimated, and it is important to recognise that they represent a significant route to the commercial exploitation of new ideas and technologies. In appropriate circumstances they can make an important contribution to regional and national prosperity. A critical challenge for HEIs is to ensure that where a firm is an appropriate vehicle, it is properly managed and there are structures to enable its true potential to be realised.

A myriad of factors affects the attractiveness and viability of UTSFs. University research and consultancy environments do little at the moment to encourage academics towards commercialisation of their research work. As a result academic researchers considering the formation of a business from their research see the process as difficult. This perception is borne out by the experience of those who start-up. Factors, which have a bearing on this situation, are rooted in the existing academic culture and university resource allocation. Change is needed prompted by the fundamental reappraisal of the higher education system by the Dearing Report (1997) and aided by other initiatives.

Finance has emerged as a constraint on the development of UTSFs and comparisons with the United States experience are illuminating. For example, effective interaction between the financial and academic communities in the Boston Area (Downes and Eadie, 1998) has produced a greater degree of understanding and communication. In order to achieve this there is a need for a radical approach to university businesses involving strong drivers to support developmental start-up change as expressed in the introduction to this chapter.

A clear finding is that insufficient attention has been paid to the economic development potential of UTSFs. The overwhelming evidence from other developed regions and countries is that vibrant university business activity has significant positive multiplier effects. With so many HEIs housing advanced scientific and technological expertise the woeful number of successful new businesses created either by or for the academic community only serves to emphasise how much work remains to be done by policy makers.

With regard to policy recommendations a single factor likely to bring about change is the recognition that UTSFs not only have a role to play in creating and sustaining a dynamic and prosperous economy they also represent attractive opportunities for venture capitalists, and may show considerable financial and other returns for the HEIs from which they emerge. There is a market for the future development and encouragement of UTSFs from university campuses, particularly amongst undergraduates, postgraduates and academic staff. Informed experience in starting up businesses from universities is not prescriptive and flexibility is required for the various university environments. Although there are support services and specific programmes available for UTSFs, there needs to be proper co-ordination in terms of the help and advice provided. This is based on evidence indicating that spending tax payers' money on this type of initiative is welfare enhancing and leads to a net benefit.

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6 University Business Collaboration

"When there is teamwork and collaboration, wonderful things can be achieved."
MATTIE STEPANEK (1990–2004)

Chapter contents:

- Introduction
- Organisational aspects of university/business collaboration
- Motivations for university/business relationships
- Formation Process
- University/business Inter-organisational relationships
- Conclusions

6.1 Introduction

University/business collaboration has had an extensive history (Bower, 1993) and there has been a considerable increase in these types of partnerships in the United Kingdom (Duggan, 1997; Powers, 2003), European Union (Caloghirou et al, 2001) and the United States (Baldwin and Link, 1998; Mansfield, 1998), for example. Such an increase is believed to be due to a combination of pressures on both universities and businesses (Meyer-Krahmer and Schmock, 1998; Santoro, 2000). For universities pressures include rising costs, funding and the growth of new knowledge – these have resulted in resource pressures on universities who have sought relationships with businesses to maintain subject area market leadership (Hagen, 2002; Nimtz et al, 1995). For businesses pressures include global competition, short product life cycles and technological change (which have transformed their competitive environment) (Ali, 1994; Bettis and Hitt, 1995). Due to societal pressure on universities they are seen as "engines for economic growth" rather than their past social remit (Blumenthal, 2003; Cohen et al, 1998). Pressures such as these have led to university/business collaborations for the enhancement of economic competitiveness and innovation (Ankrah, 2007). Within this context Autio and Laamanen (1995) talk about "the ability to recognise technical problems, the ability to develop new concepts and tangible solutions to technical problems, the concepts and tangibles developed to solve technical problems, and the ability to exploit the concepts and tangibles in an effective way" (p. 647). Further to this, knowledge transfer is considered different to technology transfer since knowledge transfer is a wider set of activities than technology transfer (Gopalakrishnan and Santoro, 2004). Technology transfer is viewed as an exchange process by Burati and Penco (2001) where a collaborative venture transpires involving a technology donor and recipient working in partnership to adapt and develop technologies (with the aim of dealing with the customisation of technology required to develop specific applications, applying new technology to create value for the recipient taking into account both internal and external factors, and the needs of potential users).

According to Ankrah (2007) there is a large amount of research on university – industry partnerships especially with regard to technology and knowledge transfer. As a consequence considerable literature is in existence regarding mechanisms developed for interaction between industry and university and collaborative outcomes (Ankrah, 2007). There is also considerable literature available regarding the university/business relationship. Furthermore, what has been published could be described as ad hoc in nature (Ankrah, 2007) and also on a regional basis (Smilor et al, 1990). The nature of the literature shows that co-operation between universities and industry was considered to be less important before 1990 than after (Howells and Nedeva, 2003; Nimtz et al, 1995; Poyago-Theotoky et al, 2002). Since university – industry, and particularly university – business relationships are evolving, contemporary papers build on the findings of the early literature (Blumenthal, 2003; Geisler, 1995; Howells et al, 1998, Newberg and Dunn, 2002). This chapter therefore seeks to answer the research question "what is the nature of the management of the university/business relationship?"

6.2 Organisational aspects of university/business collaboration

Various types of inter-organisational relationships undertaken in practice are reported in the literature and these include interlocking directorates, trade associations, alliances, consortia, networks and joint ventures and these vary according to partnership linkages (Barringer and Harrison, 2000). In fact, it has been observed that in the literature a number of terms are used to describe the different inter-organisational relationships (Chiesa and Manzini, 1998). Furthermore, it is concurred that co-operative arrangements take various forms to a varying degree of complexity and partner involvement (Geisler, 1997). Indeed, it is posited that the possibility for university – industry relationships are fairly wide (Shenhar, 1993). Moreover, forms of university – industry inter-organisational relationships in the case of technology transfer occur according to the technology flow and the length of the relationship (Figure 6.1) (Chen, 1994).

Four classifications for university industry inter-organisational relationships have been given and these are research support, co-operative research, knowledge transfer and technology transfer (Santoro, 2000). Research support includes endowments and trust funds, co-operative research – informal intentions, institutional facilities, group arrangements, institutional agreements, knowledge transfer – co-operative education, institutional programmes, personal interactions and technology transfer – commercialisation activities and product development through research centres at universities (Santoro, 2000).

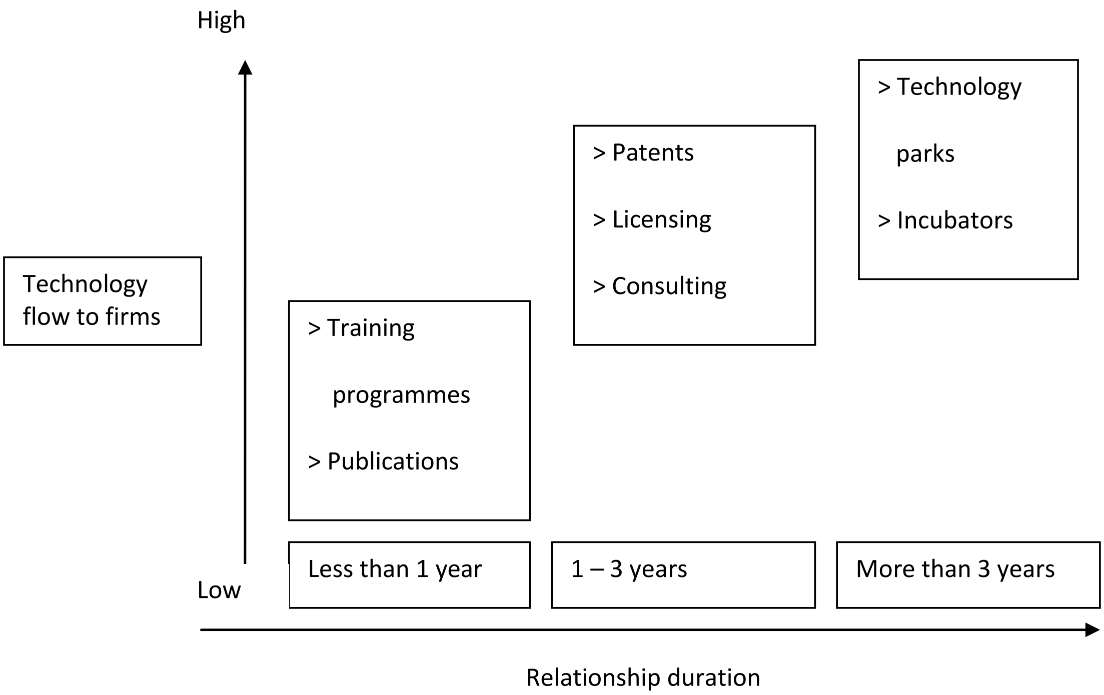

Figure 6.1: Technology transfer mechanisms (Source: Chen, 1994, p. 451)

It is considered that the creation of a typology that illustrates the possible links between universities and industry, and more specifically between universities and businesses, is not easy (Blackman and Seagal, 1991). Furthermore, the framework of Bonarccorsi and Piccaluga (1994) is reasonably wide and consists of the categories of the creation of focused structures, formal non targeted agreements, formal targeted agreements, personal informal relationships and personal formal relationships. It is noted by Bonarccorsi and Piccaluga (1994) that these six groups provide an increasing involvement level according to the degree of formalisation, length of agreement and organisational resource involvement from the university. In fact a university's resource involvement progresses from formal personal relationships through the categories to focused structures where there is a university wide involvement in industry collaboration structures (Bonarccorsi and Piccaluga, 1994).

Formalisation of agreement can exist for personal formal relationships and third parties whilst in remaining groupings formalised relations are evident (Bonarccorsi and Piccaluga, 1994). The issue of formalisation is considered to be significant since formalisation and monitoring of inter-organisational relationships can cause disagreement and loss of trust amongst partners through them attempting to retain independence for their organisations in a situation where interdependence is increasing (Ring and van de Ven, 1994).

6.3 Motivations for university/business relationships

From the literature on inter-organisational relationships between 1960 and 1990 six critical contingencies have been posited by Oliver (1990) across linkages, settings and organisations and these are necessity, asymmetry, reciprocity, efficiency, stability and legitimacy (Oliver, 1990). According to Oliver (1990) two delimiting assumptions are behind the determinants which are that deliberate decisions are assumed to be made to form an inter-organisational relationship by organisations and an organisational perspective involving a top management approach is assumed (the determinants can also explain lower reasons) (Oliver, 1990). The six contingencies show strong correlation with alliance strategy motives (Eisenhardt and Schoonhoven, 1996). Motivations for universities and businesses engaged in inter-organisational relationships appear to closely align with the six critical contingencies/determinants (Oliver, 1990) as motives for organisations to embrace inter-organisational relationships.

Many governments are encouraging collaboration between universities and businesses, in a situation of rapid technological change and international competition, for wealth creation through improving innovative activity (Barnes et al, 2002; Schartinger et al, 2001). It appears that a significant issue for policy making by governments, especially with regard to research council budgets, is the operation of the university – industry interface to enable the exploitation of research to be transferred to industry for economic growth (Hall, 2004; Lopez-Martinez et al, 1994). Universities therefore encourage university – industry relationships in accordance with government and institutional policy (Howells et al, 1998). Whereas industry offers expertise in product development, commercialisation, market knowledge (Sherwood et al, 2004) and employment openings for graduates (Lee and Win, 2004; Santoro and Betts, 2002) universities offer research infrastructure and expertise (Sherwood et al, 2004). Therefore, in order to take advantage of these mutual advantages, there is motivation for universities to develop relationships with industry (Ankrah, 2007).

Increasing pressure on public finance for universities, against a background of government grants for university industry initiatives (Harman and Sherwell, 2002), has given an incentive for universities to look for other revenue to fund research and equipment. This has been through the exploitation of intellectual property rights, licensing of patents and the commercialisation of research to reduce university dependence on public funds (Logar et al, 2001). It has also been reported that relationships with industry appeal to universities since there is more bureaucracy involved with public funding than with industrial funding (Blumenthal, 2003; Santoro and Chakrabarti, 1999). It has also been reported that academic staff are motivated to enter into relationships with industry through personal financial gain (Siegel et al, 2003; Siegel et al, 2004).

It has been found that organisations are motivated to enter into inter-organisational relationships to attain dependability and predictability in order to respond to environmental uncertainty (Oliver, 1990). Related motivations have included the shift to the knowledge based economy and the change in university industry relationships to partnerships from sponsorship involving ongoing interaction (Jacob et al, 2000). Considerable resource pressure has affected universities due to the growth in new knowledge which has resulted in universities entering into alliances with industry to stay at the forefront of academic areas in terms of subjects and research (Ankrah, 2007). In particular university academics consider such links to provide opportunities to enable them to train and place students, develop skills, and develop and test theories (Cyert and Goodman, 1997). It has also been posited that universities undertake collaborative arrangements with industry, including businesses, to enable students and academics to solve practical problems through project work, undertake instructional case studies, gain insights from industrial research and to gain exposure to industrial environments (Meyer-Krahmer and Schmoch, 1998; Santoro and Chakrabarti, 2001). These activities contribute to the improvement of teaching quality and curriculum development (Santoro and Gopalakrishnan, 2001; Meyer-Krahmer and Schmoch, 1998). Moreover, it has been suggested that a significant incentive for Higher Education Institutions (HEIs) to partner with industry, including businesses, is for journal publications (Harman and Sherwell, 2002).

Due to the need for universities to enhance their image they will form relationships with industry (Lopez-Martinez et al, 1994; Mora-Valentin, 2000) and there are societal, political and public pressures for them to show their economic relevance to society and to exhibit entrepreneurship and social accountability (Cohen et al, 1998). Through the need for knowledge and technology transfer, and diffusion, they will be motivated to enter into collaboration with industry in order to drive economic development (Blumenthal, 2003; Hagen, 2002; Siegel et al, 2003; 2004). In relation to this it has been found that a fundamental motive of scientists in universities is for recognition in the industrial scientific community (Hagstrom, 1965) and this can be achieved by research grants, presentations at international conferences and joint publications (academic eminence can be achieved through industry supporting university research) (Siegel, et al, 2003; 2004).

Due to the fast changing technological and competitive environment governments have taken action to support research interaction between universities and businesses since it is considered that universities can support economic regeneration and act as engines of economic growth through dissemination of expertise and knowledge by higher education industry linked partnerships (Bettis and Hitt, 1995; Mora-Valentin, 2000). National and regional research programmes have been created by governments and a good example of these in the UK are the Knowledge Transfer Partnerships (KTPs) (Caloghirou et al, 2001), and businesses can benefit from these programmes through collaboration with universities (Howells et al, 1998).

Motivation for businesses to enter into inter-organisational relationships with universities is for financial gain from the commercialisation of academic based technologies and many businesses will require exclusive rights to technologies (Siegel et al, 2003). Industry is therefore interested in controlling the direction of academic research as well as control of the technologies generated (Newberg and Dunn, 2002; Rappert et al, 1999; Siegel et al, 2003). Other motivations for firms to subscribe to university – industry inter-organisational relationships are to have access to students and for hiring and most collaborative research programmes will seek to target the most able students (Bloedon and Stokes, 1994). According to the OECD (1990) university staff and senior researchers will undertake consultancy work for the time they are allowed to undertake activities outside academia.

There will be several motivations for businesses to have inter-organisational relationships with universities from a standpoint of efficiency (Ankrah, 2007). It has been reported that university – industry research increases patenting activity, research and development (R&D) and firm sales (Cohen et al, 1998). Businesses will partner with HEIs for knowledge creation and exploitation, cost savings, innovative activity and research outputs (George et al, 2002). This will result in businesses having competitive advantage and improved financial performance (Grant, 1996). The enhancement of R&D and technology growth through grants, tax credits and a legal environment underpinning R&D is another motivation for government (Barnes et al, 2002; Bramorski and Madan, 1993). Continuing professional development (CPD), multidisciplinary leading technologies, advanced expertise and research facilities as part of human capital development will also be industrial motives since there will be enhanced competitive advantage and the shortening of life cycles (Bonaccorsi and Piccaluga, 1994).

The move to the knowledge based economy has been considered to be an influencing factor for businesses to enter into relationships with universities (Santoro and Betts, 2002). It has also been concluded that academic research has augmented the ability of businesses to resolve complicated problems (Pavitt, 1998). According to Howells et al (1988) and Klofsten and Jones-Evans (1996) university – industry partnerships are a good way of influencing technology-based firms, especially businesses to achieve growth. Lopez-Martinez et al (1994), in their study on university – industry relationships, have illustrated that the lack of in-house ability by industry to undertake technological research has been an important business executive motivation. It has also been found that for firms with an R&D capacity collaboration is still appreciated since it enhances limited human and financial resources and reduces risk (Hicks, 1993). Research networks with other universities and firms and the potential for more complicated collaborative arrangements such as consortia with multiple businesses and universities are a motivation for businesses to enter into inter-organisational relationships with universities (George et al, 2002; Cyert and Goodman, 1997).

It has also been found that businesses can improve their standing by associating themselves with leading universities (Siegel et al, 2003) and links with prominent research universities are believed to increase a firm's position with regard to important stakeholders (Mian, 1997).

6.4 Formation Process

Out of the models on the process of inter-organisational relationship formation (Tuten and Urban, 2001) a model which is believed to be relevant for university – industry inter-organisational relationships formation is the Mitsuhashi (2002) business to business alliance formation model which describes a five stage alliance formation process (Figure 6.2).

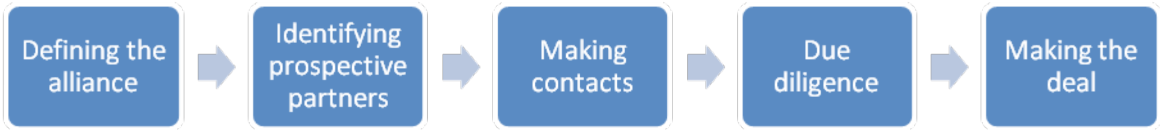

Figure 6.2: The Alliance Formation Process (based on Mitsuhashi, 2002, p. 113)

The initial stage in the formation of a university – business inter-organisational relationship is the determination of the purpose of the partnership and this will be followed by finding an actual partner (Mead et al, 1999) and a number of criteria have been proposed for the selection of partners (Champness, 2000; Dodgson, 1991). It is, however, believed that efforts should be made to undertake prospective partner evaluation, no matter what partner selection criteria are adopted, since there are benefits including ensuring that the collaboration is appropriate (Barnes et al, 2002).

It has been found that if partners have previous experiences of co-operation then the outcomes of inter-organisational relationships are better (Dill, 1990; Geisler, 1995). Existing relationships between partners are crucial since, where experience with an existing partner exists, trust will be developed and universities and businesses will adjust to the demands, evolution and expectations of previous alliances (Gulati and Gargiolu, 1999). Previous collaboration experience (Schartinger et al, 2001) will be important from earlier research, technological and personal interactions and this will reduce organisational and personal obstacles and enhance contact between universities and businesses.

During the formation stage it is critical to define administrative and managerial responsibilities for the inter-organisational relationship, involving financial accountability, and a suitable partnership objective is for the partners to select a project manager (equal collaborative participation by partners will be important) (Peterson, 1995). A project plan needs to be agreed by partners with the specification of milestones (Buttrick, 2000). Differences between partners should be dealt with to avoid collaboration conflict, specification of interim, and end delivery provided, and measures of success identified (Peterson, 1995).

Depending on the complex and formal nature of the inter-organisational relationship it will be essential to have it legally bound by a contract to underline the commitment of the partners (Kanter, 1994; Burnham, 1997). For the inter-organisational relationship of universities and businesses the intellectual property agreement will be the same as the legal document and will specify partner agreements and relationships during, and after, the project collaboration approved by partners (Ankrah, 2007).

6.5 University/business Inter-organisational relationships

The university and business inter-organisational relationship will enter the operational stage (Sherwood et al, 2004) following its formation and this involves a constant evolutionary and learning process (several factors will influence this relationship) (Doz, 1996; Ritter and Gemünden, 2003). A number of activities will take place between the organisations during the operational phase and these will have the objective of attaining the goals of the inter-organisational relationship (Ritter and Gemünden, 2003). In the literature a number of factors are found to induce or restrict inter-organisational relationships between universities and industry (Azaroff, 1982; Dean, 1981; Fowler, 1984). These include capacity and resources, legal issues, institutional policies and contractual mechanisms, management and organisational issues, issues relating to the technology, political issues, social issues and other issues (Ankrah, 2007). The complex interaction of these factors, with the resultant positive and negative impacts, will determine the success of a collaborative project (Barnes et al, 2002). In particular, managerial and organisational issues are critical factors inducing or restricting relationships between universities and businesses (Siegel et al, 2003). It is also considered that substantial managerial effort is needed for university and industry inter-organisational relationships to succeed taking into account the cultural nature of the partners concerned (Dodgson, 1991).

6.6 Conclusions

With regard to the research question "what is the nature of the management of the university/business inter-organisational relationship?" a number of typologies have been developed to express the diversity of relationships that may be employed in the collaborative process. Freeman (1991) distinguishes between the following: joint ventures and research corporations; joint R&D agreements; technology exchange agreements; direct investment motivated by technology factors; licensing and second-sourcing agreements; sub-contracting, production-sharing and supplier networks; government-sponsored joint research programmes; computerised data-banks for technical and scientific interchange; and informal or personal networks.

Although there have been many studies indicating the importance of formal relationships for the transfer of technology, a number of recent investigations have also highlighted the key role played by informal relationships as a means for sourcing ideas and information during the development process (Kreiner and Schulz, 1993; Shaw, 1993). However, in relation to informal exchange, this research has typically been anecdotal in nature. This view is supported by Freeman (1991) who argues that `although rarely measured systematically…informal networks are extremely important, but very hard to classify and measure'. More in-depth and systematic studies of informal interaction in the innovation process do exist, but these have been largely exploratory and have not been examined in different regional or technological contexts.

It has been noted in the literature that closely related to the subsequent benefits realised are the motivations (Geisler, 1995; Lee, 2000). There is also evidence that there is a positive relationship between outcomes and motivations (Lee, 2000). Although the benefits of university and business inter-organisational relationships will outweigh any costs it is necessary for both sides to be aware of any limitations so that action can be taken to alleviate any problems through management procedures and policies (Harman and Sherwell, 2002). By doing this it will be possible to ensure that the relationship is successful and to make failure less likely (Ankrah, 2007). This will also ensure that the goals of both universities and businesses are met (Harman and Sherwell, 2002).

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7 University Business Partnerships and Models of Technology Transfer Offices

"The modern university looks forward, and is a factory of new knowledge."
THOMAS HUXLEY (1825–1895)

Chapter contents:

- Introduction
- The Management of University Business Partnerships
- Models of University Technology Transfer Offices
- Networking Activities
- Discussion
- Conclusions

7.1 Introduction

In order to compare business partnerships for different universities and their models of technology transfer offices (TTOs) a sample of six UK universities were considered which include the universities of Oxford, Imperial College, Warwick, Portsmouth, Hertfordshire and University College London, which were highlighted by Tang (2008). According to Tang (2008) five key findings with regard to business projects and processes are: the speed of response from academics in contract agreement is important when dealing with business; it is essential to have an effective incentive structure to encourage academics to engage with business; of particular importance are R&D research partnerships which help generate academic intellectual property and are a route to commercialisation; universities need to engage in active measures in order to increase the knowledge about the commercialisation process and the benefits that arise from it for students, researchers, lecturers and faculty heads; for university business partnerships to be successful there is a need for expertise and commitment by university senior administrators to support and build partnerships who need to understand academia and industry technology/knowledge transfer dynamics; and in order for good practice there is a need for internal university cultural change especially at senior management level.

The importance of university business partnerships, in a policy context, can be traced to the 1993 Government White Paper "Realising Our Potential" (OST, 1993) which recognised the need for universities to identify 'potential users' of the results of their research in industry and other areas, and with these to ensure successful exploitation. Furthermore, the Lambert Report (Lambert, 2003) also identified the importance of universities working with industry to optimise the exploitation of outputs.

According to Tang (2008) there is a wide range of practices undertaken by university technology transfer offices (TTOs) to enhance university business partnerships ranging from a relaxed approach to structured proactive business facing strategies. These practices include market and sector research, regulatory developments to increase demand for products, creating new businesses and supporting businesses, exploring new opportunities and R&D partnerships, collaborative agreements and projects.

7.2 The Management of University Business Partnerships

A recent review of business university collaboration (Wilson Report, 2012) has reported considerable progress in the cooperation of universities and businesses over the last decade. This has been evidenced thorough three main methods to stimulate university and business collaboration involving change through good management to improve an institution's performance to achieve objectives, indirect and direct funding incentives, and regulatory requirements (Wilson Report, 2012). An example of this was the Confederation of British Industry taskforce report (CBI, 2009) which set an agenda to improve the collaboration of universities and businesses. Moreover, businesses appear to value partnership collaboration with universities to a greater extent than linear intellectual property (IP) innovation process transactions (Perkmann and Walsh, 2007). Contrary to many universities' approach to knowledge exchange much contact between external organisations and academics involves direct contact between the academic and the business rather than the university technology transfer or knowledge exchange office (PACEC/CBR, 2011). Here networks between industry and academics are important and a recent study has indicated that some 40% of academics interact with businesses in this way (Abreu et al, 2009). Although these types of collaborations and partnerships in the past have been through personal relationships and ad hoc types of cooperation (Melese et al, 2009), individuals have had to be involved in the early stage development of technologies by businesses and universities (Termouth and Garner, 2009). Further to the activities of individuals secondments, internships and placements are also considered to be good ways to enhance knowledge exchange (CBI, 2009), although secondments for post doctoral researchers has been low (CROS, 2011) and academics tend to be limited in their availability for placements (Wilson Report, 2012). With regard to global innovation environments a Higher Education Funding Council for England (HEFCE) study reported that higher education centres of excellence can offer access to expertise by providing networking opportunities and interactions with corporate partners being made aware of centre technical themes (Knee and Meyer, 2007). The establishment of a network of centres to commercialise research in the UK was advocated by the Dyson (2010) and Hauser (2010) reports which would aid the development of business sectors by facilities with public subsidies similar to the Fraunhofer German institutes although offering greater university business collaboration. This was realised through the announcement of funding for 6 technology and innovation centres (TiCs) in 2011 (TSB, 2011). The analysis of the latest literature illustrates that there has been much progress in the management of university business partnerships built upon the original developments evidenced in previous studies and this is further substantiated through the models of technology transfer offices.

7.3 Models of Technology Transfer Offices

University TTOs/business development units are central to the exploitation of university business partnerships and they undertake many activities to bridge the academic industry divide including the creation of networks of industrial links. Three models of TTOs have been identified from Tang (2008) that have different approaches to university business partnerships with industry and these are:

- Internal model – TTO integrated into the university administrative structure;
- External model – TTO operates outside the university either as a subsidiary or independent entity with autonomy over its operations;
- Hybrid model – A hybrid consisting of a combination of the above.

Through working with industry (Rogers et al, 2000) there is greater experience and professionalism of the TTO (Siegel et al, 2003). Developing the work of Tang (2008), the three different approaches are illustrated with reference to the sample of six UK University TTOs (Table 7.1) (Oxford, Imperial College, Warwick, Portsmouth, Hertfordshire and University College London).

Table 7.1 shows that there is a mixture of business partnership approaches among UK universities. The large research intensive universities, such as Oxford and UCL, have an externally organised approach or a hybrid approach as illustrated by Imperial College with Business Development Higher Education Funding Council for England (HEFCE) supported and Imperial Innovation traded publicly. Since the TTOs of Warwick, Hertfordshire and Portsmouth are integrated into the university administration they have an internally organised approach. They are mainly supported by the University and the Higher Education Innovation Fund but they are not all profit generating. Furthermore, the TTO at Portsmouth does not have a central objective to be a for-profit organisation and neither is the Business Development Unit of Imperial. All these universities have a mix of methods of exploitation practices (Tang, 2008) and all practice the three phases of (i) opportunity recognition, (ii) opportunity development, and (iii) opportunity exploitation (Van der Veen and Wakkee, 2006). A major part of the metrics of business related activities of universities involve spin outs, licences and patents and they are the key proxies for university commercialisation activities resulting in them being grouped together (spin outs are the best mechanism for "disruptive" technologies) (Tang, 2008). It appears that building good relationships between academics and industry underpins successful university industry partnerships.

University	Technology Transfer Office	TTO Model	Business Partnerships approach	Structure
Oxford	Oxford ISIS	External Model	Externally organised approach	Twenty seven project managers
Imperial College	Imperial College Business Development Unit	Hybrid Model	Hybrid approach	Three units: Imperial Consulting, Imperial Innovation, Business Development
Warwick	Warwick Ventures	Internal Model	Internally organised approach	Director, Five business managers, marketing manager and administrative assistant
Portsmouth	Portsmouth Research and Knowledge Transfer Services	Internal Model	Internally organised approach	Four managers of priority areas and a Business Development Manager
Hertfordshire	University of Hertfordshire Intellectual Property and Contracts Services	Internal Model	Internally organised approach	Head of IP and Contracts Support and academics
University College London	University College London Business Plc	External Model	Externally organised approach	Four divisions and about forty staff

Table 7.1: Different Approaches to University Business Partnerships for a sample of six UK universities
Source: Developed from Tang (2008)

7.4 Networking Activities

Existing university business relationships can be strengthened through networks and they offer the possibility for new relationships to be developed with increased benefits from working with other industrial participants, which can lead to not only new collaborations and sources of expertise but also provide awareness of company competition (Tang, 2008). Networking activities can help SMEs who are excluded from networks involving research intensive corporations and universities (for example the universities of Portsmouth and Hertfordshire target SMEs in their networking activities). Networking through clubs/associations/societies can link researchers with industry, a notable example being the Oxford Innovation Society, and can result in the commissioning of studies by members (Molas-Gallart and Tang, 2007). Furthermore, the use of the alumni office for networking can be of particular benefit through contacting alumnae to obtain research sponsorship and the commercialisation of university IP (the University of Hertfordshire has attempted to harness alumni with the aim of exploitation).

Collaborative R&D projects are important university business partnerships and this form of "joint research" is a significant factor for connections with industry and knowledge transfer (Tang, 2008). This type of research enables the university researcher to keep up-to-date with industrial research, to obtain access to industrial research expertise and to increase the exploitability and applicability of university research (D'Easte-Cukierman and Patel, 2005). Collaborative projects and partnerships are a significant form of exploitation of academic research for the Research Division at Oxford University, for example, and together with agreements they are a major mode of exploitation for the University of Portsmouth (Tang, 2008). They are also the second most important mechanism for the University of Hertfordshire. With Knowledge Transfer Partnerships in an area outside the company's business the industrial partner will allow the university to exploit the IP. Since the innovation process is moving towards an "open" model (Chesbrough, 2003a&b) protecting IP in collaborative projects is a vital consideration (Tang and Molas-Gallart, 2008).

Collaborative projects undertaken for the Engineering and Physical Sciences Research Council (EPSRC), Technology Strategy Board (TSB) and Faraday Partnerships with industry are another important form of university business projects. Faraday Partnerships are networks of organisations aimed at improving innovation competitiveness and performance of UK industry through research and development, knowledge transfer and exploitation of science and technology from the science base, and involve Research and Technology Organisations, businesses and universities (DTI, 2006a&b). The value of these partnerships has been recognised by the Economic and Social Research Council (ESRC), and through its Business Engagement Strategy, has encouraged academics involved in ESRC funded projects to work with industry.

7.5 Discussion

Good practices (Tang, 2008) for identifying university business partnerships include: establishment of a professional TTO with a staff mix involving academic and business experience; commitment to building and maintaining trust between academics and industrialists involving an understanding of the workings of academia and industry; maintaining continual contact on an informal basis with academics; adopting a transparent approach to explaining the process of commercialisation to academics; establishing an incentive structure for academics to engage with – consultancies as an entry point to understanding how companies operate to develop client lists and joint R&D projects/partnerships to exploit university IP; and avoiding over bureaucratisation of processes and procedures for engaging industry.

Good practices (Tang, 2008) for the successful exploitation of university business projects include: support from, and ability of, the TTO to undertake university business partnerships through three activities: (i) opportunity recognition; (ii) opportunity development and (iii) opportunity exploitation (Van der Veen and Wakkee, 2006); licensing is important; spin outs to provide a route to market and engage investors; Research and Development Partnerships to provide more academic IP and a route to commercialisation; consultancy to provide an initial route to exploitation; a "capabilities map" or "capabilities audit" to match industry needs coordinated with the Research Office and academics; implementation of active measures to raise awareness and knowledge about potential university business projects and the benefits with heads of faculties, lecturers, researchers and students; and submissions of bids to invitations to tender that require an industrial partner.

As well as the current proxies for successful university business projects and processes that focus on spin outs, licensing and patents other paths for successful university industry partnerships include support measures for entrepreneurial undergraduates and postgraduates, continuous professional development and training services, networking, collaborative research and consultancy partnerships and maintaining a strong relationship between industrialists and academics (Tang, 2008).

7.6 Conclusions

For university business partnerships to be successful there is a need for expertise and commitment by university senior managers to support and build partnerships who need to understand academia and industry technology/knowledge transfer dynamics (as noted by Tang (2008) in relation to findings from a study of university TTOs' exploitation of intellectual property in the UK). Research and Knowledge Transfer Services could make greater use of the services of the university business school (an example being Portsmouth University). The identification of university business partnerships could have greater assistance provided by the Research Office (as evidenced at the University of Hertfordshire). The three phases of (i) opportunity recognition, (ii) opportunity development, and (iii) opportunity exploitation need to be practiced similar to the universities of Oxford, Imperial College, Warwick, Portsmouth, Hertfordshire and University College London (Tang, 2008). The key proxies for university commercialisation activities of spin outs, licences and patents need to be recognised as a major part of business related activities of a university. Good relationships need to be built between a university and industry to underpin successful university industry partnerships. Existing university business relationships can be strengthened through networks and they offer the possibility for new relationships to be developed with consequent increased benefits. Greater networking, through clubs/associations/societies, needs to be undertaken by university researchers with industry to enable the commissioning of research projects. The development of an alumni office to enable networking is of particular benefit involving contacting alumnae to obtain research sponsorship and commercialisation of a university's IP (the University of Hertfordshire for example has harnessed alumni with the aim of exploitation). Protecting IP in collaborative projects is a vital consideration (Tang and Molas-Gallart, 2008) for a university since the innovation process is moving towards an "open" model (Chesbrough, 2003a&b).

Recommended Reading

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8 Growth of a Technology Concept: A Case Study

"Technology has advanced more in the last thirty years than in the previous two thousand. The exponential increase in advancement will only continue."
NIELS BOHR (1885–1962)

Chapter contents:

- Introduction
- Methodology
- Findings
- Conclusions

8.1 Introduction

A new form of incubation developed in Wales is the Technium 'concept' which has resulted in new participants entering the incubation industry (Thomas et al, 2004). This new wave of incubation, experienced in recent years, can be related to regional dynamism (Gonzalez and Lucea, 2000, 2001) and the creation of new incubators in Wales. It appears that existing incubators are at different stages of development and serve different types of clients (Thomas et al, 2003). With regard to this UK Business Incubation (UKBI) is the main proponent of business incubation through its Web site (UKBI, 2003a) and has undertaken a study of the UK business incubation environment to create a benchmarking framework for the sector. In fact, UKBI (2003a) is the lead body promoting and supporting the successful operation of all types of incubation facilities at a regional and national level. A two-stage model of development described in the study parallels the development of small businesses – foundation, development and mature incubation. The report provides standards of "good practice" applicable to differing incubator environments (UKBI, 2003b). In Wales the Technium network is one of these incubator environments.

Supported by the Welsh Assembly Government (WAG) a programme was developed of ten centres of excellence in Wales under the Technium "banner" for specific technology sectors. The technium concept has been defined as "a new world-class commercial concept that is set to strengthen Wales as an innovation destination for knowledge based businesses" (WDA, 2002) and this has an objective to create spin-off employment. The network has the aim to bring together industrial market leaders, researchers and developers, start-up and university entrepreneurs at the Technium sites. Technology-based entrepreneurship is central to the Technium "idea" (Thomas et al, 2004). Technium tenants are able to access business support, office space, telecom links and venture finance. Access to the twelve thousand annual technology graduates in Wales enables new businesses to take innovative products to market. In this way enterprises are able to mature commercially and graduate from technium centres.

From the roll-out of the Technium programme an all-Wales integrated network of centres has been developed. This provides a supportive environment for enterprises to develop involving a cost of £150 million over three years (NAFW, 2003). The centres:

- "provide incubation space for exciting companies with growth potential;
- act as a highly-visible vehicle for company-academic links;
- provide an attractive way for global companies to invest in Wales in high value-added activities;
- host mixed private/public sector support teams;
- act as strong physical focal points for (an) innovative communication campaign" (NAFW, 2003)

The process of the development of the "hub" Technium centres has been ongoing with sector specific "satellite" Technium centres being rolled out across Wales.

In the body of understanding presented in the literature three incubation models have been identified for the management of new technology-based firms (NTBFs) (Clarysse et al, 2004). These are the low selective, supportive and incubator models. The low selective model involves initiatives from public bodies linking with universities with the aim to generate NTBFs. Private organisations undertake action for the supportive model to generate NTBFs that remain local. The incubator model commences with a centre of excellence in a technological area with close ties to academia or research establishments. Since this model is based on the profit motive less NTBFs are generated but it is more sustainable. A development of these models is the network incubator (van Geenhuisen, 2004). A further concept is 'technological incubation' which takes place in a technology-based incubator (TBI) of which techniums are a form. Here the stage model (Hannon, 2003; Hisrich, 1988; Koschatzky, 1997; Scherer et al, 1988; Vohora et al, 2002) will be characterised by the development of the idea involving resources, launch, start-up and development.

Three differences between TBIs and 'traditional' incubators have been outlined by Phillips (2002). TBIs are concerned with NTBFs, they offer different support (laboratories, equipment, technical research resources, staff, researchers and learning resources) and are linked to higher education institutions (HEIs) and research centres involving technology transfer networks (TTNs). Added value for NTBFs is realised by the different support provided. In fact, the overriding factor providing added value by TBIs to NTBFs is considered to be the linkage to academia (Phillips, 2002). Indeed, the added value from universities is perceived to be essential for the success of the incubator. In particular, significant aspects of TBIs are considered to be the development of innovation networks (Phillimore, 1999). Here the TBI is not only the link between the HEI and the business but is also part of the overall innovation network. This suggests an integrative dynamic for TBI performance (Mian, 1997) although Colombo and Delmastro (2003) have doubted the success of TBIs in assisting start-up development. This contention is obviously debateable based upon the evidence presented in this chapter with regard to the exponential growth of the Technium concept on the Internet and the implications of the findings for both theory and practice.

The establishment of techniums was a major strand for programmes such as the Entrepreneurship Action Plan (EAP, 1999), "A Winning Wales" (NAFW, 2002) and the Global Entrepreneurship Monitor for Wales (Jones-Evans and Brooksbank, 2004). Initiatives included the Knowledge Exploitation Fund (KEF), "Know How Wales", Intellectual Property (IP) Wales, the Technology Exploitation Programme and Technology Transfer Centres. The significance of techniums in terms of these policies evolved from the Regional Technology Plan (RTP) (WDA, 1996) with Wales at the forefront of EU regions developing this policy framework. The RTP (WDA, 1998) has now been succeeded by the national Innovation Action Plan (launched March 2003) (NAFW, 2003) as the long-term technology and innovation strategy. An important role will be played by the development of techniums in the long-term plan to create a culture in Wales to enhance innovation. The RTP first phase involved the development of a strategy to improve technology and innovation for the Welsh economy and a significant aspect of the development of this strategy is the technium infrastructure.

Previous research has described techniums established in Wales (Thomas et al, 2004). These include Optic Technium, Technium centre Swansea, Bio Technium and techniums at Natgarw, Aberystwyth and Technium II at Swansea. Since technium and business incubator premises development is a fast growing area there has been considerable activity. This is set against the background of the distribution of incubator premises available in the UK for new business starts which shows approximately 77% of premises located in England, 14% in Scotland, 6% in Wales, 2% in Northern Ireland and 1% in the Isle of Man (Barrow, 2001). More recent data for the UK (Europa Enterprise, 2004) shows Wales with 5% of the business incubators.

The Technium at Swansea was developed from the Innovation Centre at Swansea University originally established in 1986. Located at the Prince of Wales Dock in 2000 it is a purpose-built two million pound facility initially let to twelve fast growing technology firms. The purpose built building houses up to 18 high growth businesses. There is specialised business support in the form of the technology transfer team of the WAG, ITC and Know-How Wales's representative. Such high-level support allows businesses to access finance, technology and business support directly. Due to success of the centre the then Welsh Development Agency (WDA), in October 2001, decided to develop five further centres to enhance high technology innovation in the Welsh economy.

One of the centres, AutoTechnium, caters for performance engineering and motorsport located at an 18 acre research site at Llanelli for fifteen new companies and at the Pembrey Circuit in Carmarthenshire and is near to car component manufacturers employing hundreds of people. With students from the Motor Sport Engineering course at Swansea Metropolitan University the aim was to develop motor racing technology. The MediaTechnium at the Gelli Aur stately home, Llandeilo, aimed to develop digital media professionals at a cost of £9.7 million. BioTechnium, for the biotechnology sector, has been set up to work from the National Botanic Gardens of Wales, Llanarthne, Carmarthenshire. Additionally, there has been Digital Technium, Technium II at Swansea and OpTIC Technium located at St Asaph, Denbighshire for the North Wales Opto-electronic industry. An opto-electronic and enabling technologies resource, Optic Technium, accommodates up to 24 start-up companies. In addition to housing a technology centre for the development of new products and processes it provides a range of business start-up support activities. Further techniums are Sustainable Technologies, Aber and the Centre for Advanced Software Technology (CAST). These technium developments (Table 8.1) show that there has been concerted activity in Wales, in recent years, based on European, all Wales, regional and local incubation initiatives.

Technium site	Location	Technology	Cost to develop (£M)	Start date	Number of NTBFs
Technium	Swansea	General	52	2000	12/18
Auto Technium	Pembrey	Motorsport	-	2002	15
Media Technium	Llandeilo	Digital Media	9.7	2002	-
Bio Technium	Llanarthne	Biotechnology	43.6	2000	12
Digital Technium	Swansea	Digital Technologies	-	2003	13
Technium II	Swansea	General	-	2001	-
Optic Technium	St. Asaph	Opto-electonics	15	2003	24
Sustainable Technologies	Baglan	Sustainable Technology	9	2005	25
Aber	Aberystwyth	Bio Science, Software, Film and Media	1.7	2004	10
CAST	Bangor	Software Technology	-	-	-

Table 8.1: Technium Network in Wales

8.2 Methodology

The objective of this chapter is to consider the exponential growth of the Technium concept on the Internet in relation to business incubation and support for new and existing enterprises in Wales. A simple calculation of the rate of increase in the posting of items on the Internet on the Technium concept has been made. This has involved the net rate of multiplication (geometric rate of increase) over the period 2001 to 2004. An elaborate method of determining the 'finite rate for increase' [λ], which is the multiplication rate of increase which results in a 'stable distribution' has been considered. The natural logarithm of λ is the 'innate capacity of increase' [r]. This is an infinitesimal rate of increase expressed by the differential equation:

$$dN/dt = rN$$

where N is the number of postings on the Internet. If N_t and N_{t+1} are the numbers before and after a time interval the relationship between λ and r is:

$$N_{t+1/}\ N_{t\,=}\ e^r = \lambda, \text{ or } \lambda = \log_e \lambda \text{ (where e = 2.7181)}$$

It is accepted that the increase in the number of postings of items on the Internet reporting the development of the Technium concept could not continue indefinitely. As the exploitation of the concept becomes complete the rate of increase will diminish until a saturation point is reached. At this point no further increase is achievable. This poses the question when will the saturation point be reached? The curve showing the increase from the initial to the saturation point delivers an S-shaped (sigmoidal) curve when the arithmetic increase in the number of items posted on the Internet is measured. These assumptions deliver the following equation:

$$dN/dt = rN\ [K-N]/K$$

where dN/dt is the rate of increase of the posting of items on the Internet on the Technium concept, N is the number of items present, and K is the number that can be achieved at saturation. An equivalent of this equation in relation to the growth curve is:

$$N = K/1+e^{a-bt}$$

Where a and b are constants related to steepness and height of curve, and t is time on the x axis.

The above equations are the theoretical formulation of the growth of the posting of items on the Internet. Since in practice there is limited data due to the short period under consideration in order to answer the question when the saturation level will be reached for the postings a doubling time approximation has been formulated for a saturation time to be extrapolated. These formulations provide an understanding of the dynamics of the exponential growth of the use of the Internet for reporting the development of the Technium concept and answer the question as to when saturation will be reached.

The research considered published materials, initiatives and project chapters highlighting techniums in Wales reported on the Internet. This was carried out as follows:

- Internet literature searches involving publications and journal articles regarding technium developments.
- General Internet searches to identify and quantify practices and perspectives in Wales.
- Enquiries with appropriate agencies such as universities and the Welsh Development Agency.

The survey method had the following salient features since it was:

- Appropriate for collecting specific technium data and information.
- Feasible given deadlines.
- Able to provide broad generalisations and inferences from a small sample and enabled greater possibility for replication.

The study also analysed data on techniums (Brooksbank, Angove and Thomas, 2004a&b) and this was considered according to developments in Wales.

8.3 Findings

Internet searches were carried out in June and October 2004 and these provided 141 and 313 results for the posting of items on the Technium concept, respectively. This showed an increase of 172 sites providing postings which is a 122% increase. An analysis of the year of posting from the results in October 2004 is shown in Table 8.2.

Year of Posting	Percentage
2001	4%
2002	16%
2003	38%
2004	42%

Table 8.2: Internet Search on Techniums (October 2004)

By plotting the findings shown in Table 8.2 for the years 2001 to 2004 this shows an exponential increase, as illustrated in Figure 8.1.

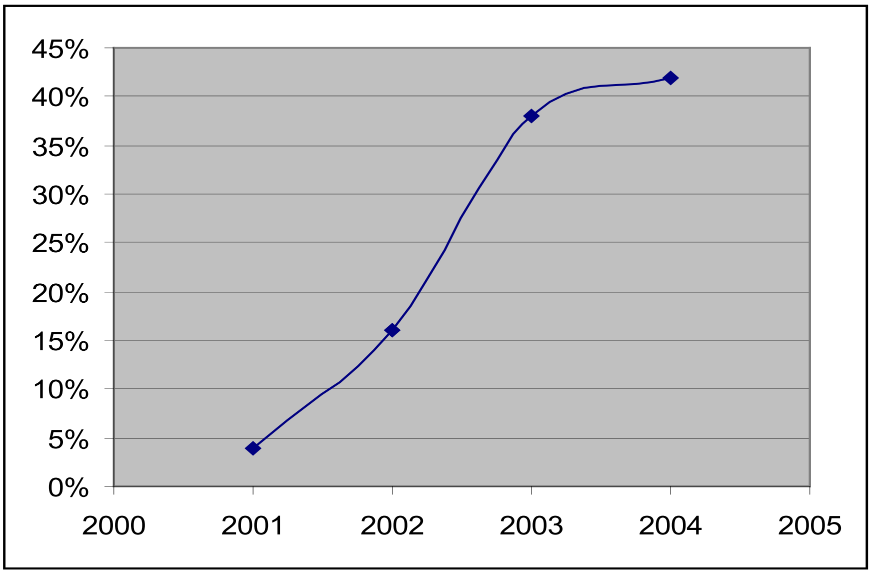

Figure 8.1: The Exponential Growth of the posting of items concerning the Technium concept on the Internet

Further analysis has been undertaken of the postings including the subject areas specified relating to the Technium concept, the organisations posting items and the location of organisations. The subject areas of the postings for items concerning the Technium concept on the Internet are shown in Table 8.3.

Subject Areas Specified	Postings (Percentage)
Technium concept	32%
Objective 1 Funding	12%
Regional Plans	12%
WDA Plans	12%
Business	8%
Economic Development	8%
Commons Debates	8%
Manufacturing	8%

Table 8.3: Subject Areas of the postings for items concerning the Technium concept on the Internet

The largest number of postings was for items concerning the Technium concept itself (32%). Considerably behind this were postings covering the Technium concept and Objective 1 funding, regional plans and WDA plans (12%). The lowest number of postings for the concept was for the subject areas of business, economic development, Commons debates and manufacturing (8%). The organisations making the above postings concerning the Technium concept on the Internet are shown in Table 8.4.

Organisation	Percentage
National Assembly for Wales	21%
BBC News Wales	9%
Carmarthenshire County Council	9%
ELWa	9%
House of Commons	9%
Welsh Labour	8%
Corporate Wales	6%
Cyfenter	6%
Deeside College	6%
IT Wales	6%
Potentia	6%
WEFO	5%

Table 8.4: Organisations making postings concerning the Technium concept on the Internet

The organisation making the largest number of postings was the National Assembly for Wales (21%) and the least was the Welsh European Funding Office (WEFO) (5%). The locations (country) of organisations making postings concerning the Technium concept on the Internet are shown in Table 8.5. As expected the largest percentage of postings for the location of organisations was Wales (81%) and then England some way behind (10%).

Location	Percentage
Australia	1%
England	10%
Spain	1%
Switzerland	1%
USA	1%
Wales	81%

Table 8.5: Locations of Organisations making postings concerning the Technium concept on the Internet

The approximate doubling time of postings in the sample can be derived from the total growth described as Pn – Pi where Pn is the number of postings in the nth year or month and Pi is the number of postings in the first year or month. The growth per year or month can be described as:

$$\frac{Pn - Pi}{N}$$

where N is the number of years or months.

To determine the doubling time (D) at certain time intervals on the exponential curve the following equation has been used:

$$D = \frac{N}{Pn - Pi} \times 2$$

where N is the number of years or months.

Applying this to the findings, as expressed in the table showing the growth of postings (Table 8.2) and exponential growth (Figure 8.1), the doubling time (D) for the 12 month period from the beginning of January 2001 to the end of December 2001 and from the start of January 2002 to the close of December 2002 is 4.8 months for both time periods. These findings are in agreement with the high growth rates for the Internet (Coffman and Odlyzko, 1998, 2001). This exhibits a constant exponential increase for these two years with slower rates for the previous year 2001 and the following year 2004. The data collected for 2004 implies a “slowing down” in the increase and therefore a levelling off.

8.4 Conclusions

This chapter has illustrated the Technium ‘concept’ as an example of an integrated support network (WDA, 2002) for small technology-based businesses. Techniums provide ‘state-of-the-art’ premises for these companies which may vary from straight forward ‘spinouts’ to global start-ups. Types of support include tailor-made specialist and technical support. The key to the success of the Technium at Swansea is the link with research and development (R&D) and training at centres of excellence at Swansea University and Swansea Metropolitan University. This is reinforced by good working relationships with sector forums and underpinned by Broadband connection. Follow-on is catered for by the provision of appropriate accommodation for enterprises that require larger premises for expansion. The Technium at Swansea is the ‘hub’ for the Technium network in South West Wales. Each concerns a particular sector with links to local higher education research and sector forum. It is shown that techniums include specialist centres such as Auo-Technium at the Pembrey Race Circuit and Bio-Technium at the National Botanic Gardens of Wales. Regional techniums are located at Bangor, a satellite Opto-Electronics Technium, St. Asaph, South East Wales and Aberystwyth. Additional techniums cover aerospace and e-media, for example. Twenty techniums were planned which follows UK government policy to build a knowledge-based economy (supporting incubators to ‘seed’ clusters) (Cooke, 2003). According to Cooke (2003) problems with policy towards techniums in Wales include replication of old incubation approaches that have failed to prioritise assistance and properties leasing space that are not necessarily innovative. Although around four hundred incubator spaces will be filled developments could fall short of this if international rates are taken into account (Jones-Evans, 2002).

This research was conducted at a time of considerable development for the technium ‘concept’ on the Internet. One of the salient features of the survey method was that it offered greater possibility for replication and could be used to provide a cyclical picture of technium development throughout Wales lending itself to becoming a longitudinal study. Results of the study show the importance of facilities and the main types of support services provided by the techniums. A significant outcome of the findings of the research will be to inform future developments. The analysis has addressed the factors involved in the development of techniums in Wales as reported on the Internet. This has shown that:

- Initiatives such as 'Know How Wales' (NAFW 1998a, 1999) and the Technology exploitation programme provide an infrastructure for technium activity in a knowledge based economy (NAFW, 1997, 1998b).
- To enhance success and encourage networking for start-up enterprises technium environments should provide comprehensive technical, administration, accountancy, legal and marketing services.
- Technologies need to be properly protected especially where prior knowledge is concerned and assistance needs to be provided so that intellectual property rights (IPR) are secure.
- Many enterprises will take 10 to 15 years to reach maturity. It is therefore necessary for techniums to provide early support in this light.

Developments for techniums in Wales have been influenced by initiatives like 'Know-How Wales' (NAFW, 1998a, 1999), the Wales Spinout Programme (WSP, 2001) and the Innovation Action Plan (NAFW, 2003). Strong drivers to support the development of techniums are expressed in the introduction to this chapter. The significance of techniums in Wales are considered in terms of analysis of the exponential growth of the Technium concept on the Internet and communicating the results of the research to policy makers. In particular, strategies need to be formulated to realise the considerable benefits of techniums as a 'new' concept for technology 'driven' incubation. Indeed, in these terms techniums are significant for the evolution of incubation and innovation for the future development of technology-based entrepreneurship in Wales.

The recommendations for future development of the measurement of the exponential growth of the Technium concept on the Internet require researching larger data sets arising from longer time frames for postings on the Internet in order to determine whether the "saturation level" has been reached for these postings. This can be achieved by determining the overall doubling time approximation which will give an indication to policy makers as to whether the concept has been fully established. By noting the equation:

$$\frac{Pn - Pi}{(n-1)}$$

the doubling time approximation can be expressed as follows:

Let N be the number of months or years in excess of n required to double the number of postings in the first year or month, then the approximation is:

$$Pn + \frac{(Pn - Pi)\,N}{(n - 1)} = 2Pi$$

$$\text{giving } N = \frac{(2Pi - Pn)\,(n-1)}{(Pn - Pi)}$$

Hence if D is the doubling time

$$D = n + N$$

By using the doubling time approximation it will be possible for policy makers to determine when the doubling time has "slowed down" and there is a levelling off in terms of the saturation of interest in the concept. This has implications not only for general awareness to the concept but also for incubation policy initiatives and programmes.

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9 Conclusions

"Technology is a gift of God. After the gift of life it is perhaps the greatest of God's gifts."

FREEMAN DYSON (1923–)

9.1 Introduction

Technology-based entrepreneurship has become ever more important over recent decades and has an important role for economic growth and industrial renewal, especially with new technologies and fast growth knowledge based sectors. The focus on technology-based entrepreneurship has consequently arisen from the importance of technology and entrepreneurship within this context (Dahlstrand, 2007).

Interest and research into technology-based entrepreneurship originated in the United States of America (USA) and following this it has become important in Europe in the last twenty five years (Dahlstrand, 2007).

Technology Transfer Policy

Policy makers have a clear agenda as to what technological innovation and entrepreneurship mean. This may adversely affect the effectiveness of economic regeneration if the wrong agenda is followed. For these strategies to be more effective they need to be developed by improving access to innovation and technology support by making services demand led rather than supply led. There needs to be the devolution of financial decision making for the financing of technology. Policy makers should create a positive climate for support including indigenous support. Awareness training should be delivered for technology-based firms (TBFs) so that they are made aware of technology transfer services. The creation of an innovation culture can influence economic regeneration in a systematic way and methods can be set up to cascade technologies and undertake new ventures.

Diffusion of Innovations into Technology-Based Firms

Although there are variables which appear to be the most important influences on technology diffusion into TBFs there will also be a multiplicity of influences that accelerate or alleviate the rate of diffusion. This spectrum of influences on diffusion rates broadens when considering technology transfer among the various different TBFs in multi-tiered networks. An extension of the hypothetical example of diffusion is the diffusion of technology into TBFs through multi-tiered networks. In these TBFs' sociological forces will have an important role to play. The rate of adoption of a new technology will be faster if it is compatible with the previous experience and present normative values of TBFs. Other influences on the speed of diffusion include the complexity of the new technology and random influences. Successful diffusion of a new technology involves considerably more than technical competence. Many complementary factors will be prominent and a TBF may be retarded in its acquisition of technology by other firms who are slow to adopt. The rapid diffusion of a technology will be facilitated by a willingness of TBFs to make adjustments.

Technology Clusters

A technology cluster will have a local production network which exists around companies. An extensive knowledge network will be built around the firms facilitated by senior staff movement between them. Competition within the group will be intense and formal collaboration rare, and international concerns and relationships will be of importance resulting in well developed global production facilities, suppliers, customers, partners and competitors, and contradictions exist between perceptions of members and the reality of linkages within the cluster. A cluster may be local to a region but part of a wider international industry cluster with simultaneous importance of local cluster effects and extensive international links.

University Technology Small Firms

University-based technology small firms (UTSFs) are companies whose activities are based on technologies developed as a result of academic research programmes. Such companies are significant in a local economic development context, since they are likely to lead to the commercialisation of research in fairly close proximity to the higher education institution (HEI) involved. This has benefit for both the local economy and the HEI itself. Risks and problems in forming and growing UTSFs must not be underestimated, and it is important to recognise that they represent a significant route to the commercial exploitation of new ideas and technologies. In appropriate circumstances they can make an important contribution to regional and national prosperity. A critical challenge for HEIs is to ensure that where a firm is an appropriate vehicle, it is properly managed and there are structures to enable its true potential to be realised.

University Business Collaboration

With regard to the nature of the management of the university/business inter-organisational relationship a number of typologies have been developed to express the diversity of relationships that may be employed in the collaborative process. Freeman (1991) distinguishes between the following: joint ventures and research corporations; joint R&D agreements; technology exchange agreements; direct investment motivated by technology factors; licensing and second-sourcing agreements; sub-contracting, production-sharing and supplier networks; government-sponsored joint research programmes; computerised data-banks for technical and scientific interchange; and informal or personal networks. Although there have been many studies indicating the importance of formal relationships for the transfer of technology, a number of recent investigations have also highlighted the key role played by informal relationships as a means for sourcing ideas and information during the development process (Kreiner and Schulz, 1993; Shaw, 1993).

University Business Partnership and Models of Technology Transfer Offices

For university business partnerships to be successful there is a need for expertise and commitment by university senior managers to support and build partnerships who need to understand academia and industry technology/knowledge transfer dynamics (as noted by Tang (2008) in relation to findings from a study of university TTOs' exploitation of intellectual property in the UK). Research and Knowledge Transfer Services can make greater use of the services of university business schools, and the identification of university business partnerships can have greater assistance provided by the research offices. The three phases of (i) opportunity recognition, (ii) opportunity development, and (iii) opportunity exploitation need to be practiced (Tang, 2008). The key proxies for university commercialisation activities of spin outs, licences and patents need to be recognised as a major part of business related activities of a university. Good relationships need to be built between a university and industry to underpin successful operation of university industry partnerships. Existing university business relationships can be strengthened through networks and they offer the possibility for new relationships to be developed with consequent increased benefits.

Growth of a Technology Concept: A Case Study

The case study of the Technium concept is an example of an integrated support network for small technology-based businesses. Techniums provide 'state-of-the-art' premises for these companies which may vary from straight forward 'spinouts' to global start-ups. Types of support include tailor-made specialist and technical support. The key to success is the link with research and development (R&D) and training at centres of excellence. This is reinforced by good working relationships with sector forums and underpinned by Broadband connection. Follow-on is catered for by the provision of appropriate accommodation for enterprises that require larger premises for expansion. The study reported was conducted at a time of considerable development for the Technium 'concept' on the Internet. Results of the study show the importance of facilities and the main types of support services provided by the techniums.

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10 References

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