Available online at www.sciencedirect.com
SCIENCE DIRECT®
Technovation 25 (2005) 739–752
technovation
www.elsevier.com/locate/technovation

Opportunity recognition and product innovation in entrepreneurial hi-tech start-ups: a new perspective and supporting case study

John S. Park*

Charles P. Skene Centre for Entrepreneurship, Aberdeen Business School, The Robert Gordon University, Garthdee Road, Aberdeen AB10 7QE, Scotland, UK

Abstract

As a key early stage in the formation of an entrepreneurial venture, there has been much recent interest in opportunity recognition as a field of academic study. Although early theorists proposed a holistic approach to the study of venture creation, much of the literature has been dominated by studies focussed on one or two components in isolation. Much of this historical research has an exclusive focus on the role of the entrepreneur or on knowledge within the firm. Such an exclusive focus can be misleading as it fails to consider the nature and dynamics of the inter-relationships taking place in high-tech firms.

This paper seeks to synthesise the available literature into a more complete and integrative model of opportunity recognition in high-tech start-ups. We propose opportunity recognition to be a complex, interactive process involving three main components, the founding entrepreneur, the knowledge and experience of the firm and technology. A case study is used to demonstrate the nature of the component interactions. It is argued that more widespread use of the qualitative research can reveal new insights into the complex and interactive process of opportunity recognition in the high-tech start-up.

Keywords: Entrepreneurship; Innovation; High-tech new venture; Opportunity recognition

1. Introduction

The origin of opportunity recognition as a research topic has its roots in the classic entrepreneurship literature. However, much of this early literature attempted to explain the process of new firm creation and growth with an almost exclusive focus on the entrepreneur's traits and personalities. Authors attempted to explain how these 'special' qualities endowed entrepreneurs with a unique ability or driving force to create and nurture new businesses. Many such driving forces were proposed, including the need for achievement (McClelland, 1961), locus of control (Rotter, 1966), or an extraordinary ability to transform markets via innovation (Schumpeter, 1934).

The focus of entrepreneurship research changed in the late 1980s and early 1990s with authors proposing a more holistic approach to the study of entrepreneurship (Gartner, 1985, 1988; Bygrave and Hofer, 1991). Gartner (1985) proposed a more complete study of the process of entrepreneurship by studying the interaction of four main factors, the individual (the entrepreneur), the organisation, the environment and the actual process of firm creation. Gartner's (1985) argument was that the process of new firm creation can only be fully understood by studying the interaction of the various components:

> The creation of a new venture is a multi dimensional phenomenon; each variable describes only a single dimension of the phenomenon and cannot be taken alone. (Gartner, 1985, p. 697)

Gartner (1988) further criticised the exclusive focus on the entrepreneur with a more detailed justification based on the limitations of the research on entrepreneurial traits. Gartner (1988) recommended that new venture creation was a process best studied in the raw, i.e. that firms and founders needed to be studied during the actual start-up process to develop and maintain a true and unbiased perspective of the phenomenon.

Bygrave and Hofer (1991) viewed the entrepreneur as the initiator, with firm creation as the actual mechanism of exploitation. Bygrave and Hofer (1991) suggested we should investigate how entrepreneurs and entrepreneurial organisations differ from the established firm in the way they develop and exploit opportunities. Bygrave and Hofer (1991) also introduce opportunity recognition as a topic in

* Tel.: +44-1224-263887; fax: +44-1224-263870.
E-mail address: j.park@rgu.ac.uk (J.S. Park).

0166-4972/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.technovation.2004.01.006

its own right and as the first part of the entrepreneurial process. Shaver and Scott (1991) argue a similar approach but with more focus on understanding the psychology of the nascent entrepreneur and the transformation of entrepreneurial inclinations and intentions into actual firm foundation. Shaver and Scott (1991) also propose in-depth investigation of the unique cognitive thinking processes, e.g. the extensive use of heuristics often exploited by entrepreneurs. They argue that we need to better understand these behaviours and thought processes to explain why entrepreneurs can see the unique potential in a situation and create an organisation to pursue it, whilst other individuals, when presented with the same information, either fail to see the opportunity or choose not to pursue it.

Opportunity recognition has subsequently emerged as a field of entrepreneurship research in its own right (Gaglio, 1997; Venkataraman, 1997; Shane and Venkataraman, 2000) with numerous conference papers on opportunity recognition and related topics (Hills and Shrader, 1998; Hills et al., 1999; Koen and Kohli, 1998; Singh et al., 1999; Zietsma, 1999; Craig and Lindsay, 2001; Shepherd and De Tienne, 2001).

However, the formal literature remains comparatively sparse (Shane, 2000; Collarelli-O'Connor and Rice, 2001; Ardichivili et al., 2003) and with very few authors following the holistic method of study proposed by earlier theorists (Gartner, 1985, 1988; Bygrave and Hofer, 1991).

The entrepreneurial process is an interactive combination of three components which ultimately result in market innovation. The three main components of the innovation process studied to-date are outlined in Fig. 1. However, few researchers have studied the interaction of these components.

This paper argues that conclusions drawn from the study of single components in isolation are potentially flawed. Such studies fail to consider important interactions that may have been key contributors or components of the innovation process.

This may explain why, after almost two decades of study, there is still such an inconclusive picture of the innovation process in entrepreneurial high-tech start-ups.

The contribution of this paper is to synthesise the existing literature into a more complete model of opportunity recognition theory, with specific reference to the field of high-tech start-ups. High-tech start-ups often function in a truly entrepreneurial environment. They are often at the cutting edge of technology, are continually developing new markets and often involve highly charged entrepreneurial personalities. This provides an ideal setting to study the entrepreneurial innovation process.

$$\text{Process} = \frac{\text{People} + \text{Technology}}{\text{Environment}}$$

Fig. 1. The three components of the entrepreneurial process.

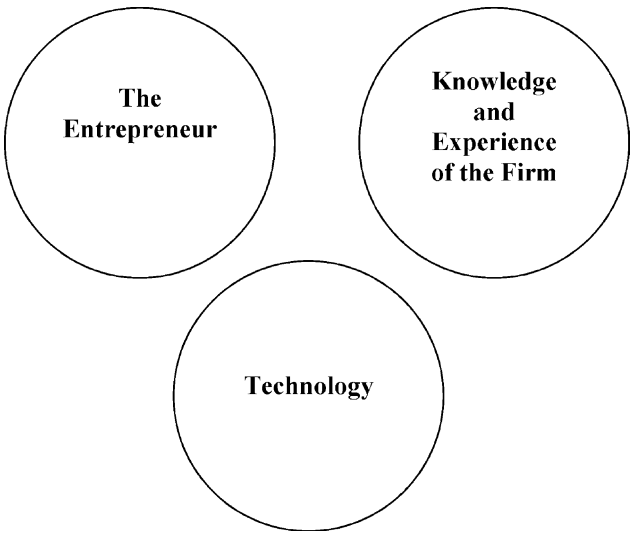

Fig. 2. The three components of the opportunity recognition process.

Three key components are widely recognised in the literature as common and important elements of the opportunity recognition process. We have chosen to study the process by focussing on the collective and interactive contribution of these three components (Fig. 2).

The first component is the founding entrepreneur who decides to create a firm to pursue the entrepreneurial technology venture. The second component studied is the organisation they build around themselves and how this collective organisational knowledge and experience impact the success of the venture. The final component of the process is the technology on which the venture is based, how this technology develops and evolves due to interaction with the founding entrepreneur and the knowledge of the firm.

The contribution of this paper has been to review the literature and uncover the specific contributions of these three model components as well as identifying gaps in the current state of opportunity recognition theory and suggestions on how to further our understanding of this important field.

We have chosen to apply these findings to a case study to effectively demonstrate the nature of the interactions between the components of the model.

2. Rationale for choosing high-tech start-up firms as the focus of this research

Opportunity recognition can be interpreted as such a loosely defined field, that we have chosen to configure the topic more precisely. In this paper the focus continues to be on the entrepreneurial firm but in a narrower frame of reference, i.e. the high-tech start-up. As there has been much debate on a suitable universal definition of the high-tech firm (Oakey et al., 1988) we have chosen to define the high-tech firm more precisely as a firm that uses or invests in

rapidly emerging or evolving technology as a key part of its product development, production or marketing strategy. The rationale behind this narrow focus is two-fold.

Firstly, these firms are important because they are seen by many governments as having a pivotal role to play in the regeneration and growth of national economies (Scottish Executive, 2001; OECD, 2003). A better understanding of effective opportunity recognition processes used in such technology sectors would have obvious benefits in helping government develop and refine appropriate policies and support programmes. From an economic standpoint, if these firms are the potential corporate giants of the future, a better understanding of how best to grow acorns into oak trees would benefit both entrepreneurs and society.

The second rationale for studying such firms is that these firms work in a truly extreme environment where the technology challenges are often on the edge of scientific possibility, but with the available resources generally scarce (Julien, 1995). In the high-tech sector, business survival, let alone growth, is dependent on finding and exploiting a reliable innovation strategy quickly, and before other firms enter the market.

3. The entrepreneur

Although the popular literature often contains many recent, high profile examples of high-tech entrepreneurs transforming markets, e.g. Bill Gates and James Dyson, the notion of technology driven entrepreneurs and entrepreneurship is not a new phenomenon. Schumpeter (1934) suggested that entrepreneurs, blessed with an ability to wield technology as agents of market change, engaged in the process of 'creative destruction'. The creative destruction described involved the use of new technology (new products, new methods of production) to transform markets, essentially destroying the status quo and creating a whole new wave of innovation.

Other scholars tried to test the hypothesis that entrepreneurs might possess 'special' personality characteristics (McClelland, 1961; Rotter, 1966; Kirzner, 1973), with little success, mainly due to limitations in the trait theory itself but also the methodology used to identify personality traits (Gartner, 1988; Chen et al., 1998; Chell, 1999). An obvious flaw in the personality theory is the assumption that the variables characterising the entrepreneur and the environment are static. The reality is that the environment is changing constantly and traits or characteristics alone have little ability to explain behaviour (Delamar, 2000). It also fails to recognise that much of the personality trait research was done after the entrepreneurial event, so the causality is difficult to establish (Gartner, 1988). Were the traits present to begin with or did they evolve during the entrepreneurial process?

However, the notion that the entrepreneur is just part of the overall process has also been emerging. In later work Schumpeter (1942) begins to see innovation as being increasingly dominated with large firms who have the critical mass necessary to engage in large scale innovation. Schumpeter (1942) proposed that a critical mass of established firms can be a barrier to new entrants, e.g. the lone entrepreneur or new start-up company, who simply do not have the established knowledge base or R&D budgets to compete with the established firms. This suggests that entrepreneurs play a more prominent role in markets that are not already occupied by large firms. In such markets, technology is advancing at such a rapid rate that barriers to entry are non-existent.

As a result, it is very important that we do not lose sight of the entrepreneur as one of many factors that can impact upon market success in high-tech start-ups. The important role of 'people' in the foundation of any venture cannot be under-estimated. Recent researchers (Shane and Venkataraman, 2000) have re-emphasised Gartner's (1985, 1988) calls for a more in-depth study of the process and actions of entrepreneurs during firm formation as being a more effective way to better understand their contribution to the entrepreneurial process.

3.1. Entrepreneurial motivations

Naffziger et al.'s (1994) investigation concluded that although individuals are often the energisers of the entrepreneurial process there is limited research that has explicitly studied the linkages between individual behaviours and firm level outcomes.

The search for the driving career motivations is well established in the academic literature. McClelland (1961) identified the need for achievement, and Rotter (1966) identified a locus of control which have both been interpreted as potential internal driving forces among entrepreneurs.

A recent study (Carter et al., 2003) attempted to probe entrepreneurs' career motivations. Six main motivating factors were studied among entrepreneurs and non-entrepreneurs, i.e. innovation, independence, recognition, roles, financial success and self-realisation. However, this study failed to uncover any significant differences between the important career aspirations of entrepreneurs and non-entrepreneurs. All of these potential motivators could easily be realised in the technology sector, but a desire to achieve innovation and external recognition are two that would be well served as a technology entrepreneur. This suggests our knowledge of the internal driving forces for embarking on an entrepreneurial career is as a whole underdeveloped and a more detailed study with specific focus on career aspirations of technology entrepreneurs would deepen our understanding of the role of the individual in the foundation of high-tech start-ups.

3.2. Entrepreneurial alertness

Early 18th century theorists (Cantillon, 1931; Say, 1964) suggested certain individuals could recognise differences in

value of goods across different market sectors and exploit this knowledge for profit. This model resurfaced in a revised form over 200 years later with Knight (1921) suggesting the entrepreneur was willing to purchase goods based on the calculated but uninsurable risk they could be sold for future profit. This arbitrage model proposed by the earlier theorists evolves into a more calculated and systematic search by entrepreneurs to identify value differences across market sectors (Kirzner, 1973).

Kirzner (1973) suggested that entrepreneurs possessed or obtained specialised knowledge and could use it to create or exploit opportunities. This is reinforced in later studies (Kaish and Gilad, 1991; Busenitz, 1996) where entrepreneurs were shown to be more active in seeking opportunity than corporate managers. Hills and Shrader (1998) and Zietsma (1999) also found that the successful entrepreneurs had high levels of entrepreneurial alertness. Timmons (1999) proposed that successful entrepreneurs have the capacity to see what others do not. Timmons (1999) cites two scientists, Edison and Einstein who between them wrongly predicted that the nickel battery would replace gasoline and that nuclear energy would never be obtainable. This reinforces the proposition that even the most brilliant scientific minds are not always fully tuned to business opportunity.

Opportunity recognition is a skill highly relevant in the field of technology where some huge product innovations have largely involved the transfer of a 'low-value' technology from one business sector to another where it becomes 'high-value' (Christensen, 1997).

Understanding how successful entrepreneurs successfully manage the opportunity recognition process is even more relevant today with so much in the way of new technology either readily available or actively sought. This can take the form of large technology firms showcasing proprietary technologies via technology licensing websites, e.g. http://www.yet2.com with the corporate objective to find external licensee partners who will recognise the potential value in new markets. The other side of the equation is technology acquisition, also used by large corporations to recruit external scientists to solve business problems that have defeated their internal R&D organisations (e.g. http://www.innocentive.com, and http://www.ninesigma.com). However, having available technology or even opportunity on show and available is just one part of the equation. It also requires an entrepreneur to be alert to its potential reapplication opportunity and willing to take the risk of starting a business to exploit it. In other words, it requires a Schumpeterian champion to engage in creative destruction of an existing market.

3.3. Internal and external interactions

One of the main issues of contention in the personality/trait explanation is that it is highly dependent on the impact of external environmental influences. Gartner (1985) identified the external environment as being a key influencing factor in the process of new firm foundation. An individual's behaviours often change as they gain experience and knowledge through interaction with the world around them. Moore (reproduced in Bygrave, 1997) proposed that the start-up process can involve the interaction of external environmental factors with individuals or collective personalities involved in starting up the firm. Moore (reproduced in Bygrave, 1997) proposed a stepwise process involving, innovation, triggering event, implementation and growth, outlining how the combined interaction of both individual personality and external environmental factors can influence each of these stages. Understanding the triggering process is very important because it is from this point that the 'scientist' turns entrepreneur and their thought paths change or the entrepreneur decides to back a scientist with a technology invention/innovation in a business venture.

3.4. Developing and growing 'entrepreneurial' experience

3.4.1. Entrepreneurial self-efficacy and entrepreneurial intent

The concept of entrepreneurial self-efficacy revolves around the notion that entrepreneurs need to develop a perception of self-confidence in their entrepreneurial abilities before they are willing to start up in business (Bandura, 1986). Boyd and Vozikis (1994) suggest that self-efficacy plays an important role in the development of entrepreneurial intentions and actions. Other authors build on this by suggesting that actual intent to start up in business, possibly fuelled by entrepreneurial self-efficacy, is the best predictor of eventual entrepreneurial behaviour (Krueger et al., 2000). This is often signalled by the fact that many entrepreneurs set up in business in advance of finding the actual opportunity (Zietsma, 1999). Such entrepreneurs are, by definition, more receptive to opportunities as they simply need to find one to generate their flow of income. Chen et al. (1998) suggest that it is entrepreneurial self-efficacy in five key skill areas: marketing, innovation, management, risk-taking and financial control which are key differentiators between people actively interested in setting up in business and those who have already started. Oakey (2003) proposes academia as a key vehicle to provide these commercial management skills to nascent entrepreneurs from a purely technology background.

3.4.2. Learning to manage risk and uncertainty on a daily basis

Researchers are increasingly focussing on defining the cognitive mechanisms used by entrepreneurs to process information (Shaver and Scott, 1991).

Palich and Bagby (1995) found that entrepreneurs, so often tarred with a swashbuckling image in the popular press, did not regard themselves as being more willing to take risks than managers in large corporations. On face

value it would seem to suggest the earlier risk and reward theories (Knight, 1921) do not hold true. However, one should interpret these results with caution. Just because entrepreneurs do not perceive themselves to be more willing to take calculated risk, does not mean that they are risk averse. This only implies that they simply do not perceive themselves to be taking risks, the actual reality may be very different.

The strategic management literature also suggests that the use of cognitive short cuts is not restricted to entrepreneurs and that strategic decision-makers also adopt such processes (Dutton and Jackson, 1987). Work by Gooding (1989) provided evidence that when presented with unequivocal data, managers and entrepreneurs processed the data in exactly the same way and arrive at the same conclusions. However, when presented with equivocal data, the entrepreneurs viewed it in a consistently positive manner. Palich and Bagby (1995) confirmed this in a study specifically conducted among entrepreneurs and managers demonstrating that entrepreneurs interpret data perceiving strengths versus weaknesses, opportunities versus threats, and make more use of heuristic thinking processes.

The uncertain world in which entrepreneurs exist renders overly cautious decision making simply impossible (Baron, 1998). Many situations regularly faced by entrepreneurs (including information overload, high uncertainty, high novelty, strong emotions, high time pressures or fatigue) frequently result in increased usage of cognitive biases or heuristic thinking processes. In such situations, the human brain suffers from an excessive amount of information to process. In order to reach a conclusion the brain attempts to find cognitive short cuts to ease the burden. One example of this is using experience to interpret uncertain situations by comparing it to a previous frame of reference as evidenced by Busenitz and Barney (1997) and Baron (1998). It has also been demonstrated that repeated use of these processes can lead to a degree of entrepreneurial overconfidence (Busenitz and Barney, 1997). As entrepreneurs repeatedly encounter situations of uncertainty, they become proficient in the use of heuristics to make reliable decisions with limited information in short timeframes.

These system simplification processes manifest themselves in the form of a number of cognitive biases (Baron, 1998). Such cognitive biases include: counterfactual thinking—the effects of imagining what might have been; affect infusion—the influence of current states of thinking on decisions and judgements; attributional style—tendencies by individuals to attribute various outcomes to internal or external causes; the planning fallacy—strong tendencies to underestimate the time or effort required to complete a piece of work; and self-justification—the tendency to justify decisions even if they result in negative outcomes.

This leads to the proposition that these thinking processes can be learned and even taught to prospective entrepreneurs. This may also offer a partial explanation why simply being intellectually adept (e.g. scientist or engineer) does not guarantee entrepreneurial success (Oakey, 2003). Scientists use a logical inclusive thinking process that almost has to be unlearned in the real world of business or complemented with an entrepreneurial partner already equipped with such skills.

3.4.3. Do cognitive biases generate innovative solutions?

Maxwell and Westerfield (2002) demonstrated that use of innovative technology was significantly higher in firms managed by 'opportunistic' entrepreneurs, i.e. founders who have a high level of education and business experience. Kickul and Gundry (2002) demonstrate how a proactive entrepreneurial personality can precipitate a number of Schumpeterian innovations (new markets, products or organisational systems) as a result of their involvement in the firm.

Baker et al. (2001) proposed that improvisation is a key part of business start-up. Baker et al. (2001) suggest that the start of the design process often coincides with the commencement of the business venture and that improvisation in the face of changing customer expectations could be a key organisational skill.

Yet, people do play an important role and without them, no business can hope to develop or survive. However, as in general entrepreneurship research, personality factors in isolation, cannot result in the development of a technology start-up.

4. Knowledge and experience as pivots of success

High growth firms generally consist of more than just a single entrepreneur, usually involving the creation of an organisation with the broad skill base necessary to transform the idea into a profitable venture (Bygrave and Hofer, 1991). This fits earlier theories (Cohen and Levinthal, 1990) which argue that the level of prior knowledge is a key factor in enabling a firm to exploit new market opportunities. Cohen and Levinthal (1990) argue that there is a knowledge-based barrier to entry where a certain level of knowledge is a prerequisite to being able to recognise and interpret new external information. This is particularly true in the technology-based firm, where specialised managerial knowledge is necessary to locate, mobilise, combine and exploit other resources in response to business opportunities (Granstrand, 1998).

Kakati (2003) identified a broad range of skills which a diversified management team combining both managerial and technical skills, contribute to successful ventures. Oakey (2003) recognises that a complex mix of both managerial and technical skills is necessary for the success and subsequent growth of high-tech firms, encouraging the entrepreneur with a technology background to share responsibility and control with a broader, more commercially adept, management team. Oakey (2003) argues technology entrepreneurs who attempt to retain and maximise control (so often a key

entrepreneurial motivator) can actually threaten the long-term survival of the firm due to a lack of essential commercial awareness.

This experience factor is prominent in opportunity recognition literature, much of it suggesting that prior experience, particularly of markets, plays a prominent role in successful opportunity recognition (Shane, 2000; Ardichivili et al., 2003). Venkataraman (1997) cites earlier theoretical propositions that each individual and organisation develop a unique knowledge corridor through which they interpret the outside world. It is this corridor which enables them to assess the potential benefit in an opportunity, using an existing frame of reference in which to interpret opportunity in either a positive or negative light. Hills et al. (1999) support this view using previous research to demonstrate that between 50 and 90% of start-up ideas come from prior work experience.

4.1. The importance of commercial knowledge

A category of knowledge that is critical in new firm creation is commercial knowledge and experience. Vesper (1996) and Bygrave (1997) describe the importance of prior commercial experience in the development of the entrepreneurial venture. Hills and Shraders' (1998) survey of successful entrepreneurs indicated that most business ideas stemmed from prior experience of customers and markets, often originating from a previous response to a specific issue in the marketplace. The importance of knowledge of customer problems is again apparent in the research by Shepherd and De Tienne (2001). This is a recurring theme in research into opportunity recognition in large firms (Collarelli-O'Connor and Rice, 2001), highlighting that it is often the senior business manager who provides the critical insight into the true commercial value of a technological breakthrough.

A lack of such commercial knowledge and experience has recently been identified as being a contributing factor in firm failure. Kakati's (2003) survey of high-tech start-ups identified the lack of necessary managerial, technical and marketing skills as being a common component of poorly performing start-up companies.

4.2. The nature of technical knowledge

Although the opportunity recognition literature has recognised the value of experience, literature focussing on technology-based firms has largely ignored the role of technology expertise in opportunity recognition and development. This is a significant oversight, given that the management of technology firms requires much in the way of additional specialised knowledge (Granstrand, 1998). Some of the key knowledge parameters are outlined below.

1. Technology is often a physical component of the start-up process in that it is linked to materials and processes which are continually evolving over time. The end product may have many such technology components, each requiring specialised knowledge, either internal or external to the firm to guide effective integration into the final product.
2. Technical knowledge can have a solid link with natural sciences and the natural evolution of the scientific field, e.g. biology, chemistry or physics both in industry and academia.
3. Technical knowledge can be highly transferable. Examples include, scientific papers, management reports and patents. Technical knowledge involves less obvious, tacit knowledge and experience which are often hard to translate into a codifiable or teachable form.
4. There are often necessary links to external knowledge and regulatory systems, e.g. patent offices, health safety legislation and environmental legislation. Each of these fields requires specialists who are trained to interpret these requirements within the firm.

The development of knowledge as a resource of the firm is an interactive process. It involves interaction of knowledge from various sources. A firm developing a new material may feed the pool of external knowledge by applying for patent protection, which requires the technical details of the invention to be described in return for commercial exclusivity. The scientific knowledge disclosed in this patent may in turn feed into other firms, who might develop technological approaches to circumvent the patents, or simply re-apply the technology in new areas. These firms may also file patent applications and the cycle begins again. An ability to develop, utilise and adapt knowledge is therefore critical for a firm operating in the high-tech environment (Granstrand, 1998; Oakey, 2003).

5. Technology: the origins of technology innovation in the high-tech start-up

The final piece of this model is the technology that provides the competitive advantage. This is almost impossible to define but recent technology development in the fields of electronics, computers, software, biotechnology and of course the internet, provide the competitive edge for many new high growth entrepreneurial firms. Technology itself is not an innovation. Innovation is the combination of technology with market need to create a profitable opportunity (Trott, 2002). As a result, two components we need to understand are the origins of the technology and how the process by which the technology is selected and developed in line with the market opportunity.

For entrepreneurial firms, technology innovation may manifest itself in many forms. Many were actually well summed up by Schumpeter (1934) in his concept of creative destruction: new products, new markets, new ways to make products, new ways of selling products.

5.1. Sources of technology

There is a wealth of literature on sources of technology uptake within industry (Klevorick et al., 1995; Malerba and Orsenigo, 1996; Shane, 2001). Klevorick et al. (1995) completed an extensive survey of many different business sectors, studying the sources of new scientific knowledge utilised in an attempt to trace significant industrial technological breakthroughs back to their scientific origins. Although it is a very broad study, it does illustrate that the type of technology exploited and the rate of technology exploitation is highly sector-specific. The results are largely predictable with the highest levels and rates of technology uptake being in technologically fast moving businesses, including electronics, computing and pharmaceuticals. Klevorick et al. (1995) also investigate the sources of technological advancement and find that most come from general advancement of science within the industry such as suppliers and competitors, and less from upstream academic and government research laboratories. The important exception cited is biology, where university research is an important source of technological innovation for the medical and pharmaceutical industries. However, the main issue with this work is that the survey was only conducted among large established firms and excluded the small high-tech start-up.

Malerba and Orsenigo (1996) conducted a similar study using patent applications as a mechanism to study the adoption of technology. Again the results are highly sector-specific, with many similarities to Klevorick et al. (1995) in that large firms form a stable core of persistent innovators in certain industry sectors. Small firm entrants were found to be more prominent in new and growing market sectors, and the patterns of technology application are also country-specific with the USA and Germany seen as primarily dominated by large firms and less developed countries and Italy with a more active small firm sector. Within international technology sectors, the pattern is largely consistent with the ratio of large firm to small firm activity consistent across geographical boundaries.

A limitation of the Malerba and Orsenigo (1996) study is that patterns of activity in the small firm sector are overshadowed by the large firms. Large firms engage in large scale R&D activity and have sufficient resources to allow speculative patent applications on new technologies. This is not the only distortion caused by the dominance of the large firm sector in such studies. Malerba and Orsenigo (1996) suggest a large degree of consistency in technological uptake across geographies. Given that legal infrastructures exist such as the International Patent Co-operation Treaty (PCT) and these enable inventors to gain simultaneous multi-patent coverage in a number of geographies. As a result, it is not surprising that the picture is geographically consistent within technology sectors. The Malerba and Orsenigo (1996) model is also misleading in that it implies the US is totally dominated by large firms and that small firms have an insignificant role in innovation. In reality the US is often held up as the model economy with high levels of high-tech small firm start-up and growth which many countries actively strive to emulate (Scottish Executive, 2001).

The use of patents to study technological evolution is used to better effect by Shane (2001) who draws some very interesting conclusions based on the profile of firms choosing to license patented technologies for commercial exploitation.

(i) New firm foundation is a more likely method of exploitation in emerging technical fields where the large firms do not have the technological expertise to dominate.
(ii) New firm foundation is more likely in highly differentiated markets supporting the view of earlier theorists (Christensen, 1997) that highly segmented markets do not provide sufficient profit incentives for large firm entrants.
(iii) New firm start-up is impacted by the effectiveness of patent protection within the industry.
(iv) New technology alone is not enough to provide the foundations for new ventures. Shane (2001) provides evidence that technology needs additional knowledge and resources either from the founding entrepreneur or from within the evolving firm, e.g. marketing and distribution. This point is supported by Carayannis and Alexander (2002):

> Firms competitive advantage in this environment is based not simply on whether a firm is able to learn, but how effectively it can recognize and exploit learning opportunities created by aligning its internal capabilities with the external technology-intensive environment. (Carayannis and Alexander, 2002, p. 629)

Technology is ever diversifying such that effective opportunity recognition in the high-tech start-up involves embracing technology diversification, combining it with either new or existing market opportunities and continually evolving the technology with market or customer needs. It is the effective management of this evolution process, using the combined skill base of the firm, that is critical to the success of the high-tech start-up (Granstrand, 1998).

6. Big is not always better: knowledge has to be effectively utilised to create new products or markets

One implication of the critical importance of knowledge in firm creation and growth is that large firms should dominate markets due to extensive technical knowledge, managerial experience, and organisational infrastructure (Schumpeter, 1942). However, the emergence of Microsoft,

Apple and Intel from mere minnows to corporate giants does much to dispel the myth that only large firms can amass sufficient knowledge to innovate and create markets. Rather this supports Schumpeter's (1934) earlier assertion that individuals and small-scale entrepreneurs can engage in the process of creative destruction in emerging markets. This suggests that knowledge alone does not guarantee innovation. Innovation is really the practical application of new or emerging knowledge for profit.

Although large firms may have an abundance of knowledge and technology they are not always the best vehicle to recognise and exploit the opportunities of the future. The role of new firms in the exploitation of new technology is well established. Schumpeter (1934) argued that small firms would be the first to adopt emerging new technologies to disrupt markets but that this competitive advantage would only be temporary, large firms deciding to enter once the markets had been established (Schumpeter, 1942). This is reinforced by Christensen (1997), with specific examples in the high-tech sector. Christensen (1997) presents an intriguing model explaining why some smaller companies are able to exploit opportunities that large corporations either fail to see or decide not to pursue. Christensen (1997) proposed that the combination of organisational knowledge and organisational culture in large firms can negatively impact upon their ability to recognise the future value of emerging markets. The most common innovation strategy by large firms is to exploit internal knowledge and experience to continually drive technology performance. The rationale that developing superior technology will deliver superior performance and market share in high value established markets, driving profitability and growth.

Christensen (1997) proposed that the end result is that the pace of technology development far outstrips the rising demands of the consumers, while the knock on effect is that last years technology can quickly become available at lower cost. This opens the way for reapplication of the technology in new, emerging and more cost-sensitive market sectors. Christensen (1997) uses the computer disk drive industry to prove this point with great effect. Continually large established firms continue to drive disc drive performance in existing applications while small firms have used second generation lower performance disc drive technologies to generate new markets. Examples include laptop computers and palm pilots where other parameters other than performance, e.g. size, are important. The apparently coincidental decision of large firms to ignore these emerging market sectors can actually be an explicit strategy. They develop a knowledge tunnel where they are unable to see beyond their current application of the technology. This tunnel vision can often be deliberate, with large organisations often unwilling to enter emerging markets as the potential returns are seen as being too low to generate expected levels of shareholder return (Christensen, 1997). When the large firm eventually decides to enter the emerging sectors they are disadvantaged versus the small firms already present. The large incumbents, however, lack the technical and commercial knowledge and expertise with which their smaller competitors are already equipped. The end result is that the large incumbents fail to compete in the emerging high growth sectors, with some actually rendered extinct as a consequence (Christensen, 1997). Cooper (1999) also maintains that a key component of failure in large firms' technology development programmes is a lack of customer understanding, despite the abundance of resources available to perform such functions.

6.1. Learn, adapt, survive and grow!

Christensen (1997) proposes a corporate spin-out model as the most effective way to diversify technology into new markets. Technology expertise is transferred from the parent to a new organisation that has the required size and culture to enter and adapt with emerging markets.

This ability to adapt is vitally important in emerging markets where the technology has to evolve with customer expectations. Kakati (2003) observed that firms that were able to exploit emerging markets did so because the firm had the necessary technical and managerial skills to develop products that would stimulate emerging markets, but were also able to adapt them in line with changing customer expectations. Stevenson and Jarrillo-Mossi (1986) also recognise the need to adapt the organisation to retain its entrepreneurial capabilities as a key strategy issue for successful firms.

7. The current state of the opportunity recognition literature and gaps in theory development

Although some authors have tried to map the opportunity recognition process the literature is still largely undeveloped (Hills et al., 1999; Shane, 2000; Collarelli-O'Connor and Rice, 2001). The most comprehensive review is by Gaglio (1997) drawing upon the earlier research proposing opportunity recognition as a long deliberate process. A four-stage process is proposed involving, prevision, vision, elaboration and eventual launch decision. However, this model fails to include the extremely important refinement stage, a critical part of any market entry.

The most recent study of opportunity recognition processes used by entrepreneurs is directly based upon technology businesses. Shane (2000) demonstrates that just one technology can spawn multiple business opportunities. Shane (2000) surveyed eight entrepreneurs who had all exploited very different market manifestations originating from one original technology patent.

Shane (2000) proposed a simple model of opportunity recognition based on two key components, technological invention and prior experience. Shane (2000) argues that the ability of an entrepreneur to recognise the market value of a particular technological innovation is based on their ability

to recognise the value of the invention in the market based on the previous experience they have in solving customer problems in related markets. This again builds much on the many works cited earlier proposing previous experience as a key factor in opportunity recognition processes.

There has been an abundance of recent conference papers on various themes of opportunity recognition in various stages of development (Hills and Shrader, 1998; Hills et al., 1999; Koen and Kohli, 1998; Singh et al., 1999; Zietsma, 1999; Craig and Lindsay, 2001; Shepherd and De Tienne, 2001).

The themes explored are:

(i) Building understanding of the sources of information used by entrepreneurs to identify opportunities (Hills, 1995);
(ii) The importance of social networks in opportunity recognition (Julien, 1995; Singh et al., l999);
(iii) The structure of the opportunity recognition process (Hills et al., 1999);
(iv) The role of personal intuition in the conception, development and execution of opportunities (Baker et al., 2001; Craig and Lindsay, 2001);
(v) The specific role of prior knowledge and the importance of knowledge of customers and markets (Shepherd and De Tienne, 2001).

The journal arena remains largely under-developed, the focus being on the importance of prior knowledge, personality traits and social networks as potential antecedents of entrepreneurial alertness to business opportunities (Shane, 2000; Ardichivili et al., 2003). The theme has also been explored in the large firm context, with particular focus on case studies on how large firms have successfully matched emerging market needs with the innovative technologies required to deliver them (Collarelli-O'Connor and Rice, 2001). Although there is considerable variety in the themes explored in previous studies, there are two striking common themes flowing through most of this literature. That is the importance of understanding markets and customers and the need to place this at the heart of any successful product development strategy and the need for ongoing flexibility, i.e. the need for products to continually evolve with changes in the external market and technology evolution.

8. Towards a model of opportunity recognition

Three key components are widely recognised in the literature as common and important elements of the opportunity recognition process. We now propose a three component model of the opportunity recognition process, integrating all these key contributions but with the additional contribution of studying the interaction of these components. This approach follows the more complete mode of study proposed by Gartner (1985, 1988) and used with great effect by Shane (2000), to develop a more complete understanding of the opportunity recognition process.

This model proposes that new product innovation results as an interaction between three individual components; the founding entrepreneur, collective experience within the firm and technology (Fig. 3).

It is how these three components interact and combine that will ultimately define the final output of the innovation process. While all of these factors have been identified in the literature, the actual interaction of the components has yet to be the focus of any real detailed empirical study (Granstrand, 1998).

One important omission in all of the current literature is the lack of real in-depth analysis of the contribution and evolution of the technology component to the entrepreneurial venture. Most studies are focussed at the macro-level. Researchers generally identify technology trends and their uptake and impact in various market sectors. Examples include broad scale expansion and diversification of technology is a key driver of corporate growth recognised by an upward trend in R&D expenditure and product diversification (Granstrand, 1998). The lack of understanding of technology evolution within the firm would have been easily explained if most of the organisations studied had not been in the technology sector, but the opposite is true in that a significant number of these studies have had technology firms as the focus of their study (Shane, 2000; 2001). Alvarez and Busenitz (2001) propose an investigation into how resources come together in entrepreneurial ventures, but the technology element and its interaction are not investigated in any real depth.

This could lead to two opposite conclusions. First, that technology is not important in the opportunity recognition process. If so, the argument would be that that in

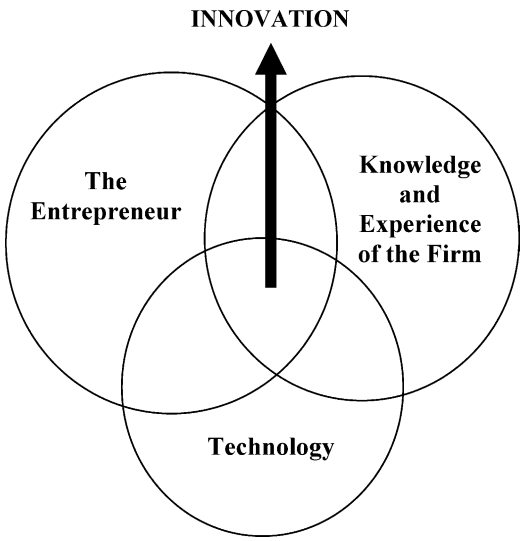

Fig. 3. A conceptual model of the opportunity recognition process in high-tech start-ups.

a technology rich world, technology is a commodity raw material just like any other. The argument could be that in a supply rich environment one could always find a technology to fit the need, once an appropriate market opportunity has been identified.

The opposite conclusion that technology does play a role, but the importance of that role has not been clearly identified. Even in established fields of innovation research, it is hard to identify the true role and nature of technology and innovation. As discussed earlier, innovative companies are often defined and measured by R&D spending levels, patents or turnover (Avermaete et al., 2003). Unfortunately, none of these measures in isolation is a good barometer of market innovation.

The other striking point is that a significant body of the opportunity recognition literature reviewed to-date seems to suggest entrepreneurs start by defining and understanding the customer and then making the rest up as they go (Hills, 1995; Hills and Shrader, 1998; Craig and Lindsay, 2001). This seems to indicate that larger firms may be failing by trying to institutionalise the process, with product development becoming a production line. In such a system it is possible that the firm may lose sight of its customers and their unique requirements. This is supported in part by Barney (1995) who demonstrated how some large firms have utilised their unique internal assets. Certain firms utilised knowledge and people to respond competitively to external market threats, while other firms have succumbed (Christensen, 1997).

The need to complement scientific brains with entrepreneurial and business ones is becoming more apparent. Many high-tech start-ups, particularly in the biotechnology sector, are increasingly using partnership arrangements to find the best home for technology. There is increased evidence of this technical/commercial partnership in action in the form of more strategic focus in the business activities of the small technology firm (Shan, 1990; Sutton and Kelley, 1997; Smith, 1998).

The model proposed in Fig. 3 suggests that new technology development is a key component in the innovation process for all high-tech firms, large or small. However, the innovation is not based on technology alone. It proposes innovation as the end result of a complex interaction of the inanimate technology with the living components of the model. These comprise the personalities driving foundation of the venture and the collective experience (both technical and managerial) within the firm.

What this model really demonstrates is the importance of understanding the complex interactions of the three model components. Moreover, studying these processes in technology firms in different technology sectors would enable us to better understand the nature and the importance of the individual contribution and interaction of the various model components. Studying these interactions across a wide range of firms would start to identify how to effectively synthesise the various model components. This could provide a useful blueprint for effective innovation strategies and resultant market success in a variety of technology and market sectors.

The following case study provides an example of how studying the effective interaction of the three model components can result in effective innovation and resultant market success. Tritech International Ltd was founded in 1990 and produces highly technically advanced sub-sea products across a broad range of market sectors. The company currently markets 30 product lines in 35 countries. Key markets include hydrocarbon and mineral recovery, oceanographic research, defence, nuclear industry, marine archaeology, deep sea fishing and IT cable industry. The company has been recognised externally for its excellent business results and its management of innovation, winning the Royal Society of Edinburgh's Millennium Prize and two Queen's awards for enterprise for export and innovation performance (Crockett, 2004).

9. Tritech International Ltd: a living example of product innovation and market success via effective interaction of the entrepreneur, the organisation and technology?

Tritech's success has been as a result of both technology and market diversification, hence innovation par excellence. This has been achieved via a continually high level of commercial alertness to opportunities but also a willingness to gather and develop the knowledge required to exploit those opportunities. The intent of this work is to analyse Tritech exploring the contribution and interaction of the three model components and their resultant impact on market success.

9.1. Richard Marsh: owner/entrepreneur

Richard Marsh was born in 1944 the son of a research physicist at Cambridge University. Marsh chose to follow his father's technical career path by studying mechanical engineering at the Central London Polytechnic. Upon graduation he chose a traditional career path as an engineer with British Aerospace, one of the world's most successful aerospace engineering companies.

This early phase of Marsh's career was far from entrepreneurial. For 11 years he further honed his technical skills, becoming a double chartered engineer, member of the Institution of Mechanical Engineers and the Institution of Electrical Engineers. During this phase Marsh learned to solve a diverse range of technical issues and also developed people management skills within his eventual role managing aircraft assembly and 1600 staff on the Concorde project. Marsh was subsequently challenged to reapply his technical and management skills in the sub-sea sector, developing a Remotely Operated Vehicle (ROV) for unmanned undersea exploration. At this point Marsh became frustrated with his career path despite his many

existing achievements. His primary frustration was financial, believing his salary was not commensurate with his abilities. With no way to change this by remaining in British Aerospace, Marsh decided the only solution was to become his own boss.

Marsh took the entrepreneurial leap before he had developed any real commercial management skills, setting up Bennico with partner Richard Wright, to exploit the commercial potential of the undersea technology under development at British Aerospace. Wright was hired to manage the technical side of the business with Marsh deciding to focus on the commercial aspects. Marsh took a big risk by assuming responsibility for an area he had no experience of and later recounted that the 10 years managing Bennico provided essential commercial skills that British Aerospace had failed to teach him, demonstrating that Oakey's (2003) proposition that entrepreneurs from a technical background can learn necessary commercial skills.

Marsh learned of important market opportunities in the undersea sonar market. Current sonar technology was expensive and cumbersome. Marsh set an external engineering firm with no experience in the sub-sea sector, the task of designing and building sonars at less than a 10th of the cost and a fraction of the size of current technology. Marsh clearly displayed a distinctly Schumpeterian approach to market transformation using technology to transform an existing market. Marsh showed some use of heuristics, he acknowledged up front, the task was likely to be impossible, but his experience suggested that some progress would guarantee the performance boost versus current technology necessary to enter the market. Marsh was ultimately proved correct when the external partner met the specification.

Marsh again became frustrated when the investors who controlled Bennico refused to recognise the potential of the miniature sonar as more than a technical gimmick. This culminated in Marsh buying the company for £1 and forming Tritech Ltd. The above demonstrates a Kirznerian alertness and use of 'special' knowledge to transform the marketplace, a high level of entrepreneurial self-efficacy and a Knightian acceptance of the risk involved.

> The greatest risk to a company is not to take a risk. Richard Marsh (2003)

Marsh's decision was justified when he confounded his critics and sold 500 sonars in his first year of operation and raised enough capital to further grow Tritech and eliminate the need for external funding or relinquishment of control. Marsh also displays Rotter (1966) like tendencies to maintain his locus of control by refusing Venture Capital funding because he would lose control to "boring, pinstriped chinless twits" (Richard Marsh, 2003) coming into the business every few months and calling the shots.

In this early phase Marsh, his partner and his external linkages to technology provided all the factors described in the earlier model of opportunity recognition (Fig. 3) and resultant innovation in the form of the sonar, comprising an entrepreneur with drive and passion, a working knowledge of both technology and markets and uniquely combining them to deliver a breakthrough product.

9.2. Building an organisation that 'becomes' the entrepreneur

Marsh's construction of the Tritech organisation provides a good opportunity to answer Gartner's (1998) challenge to study how an organisation evolves when the entrepreneur takes on the role of owner/manager. In the early Tritech years all functions were performed by Marsh and Wright, but Marsh was subsequently able to create an organisation that in many ways resembled the early Tritech but on a larger scale, thus a truly entrepreneurial organisation.

Marsh recruited staff with the necessary technical grounding but asserted that technical 'experience' was worth more and was cheaper to recruit than raw university graduates or PhDs. He also recruited staff with the requisite technical knowledge from different backgrounds and a 'can-do' attitude to problem solving as a specific strategy to enhance organisational capability. This demonstrated his belief that technical knowledge on its own is not enough, it is knowledge of the broad ranging practical application of basic scientific principles, in this case physics, that can lead to product innovation. Marsh also created a hierarchy-free structure with salary the only factor distinguishing employee performance with constant encouragement for the organisation to embrace risk.

Marsh further built customer understanding into the very fabric of Tritech having engineers working with customers, refining products, performing training and writing technical manuals designed to help customers utilise products. As a result Tritech has continually increased its knowledge base (Shane, 2000), absorptive capacity (Cohen and Levinthal, 1990) and ability to adapt products to customer expectations in emerging markets (Kakati, 2003).

9.3. The source of technology?

Unusually, Tritech have no in-house R&D. Marsh has always believed that utilising external technology development sources as sub-contractors has enabled Tritech to simultaneously embrace many different technologies, e.g. acoustics, lasers, hydraulics, video. This has enabled Tritech to focus internal resources on customers and their needs and searching externally for suitable technologies to fulfil them. The early success of using contractors with no experience of the industry has also continued with their reward being a share of the subsequent sales revenue. In many senses this is the reverse of the spin out model and reinforces much of what has been uncovered in opportunity recognition research, i.e. the most successful strategy is to start with

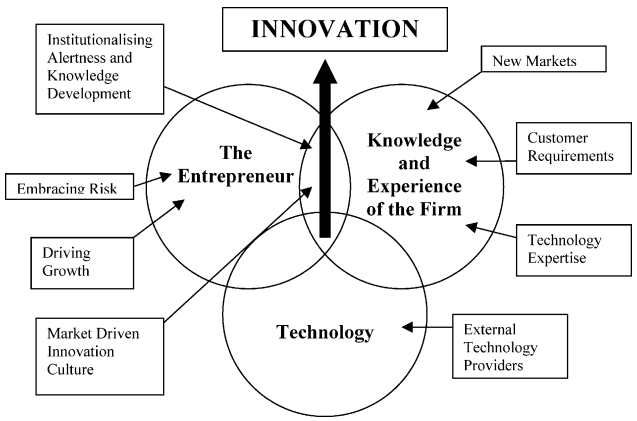

Fig. 4. The contribution and interaction of the model components in Tritech Ltd.

a market need and to find the technology and the product to fill it. Such an approach makes it easier to entice subcontractor involvement as potential profits are already visible before technology development begins. Contrast this with university or corporate spin outs that start with a technology and the difficult quest of establishing the potential market in which this technology can compete.

9.4. Mixing it all up…

Analysis of Tritech supports Gartner's (1985) view that successful innovation in high-tech start-ups is a highly complex and interactive process.

In Tritech innovation and market success are a result of a complex interaction between the entrepreneur, the organisation and technology. Tritech's innovation performance is impressive with 50% of proposed ideas deemed suitable for development and around 85% of product development effort proving successful.

Analysis versus the earlier proposed three component model opportunity recognition supports the notion that the innovation involves continual interaction of the component parts (Fig. 4).

Most surprisingly is that in the Tritech case technology is treated as a commodity to be found upon demand to suit the market need. This supports the conclusion that the market focussed approach already discussed in general opportunity recognition research is also highly relevant in the high-tech sector.

10. Conclusions

The objective of this paper has been to analyse the literature to-date, to establish a better model to understand the opportunity recognition processes used in high-tech start-up companies.

The model proposed in this work is that new product innovation results as an interaction between three individual components: the entrepreneur, the experience within the firm and technology. While all of these factors have been identified in the literature the actual interaction of the components has yet to be the focus of any real detailed empirical study. The current literature has studied these three components, but often in isolation. Research is now moving towards a more dynamic and contextual appreciation of these elements but this work highlights the need to synthesise the contributions and their interactions in high-tech start-up firms.

In the technology sector the presence of a driving entrepreneur is not, by itself, sufficient. Technology requires the necessary knowledge to exploit it and the importance of prior experience and market knowledge has become a recurring theme in recent entrepreneurship research. However, most focus has been on the knowledge of markets, the role of technical knowledge and its role in the transforming of embryonic technical breakthroughs in to real products and processes has been largely ignored. This new model proposes that technology innovation requires a mix of technical, entrepreneurial and managerial experience to turn an embryonic new technology into a market success. A key part of this is matching the logical thinking processes of the scientific world with the ability to learn as you go. An ability to improvise is so often a critical feature of the entrepreneurial venture in the face of ever changing technologies and external market conditions.

The contribution of this model is a new way to look at technology innovation, a market-driven approach with a partnership between those who are really attuned to the opportunity and technology. It also reflects a need to better understand the detailed interaction of the three components of the model.

By exploring the literature this work has identified the symbiotic character of the elements of opportunity recognition and development, thus demonstrating the need to synthetically model these interactions. This new model provides a theoretical platform from which to explore further the nature and dynamics of the opportunity recognition and development process in high-tech start-up firms. We also propose a need for more case study material, from different situations. This will help us to better understand how inanimate technology evolves with the help of entrepreneur and scientist, into winning products and successful high-tech companies.

Acknowledgements

Carter Crockett and Jane Cassera (Charles P Skene Centre for Entrepreneurship, Aberdeen Business School, The Robert Gordon University, Aberdeen) for researching and writing the Tritech case study.

Professor Alistair Anderson and Dr Paul Robson (Charles P Skene Centre for Entrepreneurship, Aberdeen Business School, The Robert Gordon University, Aberdeen) for invaluable support and guidance in writing this paper.

References

Alvarez, S.A., Busenitz, L.W., 2001. The entrepreneurship of resource-based theory. Journal of Management 27(6), 755–775.

Ardichivili, A., Cardonzo, R., Sourav, R., 2003. A theory of entrepreneurial opportunity identification and development. Journal of Business Venturing 18(1), 105–123.

Avermaete, T., Viaene, J., Morgan, E.J., Crawford, N., 2003. Determinants of innovation in small food firms. European Journal of Innovation Management 6(1), 8–17.

Baker, T., Miner, A.S., Eesley, D.T., 2001. Fake it until you make it: improvisation and new ventures, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

Bandura, A., 1986. The Social Foundations of Thought and Action, Prentice Hall, London.

Barney, J.B., 1995. Looking inside for a competitive advantage. Academy of Management Executive 9(4), 49–61.

Baron, R.A., 1998. Cognitive mechanisms in entrepreneurship: why and when entrepreneurs think differently than other people. Journal of Business Venturing 13(4), 275–294.

Boyd, N.G., Vozikis, G.S., 1994. The influence of self-efficacy on the development of entrepreneurial intentions and actions. Entrepreneurship Theory and Practice 18, 63–90.

Busenitz, L., 1996. Research on entrepreneurial alertness. Journal of Small Business Management October, 35–44.

Busenitz, L.W., Barney, J.B., 1997. Differences between entrepreneurs and managers in large organisation: biases and heuristics in strategic decision making. Journal of Business Venturing 12(1), 9–30.

Bygrave, W.D., 1997. The Portable MBA in Entrepreneurship, Wiley, New York.

Bygrave, W.D., Hofer, C.W., 1991. Theorizing about entrepreneurship. Entrepreneurship Theory and Practice 16(2), 13–22.

Cantillon, R., 1931. Essai sur la Nature do Commerce en General, McMillan, London.

Carayannis, E.G., Alexander, J., 2002. Is technological learning a firm core competence, when, how and why? A longitudinal, multi-industry study, of firm technological learning and market performance. Technovation 22(10), 625–643.

Carter, N.M., Gartner, W.B., Shaver, K.G., Gatewood, E.J., 2003. The career reasons of nascent entrepreneurs. Journal of Business Venturing 18(1), 13–39.

Chell, E., 1999. The entrepreneurial personality—past, present and future. The Occupational Psychologist 20, 5–12.

Chen, C.C., Greene, P.G., Crick, A., 1998. Does entrepreneurial self-efficacy distinguish entrepreneurs from managers? Journal of Business Venturing 13(4), 295–316.

Christensen, C.M., 1997. The innovators dilemma: when technologies cause great firms to fail, Harvard Business School Press, Boston, MA.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152.

Collarelli-O'Connor, G.C., Rice, M.P., 2001. Opportunity recognition and breakthrough in large established firms. California Management Review 43(2), 95–116.

Cooper, R.G., 1999. From experience: the invisible success factors in product innovation. Journal of Product Innovation Management 16, 115–133.

Craig, J., Lindsay, N., 2001. Quantifying 'gut feeling' in the opportunity recognition process, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

Crockett, C., 2004. Tritech: innovation by cross pollination. The International Journal of Entrepreneurship and Innovation 4(4) 275–282.

Delamar, F., 2000. The psychology of the entrepreneur. In: Carter, S., Jones-Evans, D. (Eds.), Enterprise and Small Business: Principles, Practice and Policy, Prentice Hall, London, pp. 132–154.

Dutton, J.E., Jackson, S.E., 1987. Categorizing strategic issues: links to organizational action. Academy of Management Review 12(1), 76–90.

Gaglio, C.M., 1997. Opportunity identification: review, critique and suggested research directions, Advances in Entrepreneurship, Firm Emergence and Growth, vol. 3. JAI Press, Greenwich, CT, pp. 139–201.

Gartner, W.B., 1985. A conceptual framework for describing the phenomenon of new venture creation. Academy of Management Review 10(4), 696–706.

Gartner, W.B., 1988. "Who is the entrepreneur?" is the wrong question. American Journal of Small Business 12(4), 11–31.

Gooding, R.Z., 1989. Decision making and the structuring of strategic problems. The Working Conference on Managerial Cognition, Washington, DC.

Granstrand, O., 1998. Towards a theory of the technology-based firm. Research Policy 27(5), 465–489.

Hills, G.E., 1995. Opportunity recognition by successful entrepreneurs, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

Hills, G.E., Shrader, R.C., 1998. Successful entrepreneurs' insights into opportunity recognition, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

Hills, G.E., Shrader, R.C., Lumpkin, G.T., 1999. Opportunity recognition as a creative process, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

Julien, P., 1995. New technologies and technological information in small businesses. Journal of Business Venturing 10(6), 459–475.

Kaish, S., Gilad, B., 1991. Characteristics of opportunities search of entrepreneurs versus executives: sources, interests, general alertness. Journal of Business Venturing 6(1), 45–61.

Kakati, M., 2003. Success criteria in high-tech new ventures. Technovation 23(5), 447–457.

Kickul, J., Gundry, L.K., 2002. Prospecting for strategic advantage: the proactive entrepreneurial personality and small firm innovation. Journal of Small Business Management 40, 85–97.

Kirzner, I., 1973. Competition and Entrepreneurship, University of Chicago Press, Chicago, IL.

Klevorick, A.K., Levin, R.C., Nelson, R.R., Winter, S.G., 1995. On the sources and significance of inter-industry differences in technological opportunities. Research Policy 24(2), 185–205.

Knight, F.H., 1921. Risk, uncertainty and profit, Houghton Mifflin, Boston, MA.

Koen, P.A., Kohli, P., 1998. Idea generation: who comes up with the most profitable products?, Babson College, Wellesley, MA.

Krueger, N.F., Reilly, M.D., Carsrud, A.L., 2000. Competing models of entrepreneurial intentions. Journal of Business Venturing 15(5–6), 411–432.

Malerba, F., Orsenigo, L., 1996. Schumpeterian patterns of innovation are technology specific. Research Policy 25, 451–478.

Maxwell, J.R., Westerfield, D.L., 2002. Technological entrepreneurism: characteristics related to the adoption of innovative technology. SAM Advanced Management Journal 67(1), 9–21.

McClelland, D., 1961. The achieving society, Van Nostrand, Princeton, NJ.

Naffziger, D.W., Hornsby, J.S., Kuratko, D.F., 1994. A proposed research model of entrepreneurial motivation. Entrepreneurship Theory and Practice 18(3), 29–42.

Oakey, R., 2003. Technical entrepreneurship in high technology small firms: some observations on the implications for management. Technovation 23(8), 679–688.

Oakey, R., Rothwell, R., Cooper, S., 1988. The management of innovation in high-technology small firms, Pinter Publishers, London.

OECD, 2003. The Policy Agenda for Growth, OECD Publications, Paris, France.

Palich, L.E., Bagby, D.R., 1995. Using cognitive theory to explain entrepreneurial risk-taking: challenging conventional wisdom. Journal of Business Venturing 10(6), 425–438.

Rotter, J.B., 1966. Generalised expectancies for internal versus external locus of control of reinforcement. Psychological Monographs 80, 1–28.
Say, J.B., 1964. Treatise on Political Economy: On the Production, Distribution and Consumption of Wealth. Traité d'économie politique: ou, simple exposition de la manière dontse forment, se distribuent et se consomment les richesses, Kelley, New York, (1st edition: 1827).
Schumpeter, J.A., 1934. Theory of Economic Development, Harvard University Press, Cambridge, MA.
Schumpeter, J.A., 1942. Capitalism, Socialism and Democracy, Harper, New York.
Scottish Executive, 2001. A Smart Successful Scotland: Ambitions for the Enterprise Networks, HM Stationary Office, Edinburgh, UK.
Shan, W., 1990. An empirical analysis of organisational strategies by entrepreneurial high-technology firms. Strategic Management Journal 11, 129–139.
Shane, S., 2000. Prior knowledge and the discovery of entrepreneurial opportunities. Organizational Science 11(4), 448–469.
Shane, S., 2001. Technology regimes and new firm formation. Management Science 47(9), 1173–1190.
Shane, S., Venkataraman, S., 2000. The promise of entrepreneurship as a field of research. Academy of Management Review 25(1), 217–226.
Shaver, K.G., Scott, L.R., 1991. Person, process, choice: the psychology of new venture creation. Entrepreneurship Theory and Practice 16(2), 23–45.
Shepherd, D.A., De Tienne, D.R., 2001. Discovery of opportunities: anomalies, accumulation and alertness, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.
Singh, R.P., Hills, G.E., Hybels, R.P., Lumpkin, G.T., 1999. Opportunity recognition through social network characteristics of entrepreneurs, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.
Smith, J.A., 1998. Strategies for start-ups. Long Range Planning 31(6), 857–872.
Stevenson, H.M., Jarrillo-Mossi, J.C., 1986. Preserving entrepreneurship as companies grow. The Journal of Business Strategy 7, 10–23.
Sutton, R.I., Kelley, T., 1997. Creativity doesn't require isolation: why product designers bring visitors 'backstage'. California Management Review 40(1), 75–91.
Timmons, J.A., 1999. New venture creation: entrepreneurship for the 21st century, McGraw-Hill, Singapore.
Trott, P., 2002. Innovation management and new product development, Pearson Education Ltd, London.
Venkataraman, S., 1997. The distinctive domain of entrepreneurship research, Advances in Entrepreneurship, Firm Emergence and Growth, vol. 3. JAI Press, Greenwich, CT, pp. 119–138.
Vesper, K.H., 1996. New Venture Experience, Vector Books, Seattle, WA.
Zietsma, C., 1999. Opportunity knocks or does it hide, Frontiers of Entrepreneurship Research, Babson College, Wellesley, MA.

John Park is a Lecturer in the Charles P. Skene Centre for Entrepreneurship (Aberdeen Business School) at the Robert Gordon University. His specialist subjects are Innovation, Product Development and Intellectual Property Protection. His interest in both theoretical and practical aspects of innovation stems from his previous career as a senior R&D manager in the Procter and Gamble Corporation.